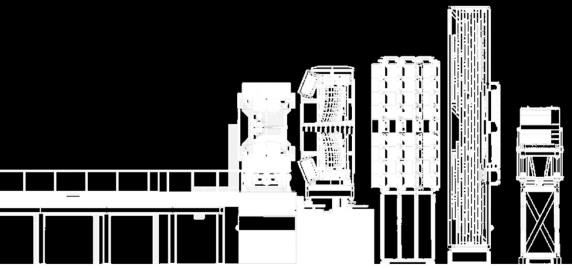
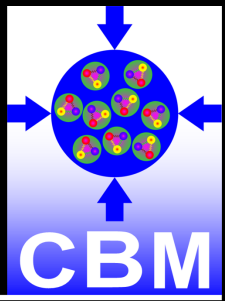
CBM: Motivation, Vision & Realization

Manuel Lorenz

GSI / GU Frankfurt



CBM Compressed Baryonic Matter experiment at FAIR



Outline

Motivation

- Zeitgeist around 2006/7
- Developments in the field and beyond since than

Vision

- FAIR/CBM is coming: Baselines and cultural reset

Realization

- The host lab group
  - Responsibilities
  - Let's get it done: Essentials
  - Let's do physics and look for the unexpected (but out of the box)

Summary

Zeitgeist in the field and at GSI around 2006/7

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New state of matter more remarkable than predicted — raising many new questions

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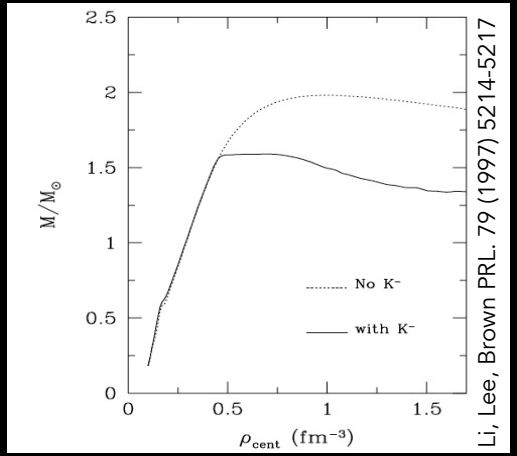
  KaoS, FOPI e.g. hint for K^- in-medium effects



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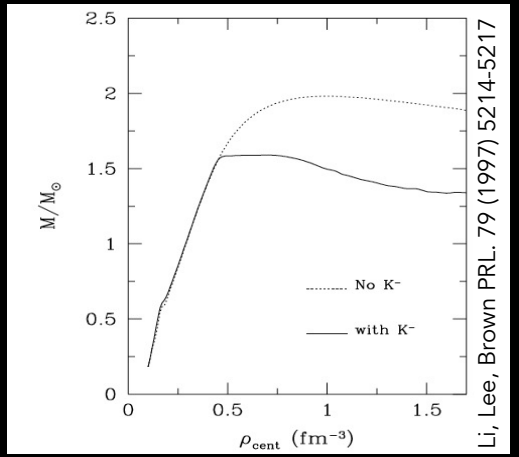

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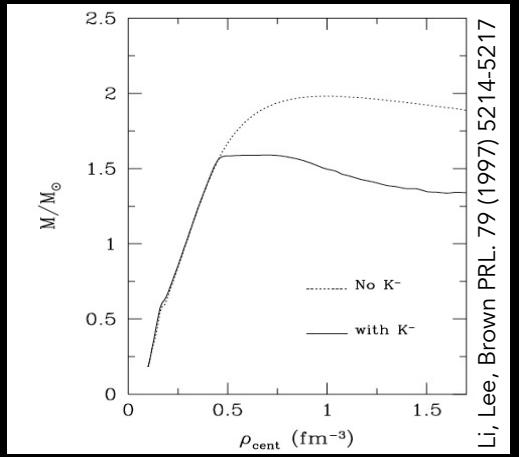

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Disappearance of QGP signatures: RHIC BES I

„Experimental and Theoretical Challenges in the Search for the Quark Gluon Plasma: The STAR Collaboration's Critical Assessment of the Evidence from RHIC Collisions" *Nucl.Phys.A* 757" (2005) 102-183

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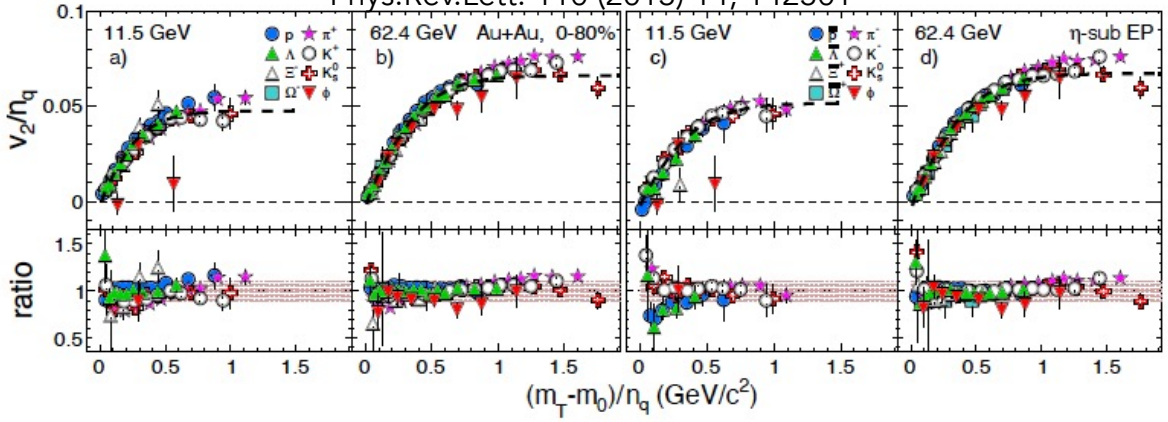

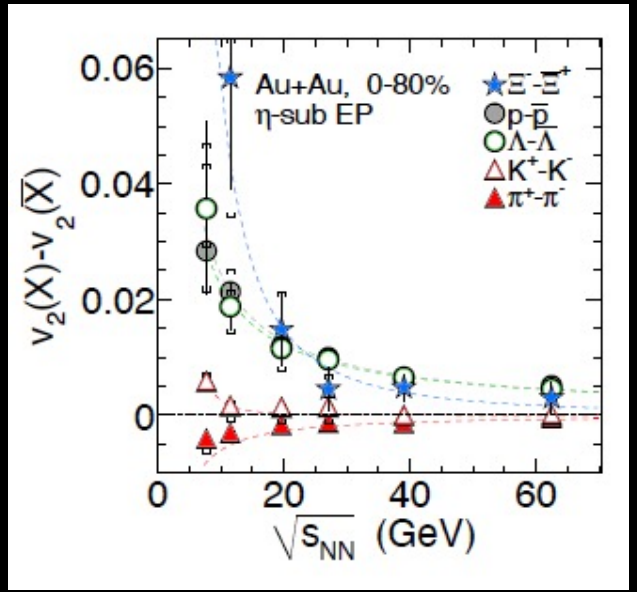

Beam-energy dependent difference of v_2 between particles and anti-particles, which increases with decreasing beam energy and is larger for baryons compared to mesons.

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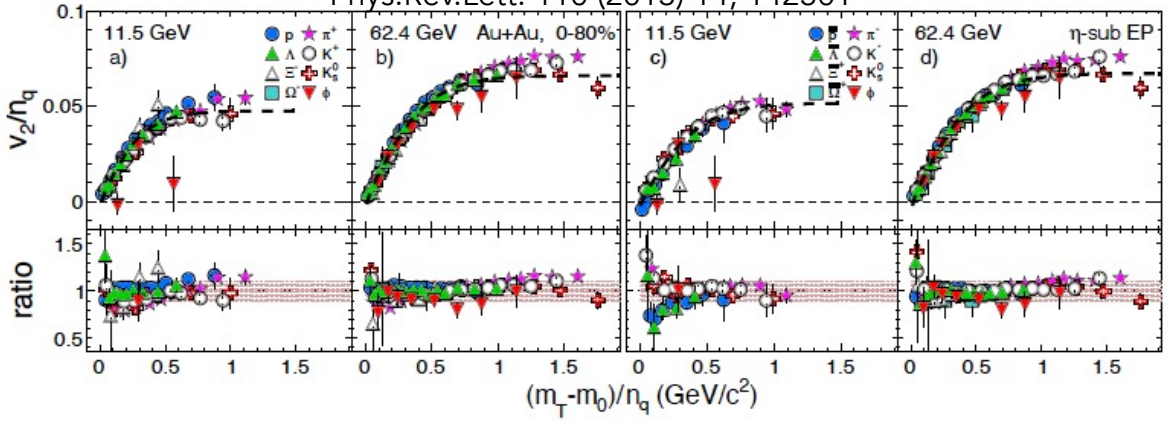

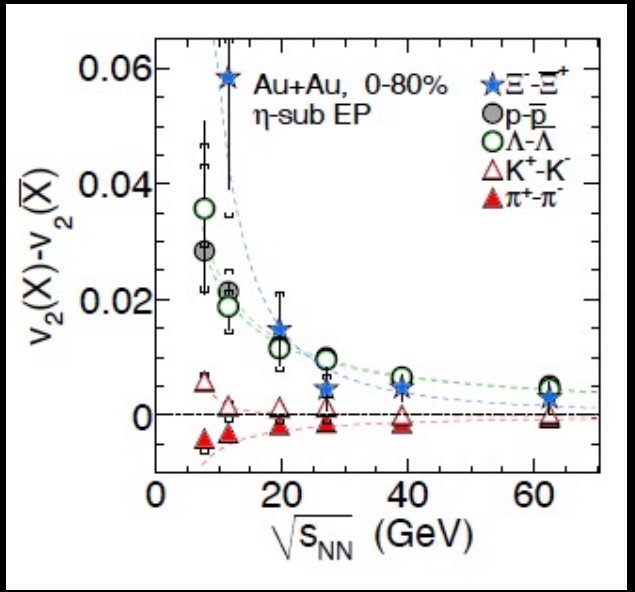

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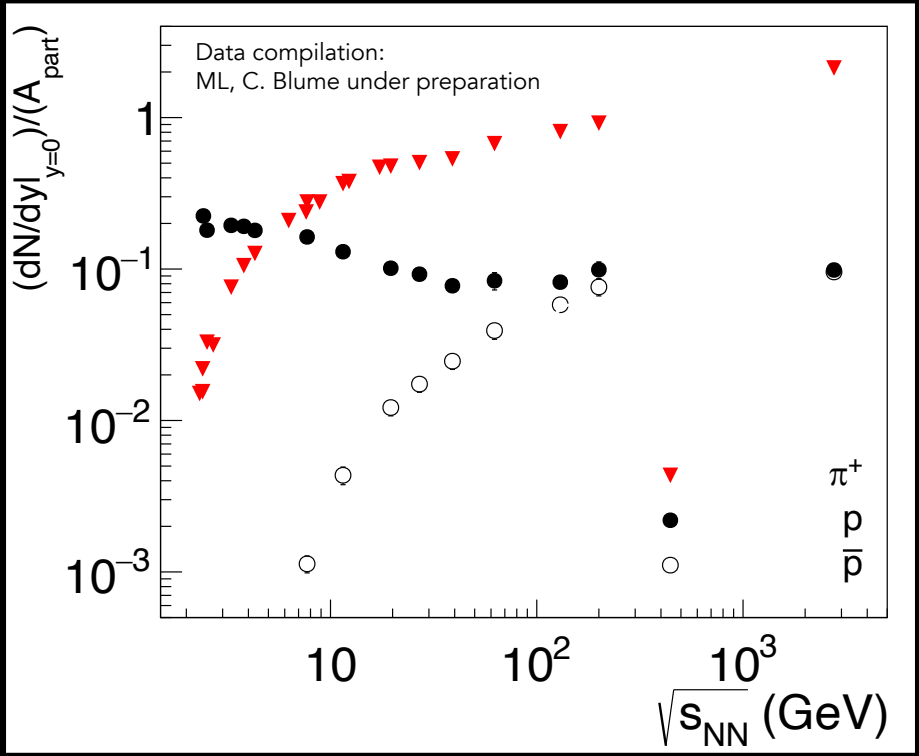
→ QGP signature disappearance: more challenging than anticipated.

Hadron Yields from SIS to LHC



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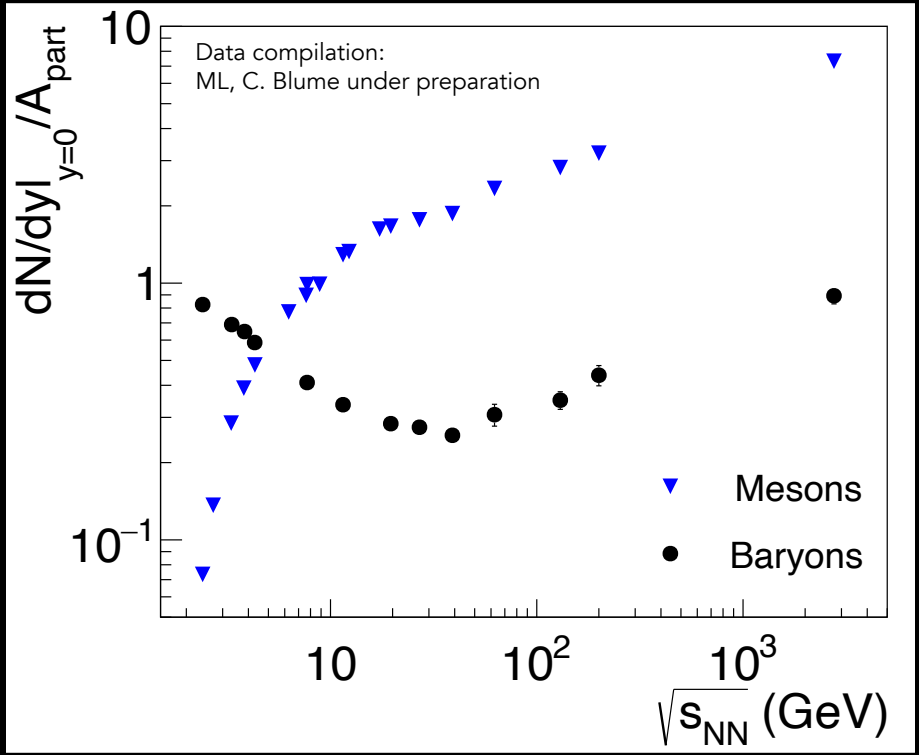

→ switch from (net)-baryon to meson dominated system ≈ 5 GeV

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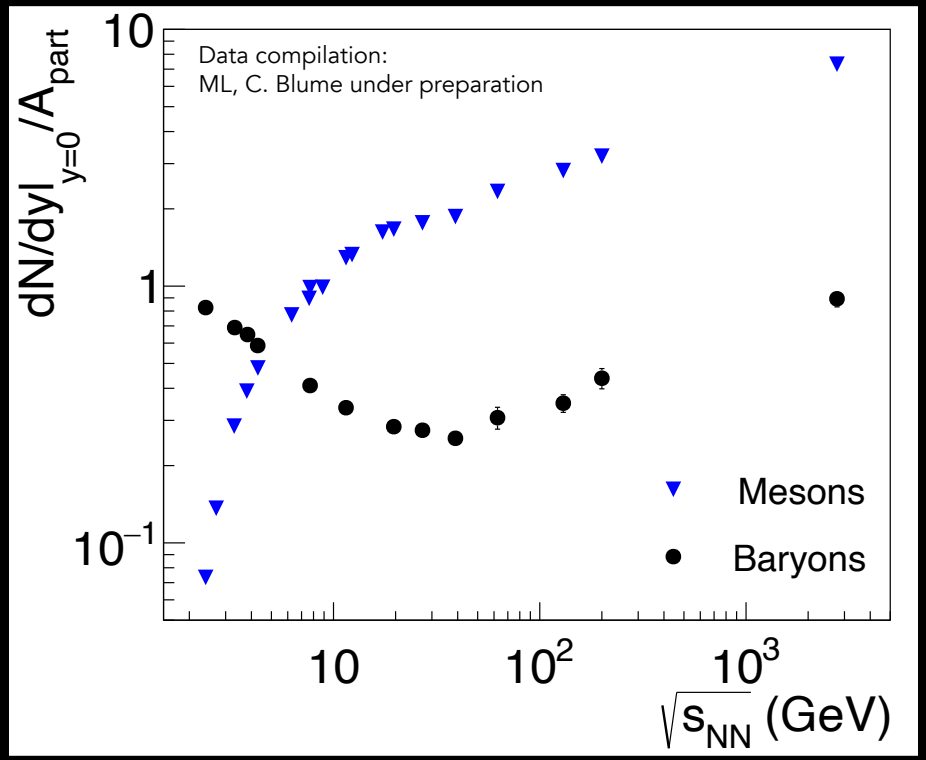
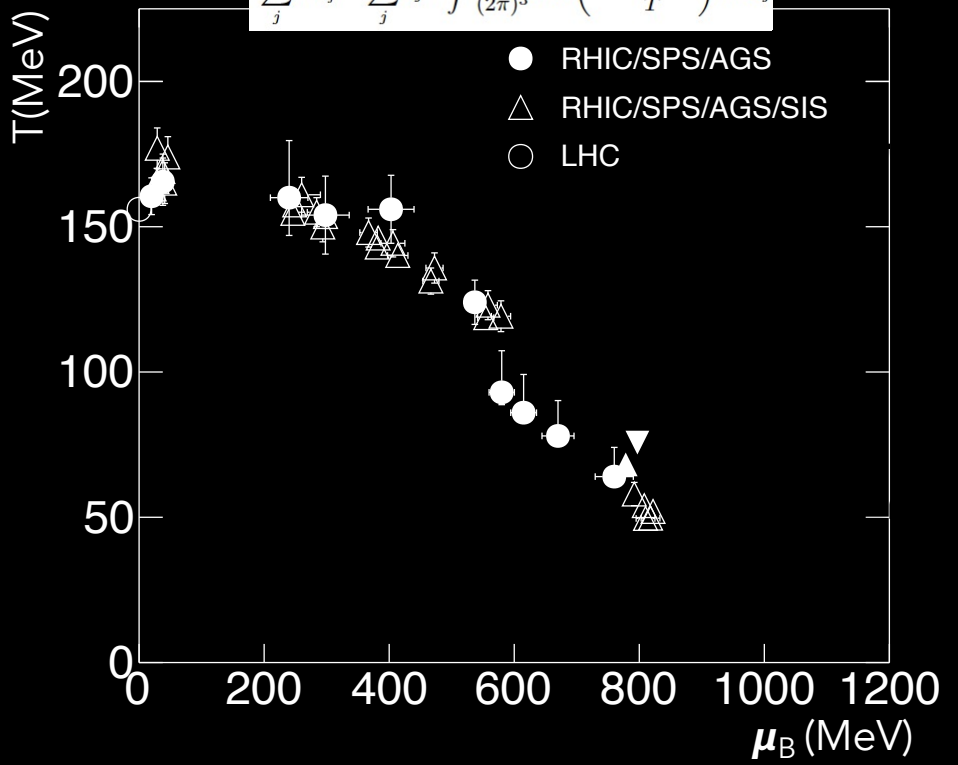


$$\sum_i M_{m_i} = \sum_i g_i V \int \frac{d^3p}{(2\pi)^3} \exp\left(-\frac{E_i}{T}\right) \times F_{Si},$$

$$\sum_j M_{b_j} = \sum_j g_j V \int \frac{d^3p}{(2\pi)^3} \exp\left(-\frac{E_j - \mu_B}{T}\right) \times F_{Sj}$$



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Measurements at different √s line up on a common curve.

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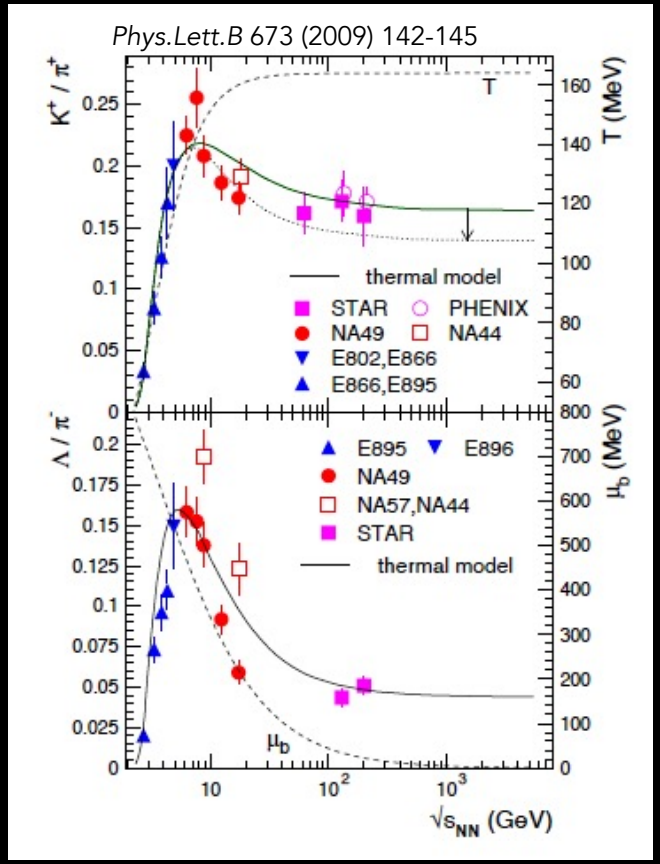

→ "Horn" reproduced in HRG model.

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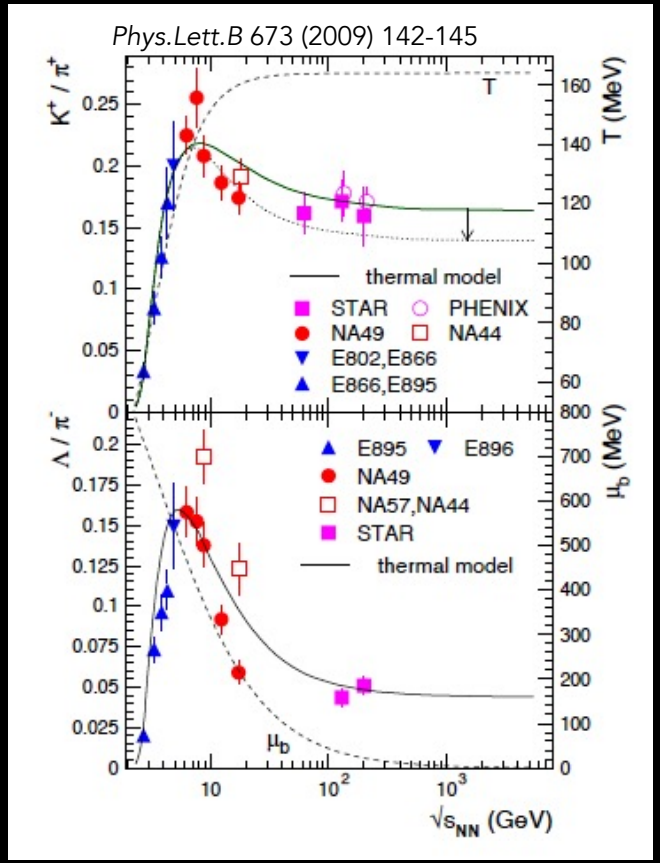

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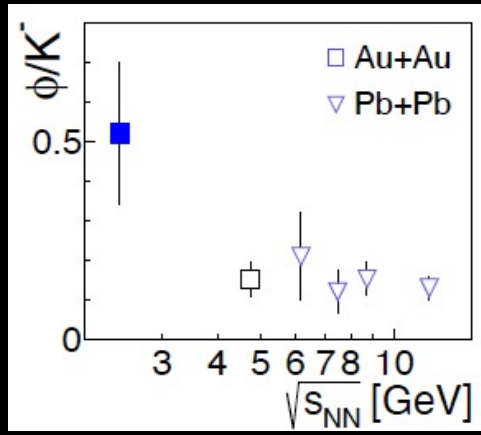

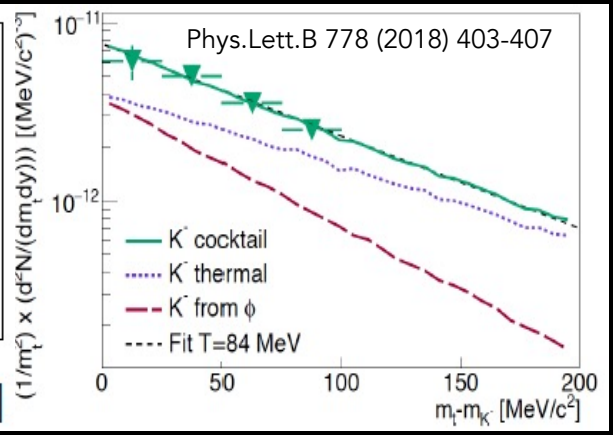

K^- in-medium effects: The observed **smaller slope** for K^- compared to K^+ is mainly due to $\phi \rightarrow K^+K^-$ **decays**

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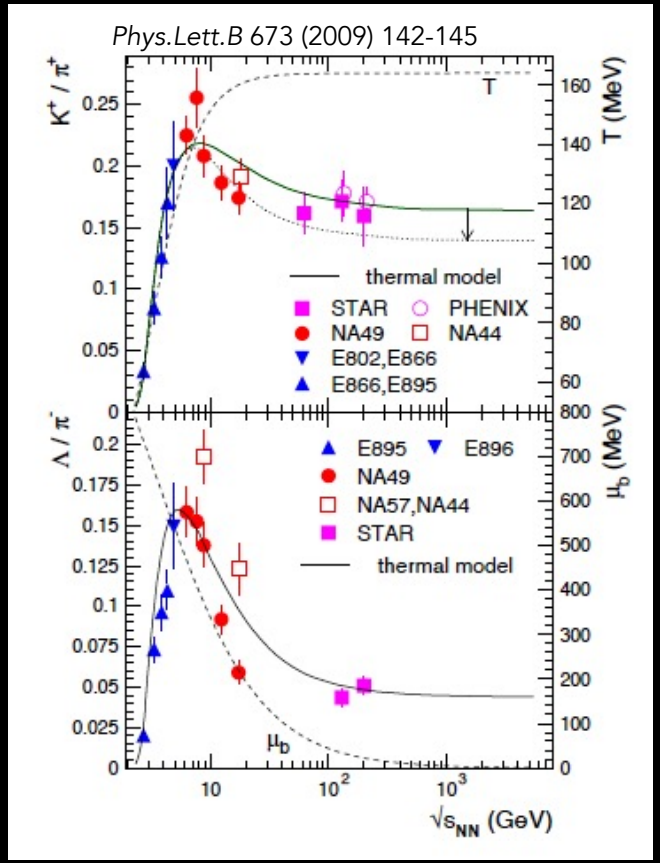

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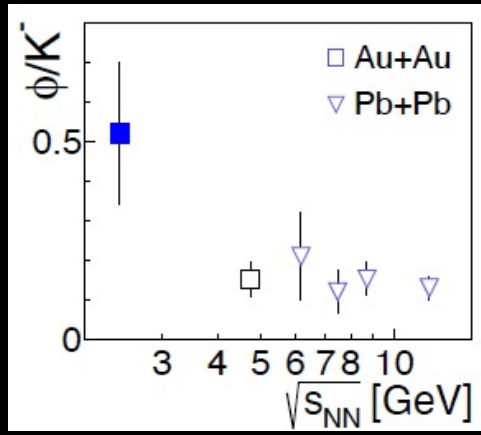
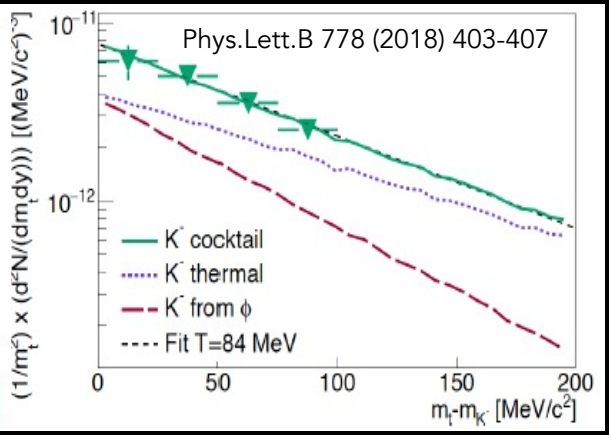




K⁻ in-medium effects: The observed **smaller slope** for **K⁻** compared to **K⁺** is mainly due to **$\phi \rightarrow K^+K^-$ decays**

Most observables evolve smoothly from SIS to LHC.

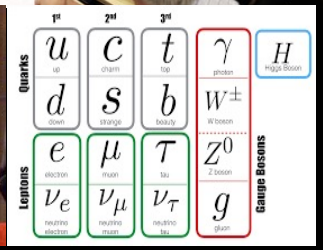
→ Baselines matter (p+p/A, QCD@FAIR Whitepaper)

→ Exp. presession – reduce sys. uncertainties.

→ Accurate modeling, quantitative data-model comparison (including baselines).

The standard model: done.

Last particle discovered



Nobel prize 2013

→ Low-Q QCD the last frontier of the SM.

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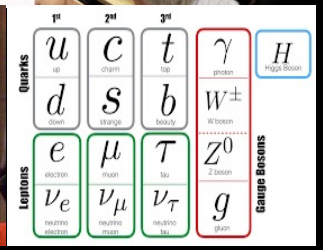

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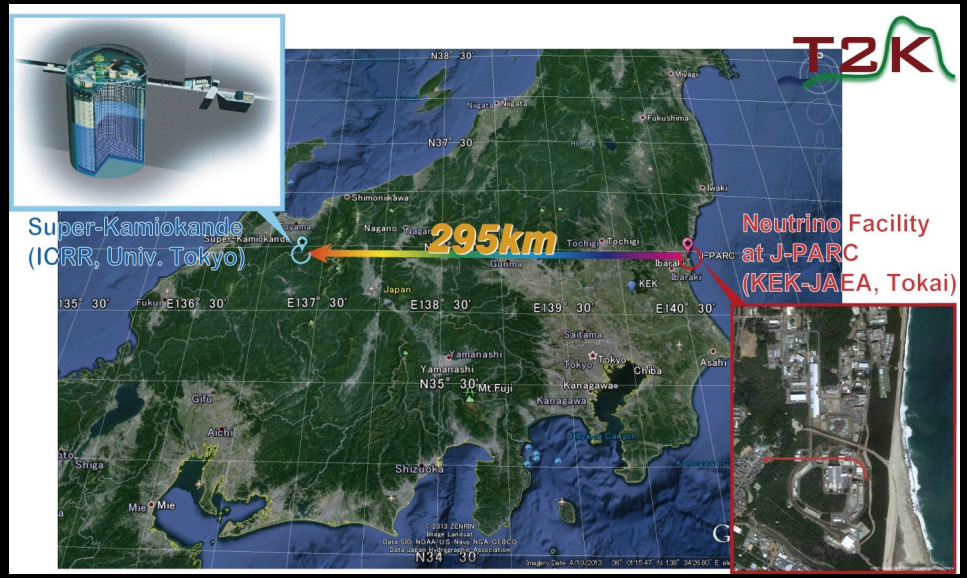
Let's go beyond!
Baryon-Antibaryon Asymmetry in the early universe
BSM Physics e.g. long-baseline neutrino exp.



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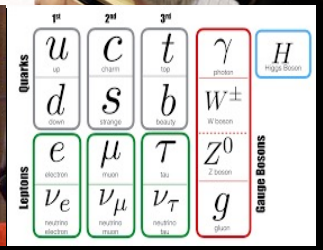

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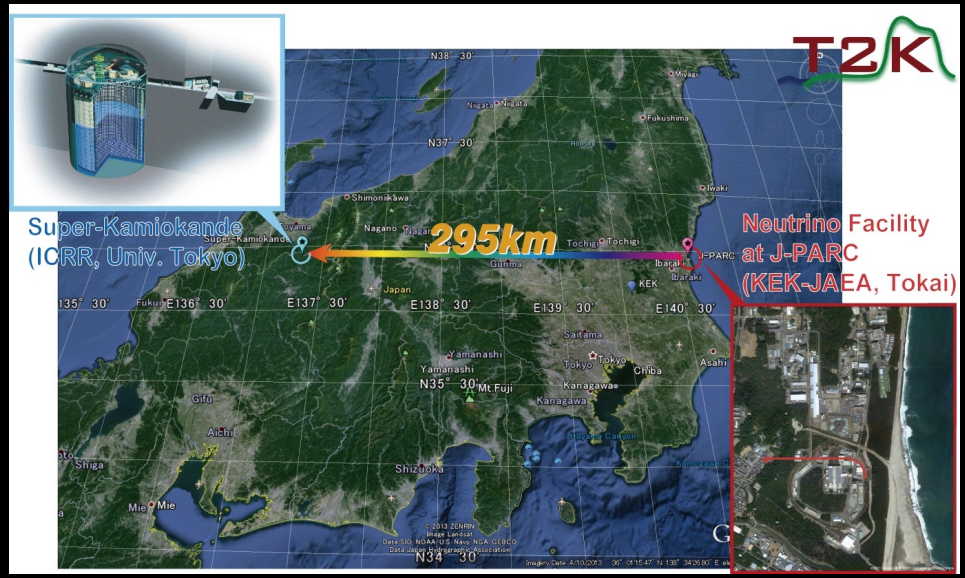

In addition general shift to AI / Life-science.

→ *Need to be open for strategic collaborations with other fields.*

FAIR/CBM is coming.

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Let's do physics!

long-range perspectives of GSI (1997)

8 working groups with broad participation of the international scientific community :

1.) Deep-inelastic electron-nucleon and electron-nucleus scattering at $\sqrt{s}$=20-30 GeV

D. von Harrach, V. Metag, A. Schäfer

2.) X-ray spectroscopy and radiation physics

H. Backe, J. Kluge, G. Soff

3.) Nuclear collisions at maximum baryon density

J.P. Blaizot, P. Braun-Munzinger, R. Stock

4.) Physics with secondary π^-, K^- and $\bar{p}$-beams

D. Frekers, U. Lynen, J. Wambach

5.) Nuclear structure with radioactive beams

D. Habs, H. Lenske, G. Münzenberg, P. Ring

6.) Plasma physics with intense heavy-ion beams

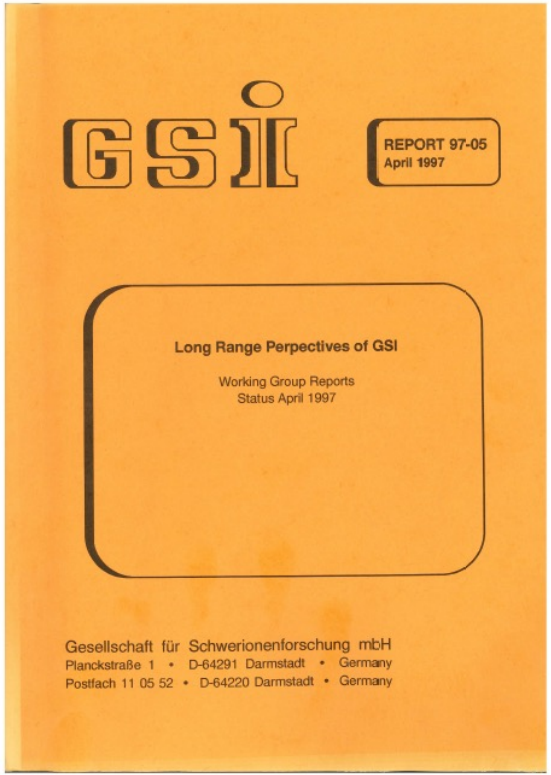
R. Bock, D.D.H. Hoffmann, J. Meyer-ter-Vehn

7.) Accelerator studies (e^- - N/A collider)

K. Blaschke, N. Dikansky, J. Maidment, B. Autin

8.) Accelerator studies (high intensity option)

D. Böhne

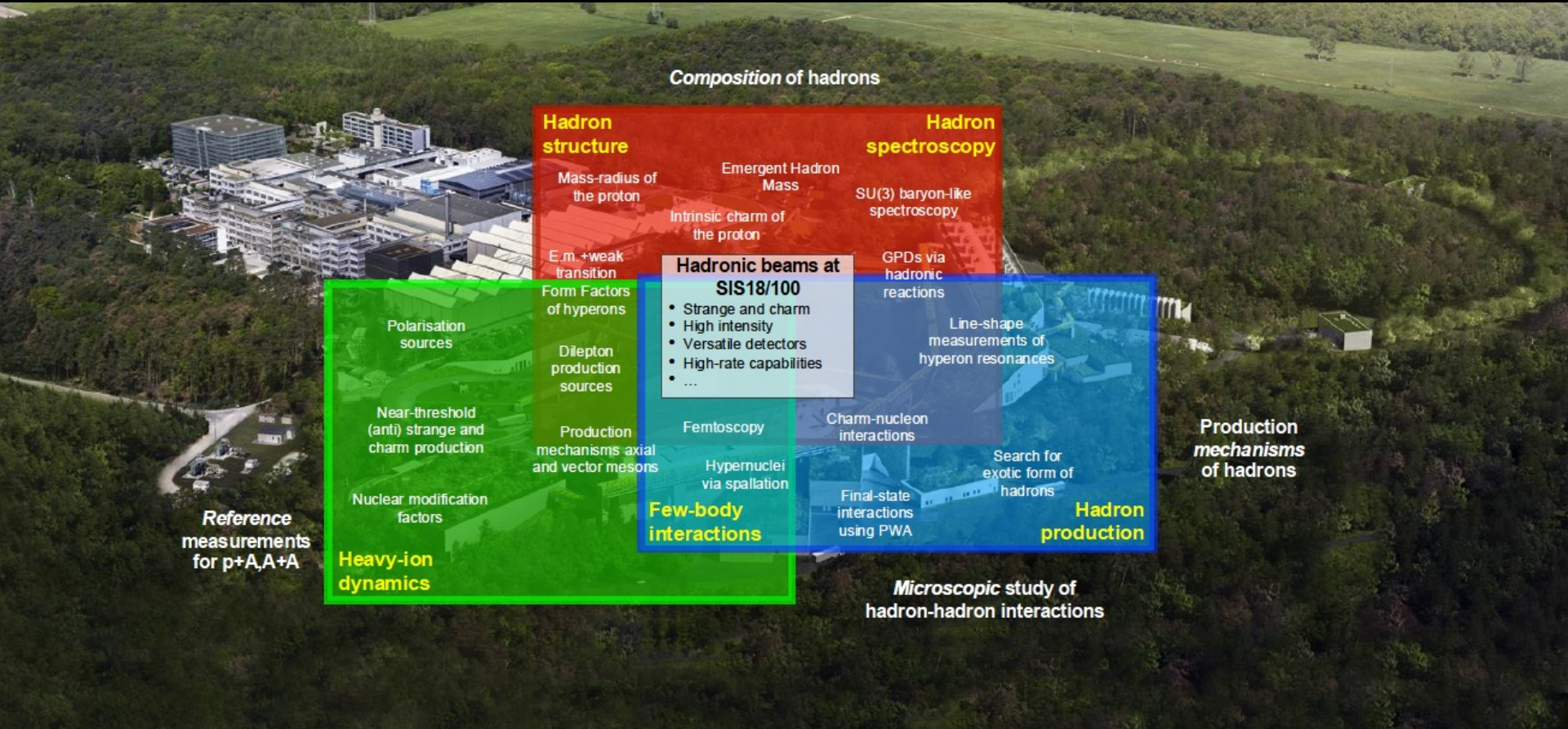


basis for further discussions → FAIR

Volker Metag

Baselines and cultural reset

White Paper: Pion and proton induced QCD studies at FAIR



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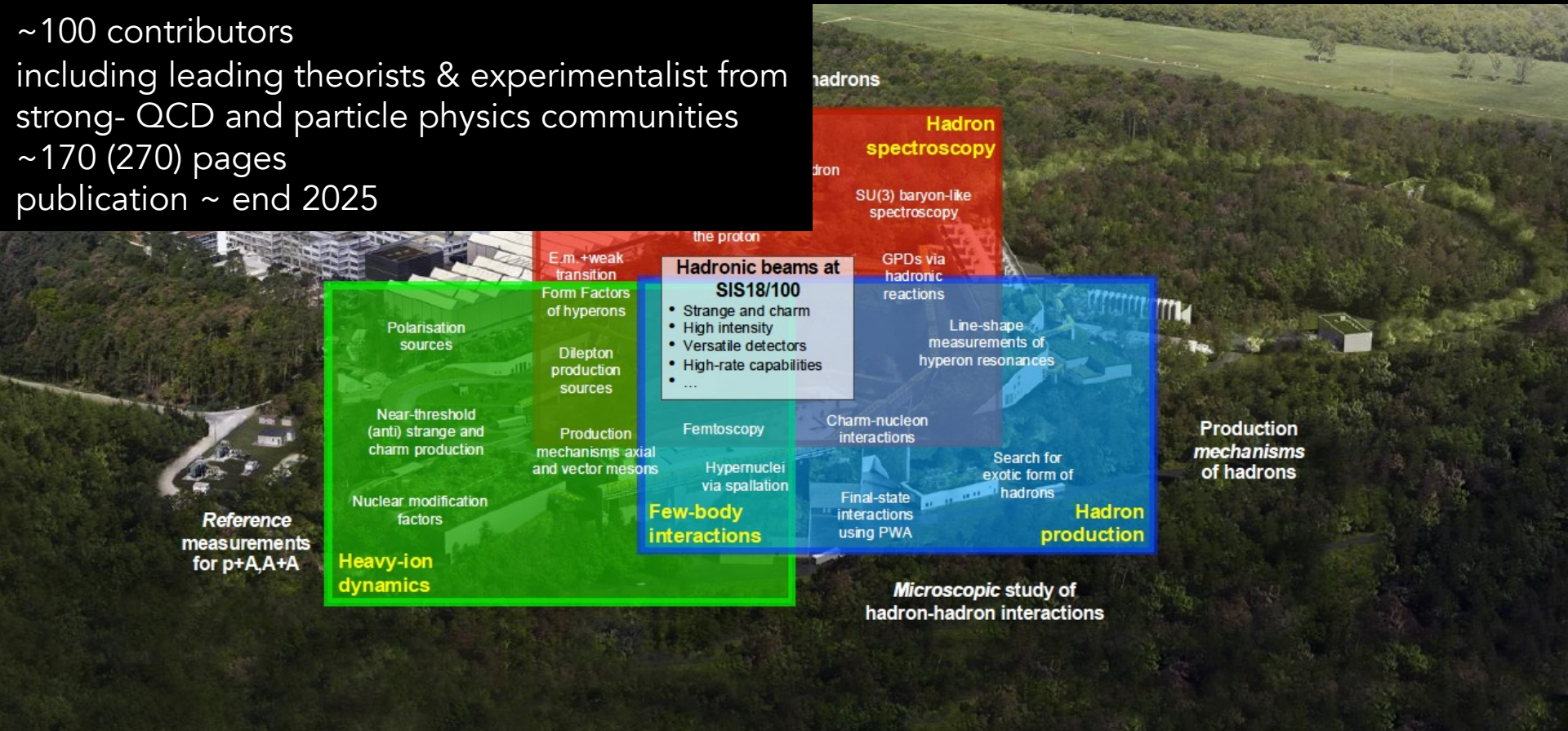

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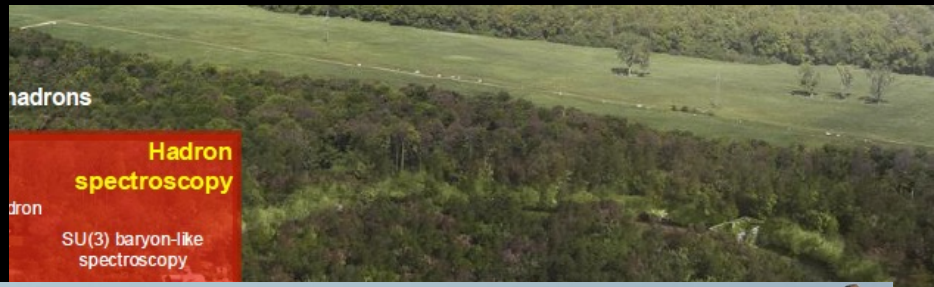

Community can self-assess constructively.

6. Probing matter: from baselines to medium modifications

PANDA delay as opportunity: anchor CBM π+A, p+A, and p+p baselines to de-risk A+A interpretations and enable global generator tuning

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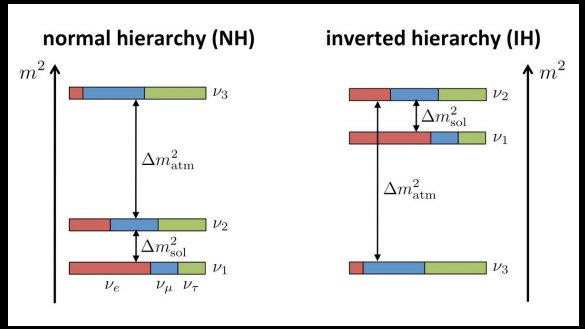
Possibility for strategic collaboration with particle physics community for long baseline (LBL) neutrino experiment applications

The LBL neutrino experiment story

Neutrino oscillations (2015 Nobel Prize)
→ neutrinos have mass → beyond SM
Mass hierarchy?
Long-baseline (LBL) neutrino experiments (T2K/Dune):



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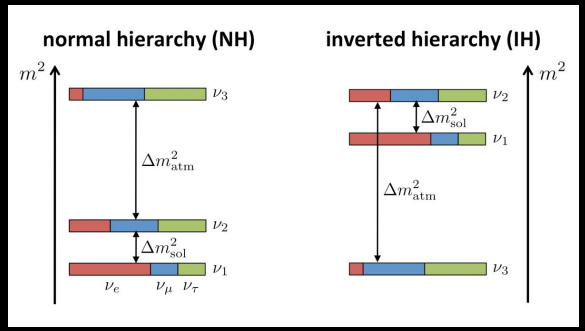

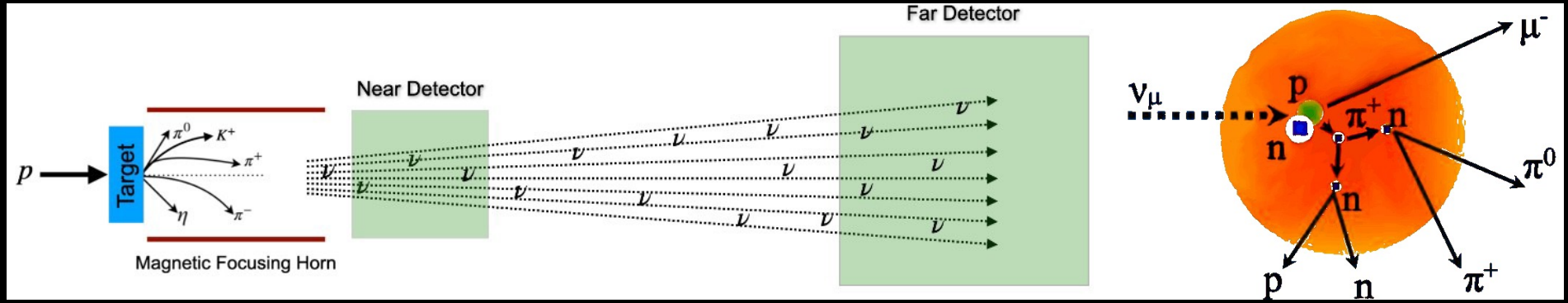

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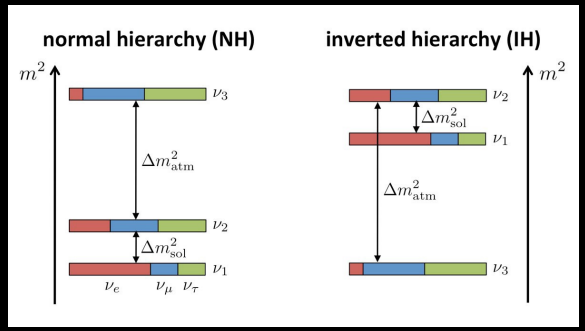

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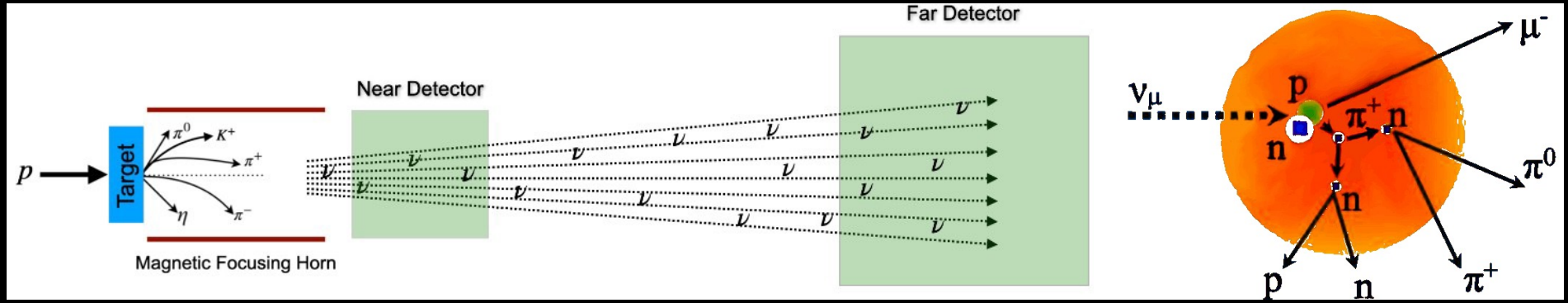
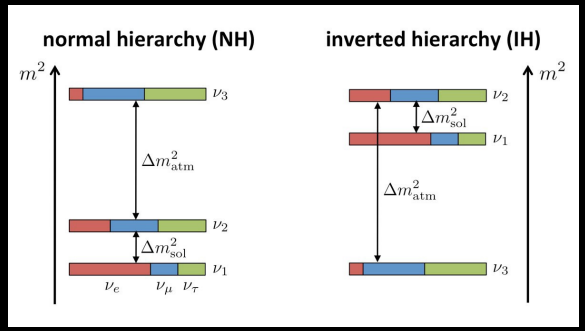
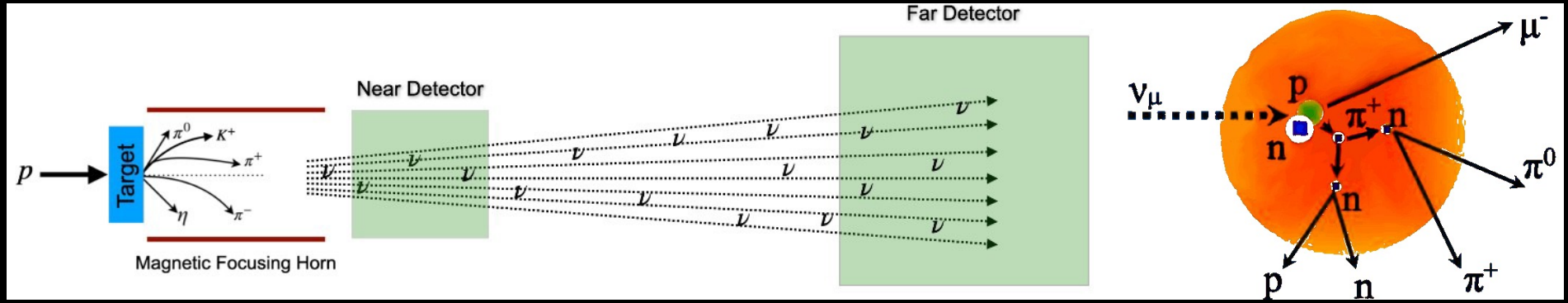


Neutrino energy is not known and is reconstructed from the interaction products measured in the detector:
Calorimetric ('full' deposited energy) method:
relies on visible energy; missing energy from neutrons, detector threshold, pion absorption, etc.

The LBL neutrino experiment story



Neutrino oscillations (2015 Nobel Prize)
→ neutrinos have mass → beyond SM
Mass hierarchy?
Long-baseline (LBL) neutrino experiments (T2K/Dune):



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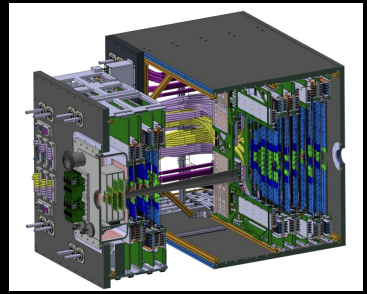
→ CBM baselines reduce **ν**–A model systematics for LBL

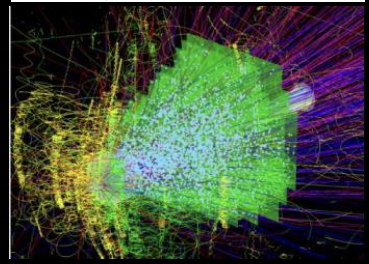
CBM excels @ FAIR:

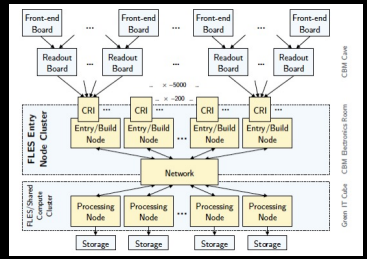
high-rates, 4D tracking, online reconstruction

Host lab group: responsibilities for the most crucial systems

- Silicon Tracking System (STS):
  Construction, Commissioning and Operation
- Tracking and Software:
  Development, Integration, Maintenance and QA
- DAQ and Detector/Experiment Control Systems







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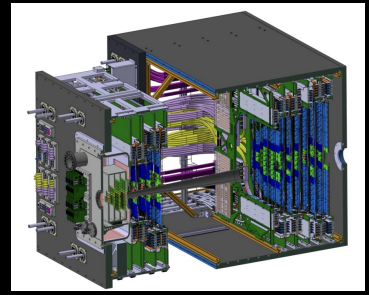
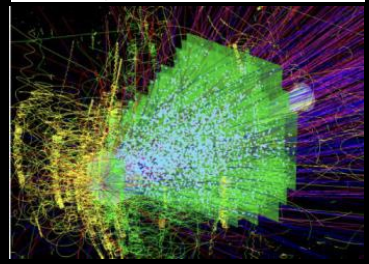
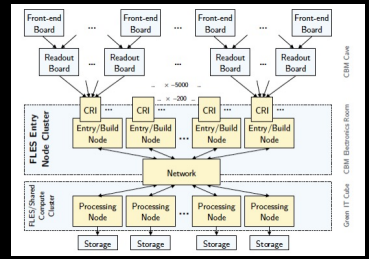




In addition:
Cave Infrastructure
Computing
Detector Lab



Future: Physics analysis

Less than 3 years and counting: Let's get it done!

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Essential: full focus on group, bi-weekly feed-back loops, no overcommitment of responsible persons and postponing of decisions.

The host lab group

Concentration of domain knowledge: physics, computing, engineering

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More work force:
Attract students from GU Frankfurt, third party funding, exchange programs, synergies with other GSI groups (*Detector Lab, Computing, Alice, Hades, Panda, NuStar, Theory)*

Knowledge transfer and mentoring:
Pair students with senior domain mentors, defined standards, documentation, open-source

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Group and meeting culture

- Diversity wins: mixed teams outperform homogeneous ones under good leadership
- Psychological safety: everyone feels safe to speak up
- Practice: ensure all voices are heard, (incl. introverts and juniors), share high-visibility work, timekeeping, clear next steps/owners

Appreciation → contribution → confidence: Enable everyone's best performance

"A team people love to join"

Physics

Physics

Dileptons:

penetrating probe, discovery potential, challenging analysis,
case for machine learning

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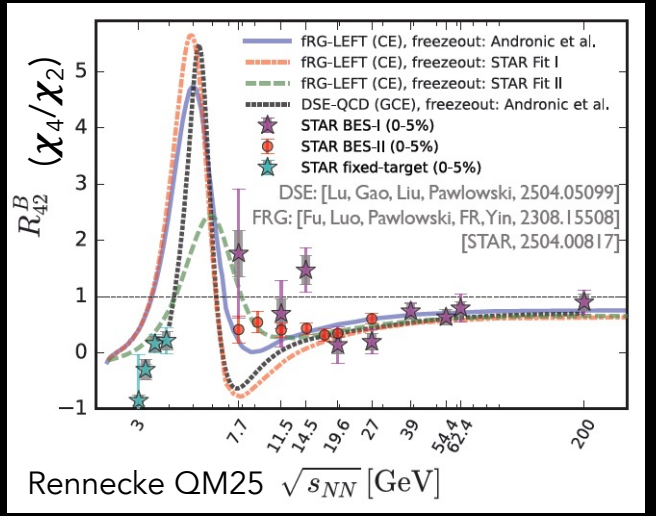
Event by event fluctuations of conserved quantities:
discovery potential at 4.9 GeV, challenging analysis



Physics

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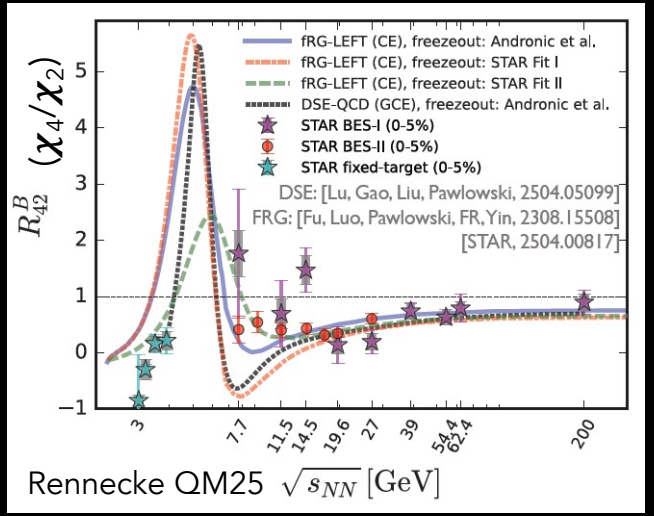
Strangeness and hypernuclei:
peak hunting, case for ml, sweet spot for hypernuclei



Rennecke QM25

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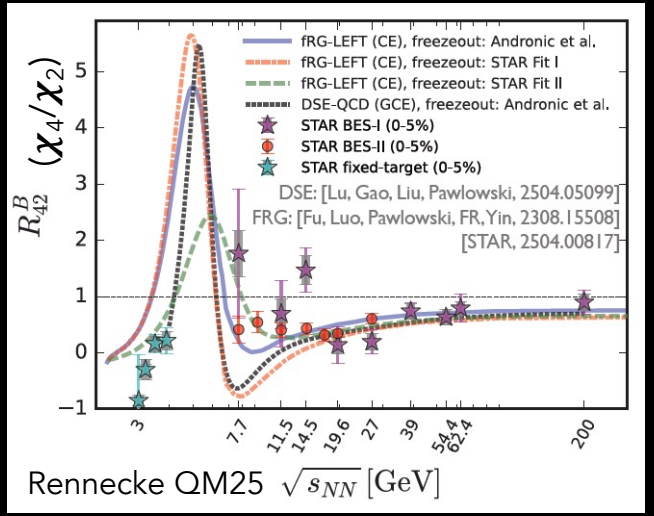

Pion and proton spectra and yields: bread and butter physics but essential!

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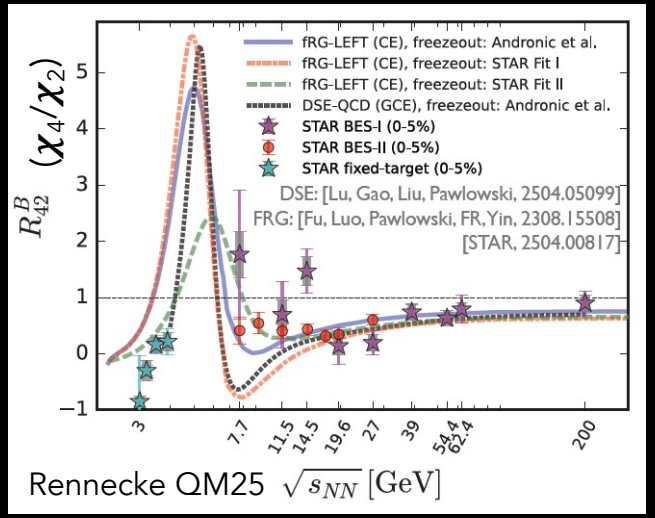

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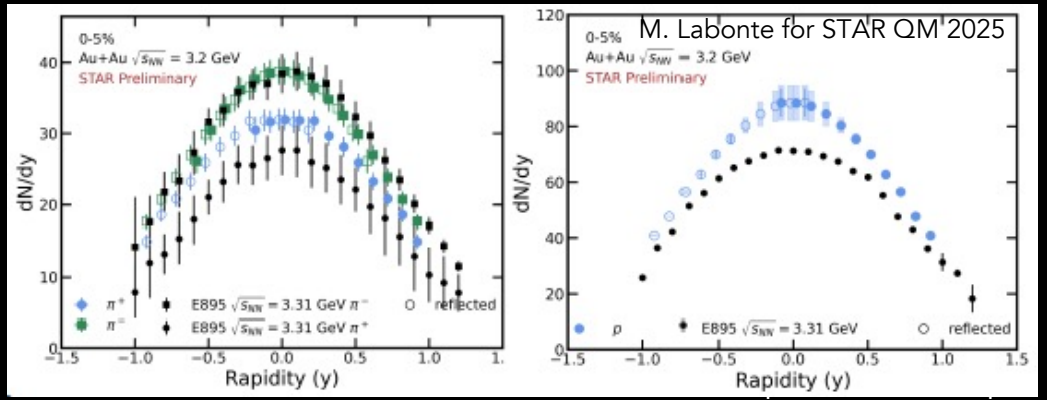

M. Labonte for STAR QM'2025

Physics

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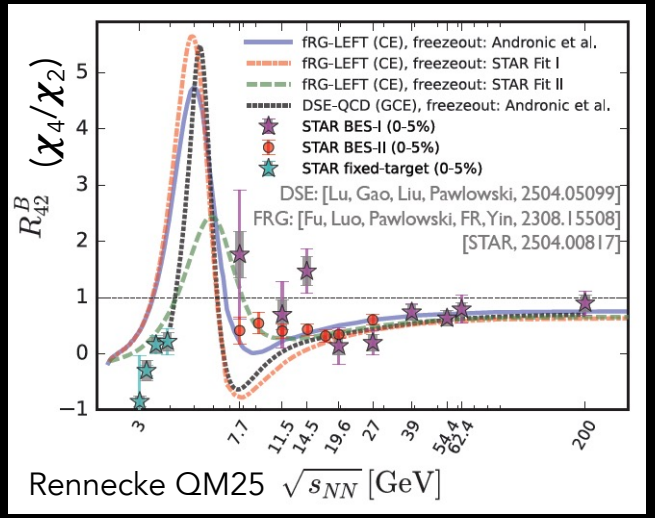
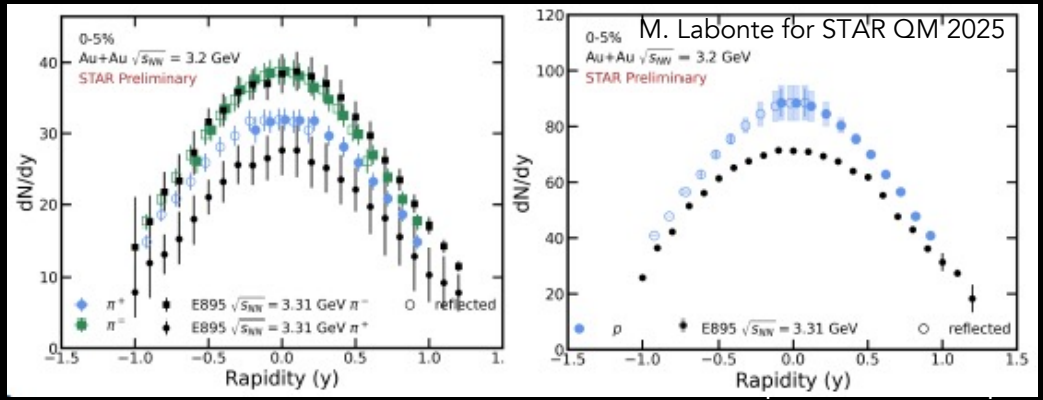


Rennecke QM25

Pion and proton spectra and yields: bread and butter physics but essential!
Systematic uncertainties dominate.
To exploit next-gen luminosities
→ reduce **systematic uncertainties**

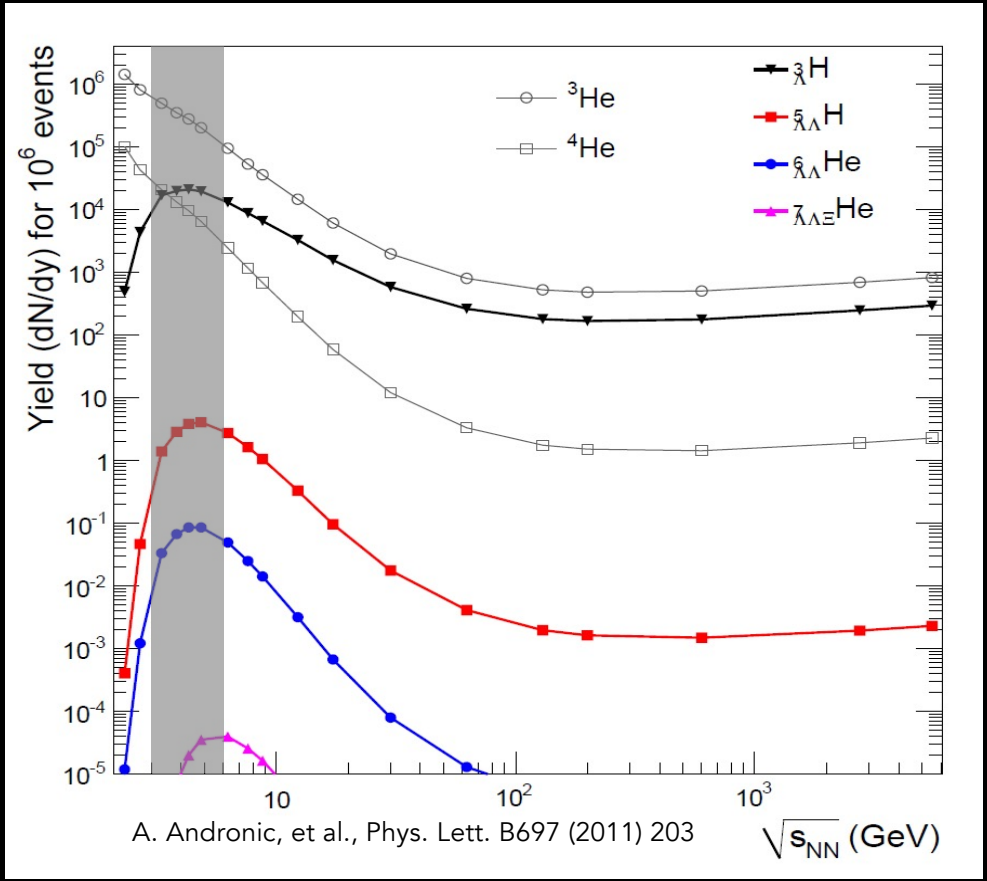
→ Common definition of systematic uncertainties between different experiments.



M. Labonte for STAR QM'2025

At the sweet spot: Hypernuclei at CBM

Thermal model prediction for Au+Au



A. Andronic, et al., Phys. Lett. B697 (2011) 203

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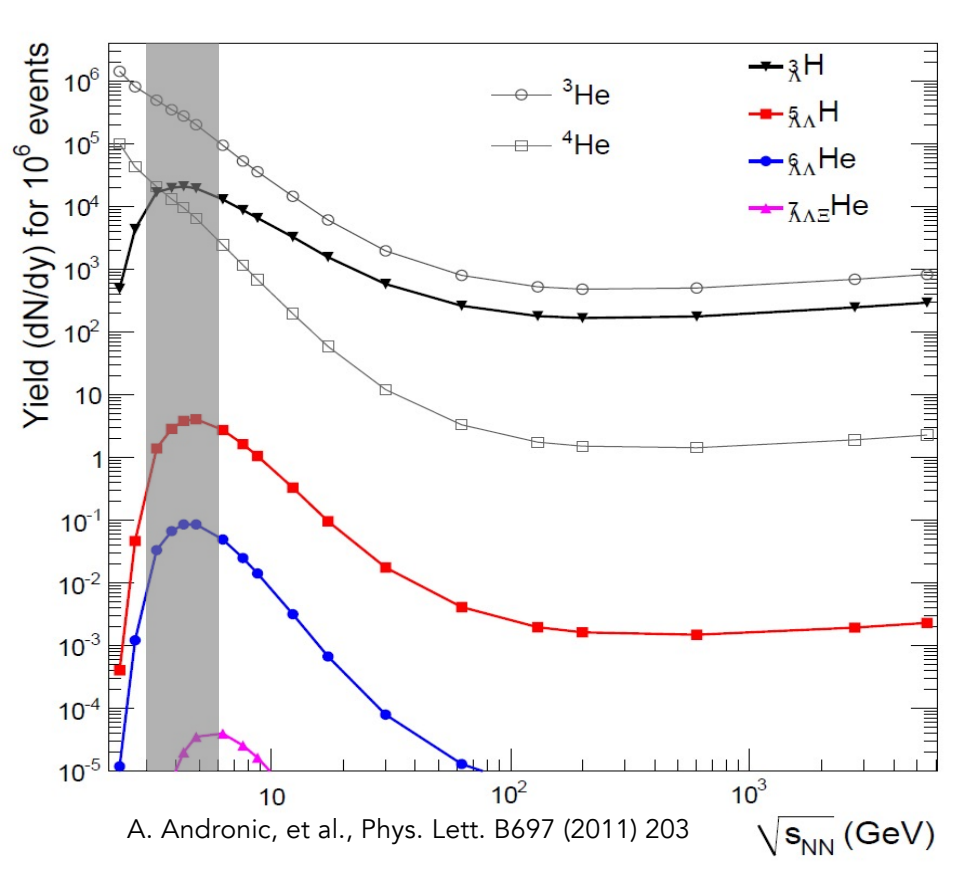

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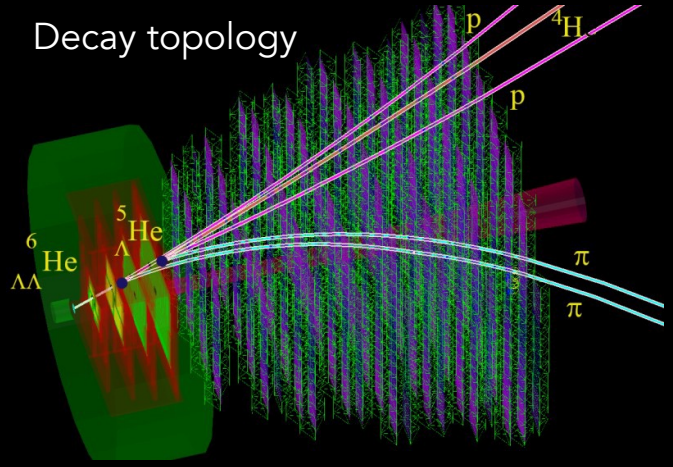
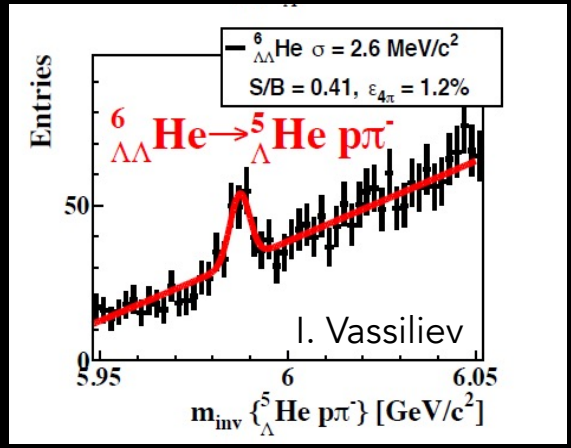
Decay topology





Hypernuclei at GSI/FAIR: CBM/HADES and NuSTAR

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Community self-assess process initiated to make best use of GSI/FAIR infrastructure.

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Formation and lifetime measurement of light hypernuclei in Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV

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(HADES collaboration)

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(Dated: November 12, 2025)

We present the first observation of $^3_\Lambda$H and $^4_\Lambda$H in Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV, emitted around mid-rapidity. The hypernuclei are reconstructed via their two-body decay channels and identified through their weak-decay topology, employing an artificial neural network for enhanced discrimination. The analysis methodology is validated using Λ hyperons. The resulting rapidity distributions, dN/dy, exhibit a bell shape centered at mid-rapidity. The yield of $^3_\Lambda$H is equal to or exceeds that of $^4_\Lambda$H, which contrasts the measurement from the STAR collaboration at $\sqrt{s_{NN}} = 3$ GeV and is consistent with a scenario in which hypernuclei receive feed-down from excited states. The data enable a high-precision measurement of the hypernuclei lifetimes. For the $^3_\Lambda$H, a lifetime of $\tau_{^3_\Lambda H} = (239 \pm 23(\text{stat}) \pm 18(\text{sys}))$ ps, is extracted, consistent on the 1σ level with that of the free Λ. In contrast, the $^4_\Lambda$H lifetime of $\tau_{^4_\Lambda H} = (209 \pm 7(\text{stat}) \pm 10(\text{sys}))$ ps, shows a 4.5 σ deviation from the free Λ lifetime. The results are compared to the available world data.

Hypernuclei at GSI/FAIR: CBM/HADES and NuSTAR

Community self-assess process initiated to make best use of GSI/FAIR infrastructure.

What measurements are most important to constrain the Y-N interaction?
Which experiment is best suited for which measurement?

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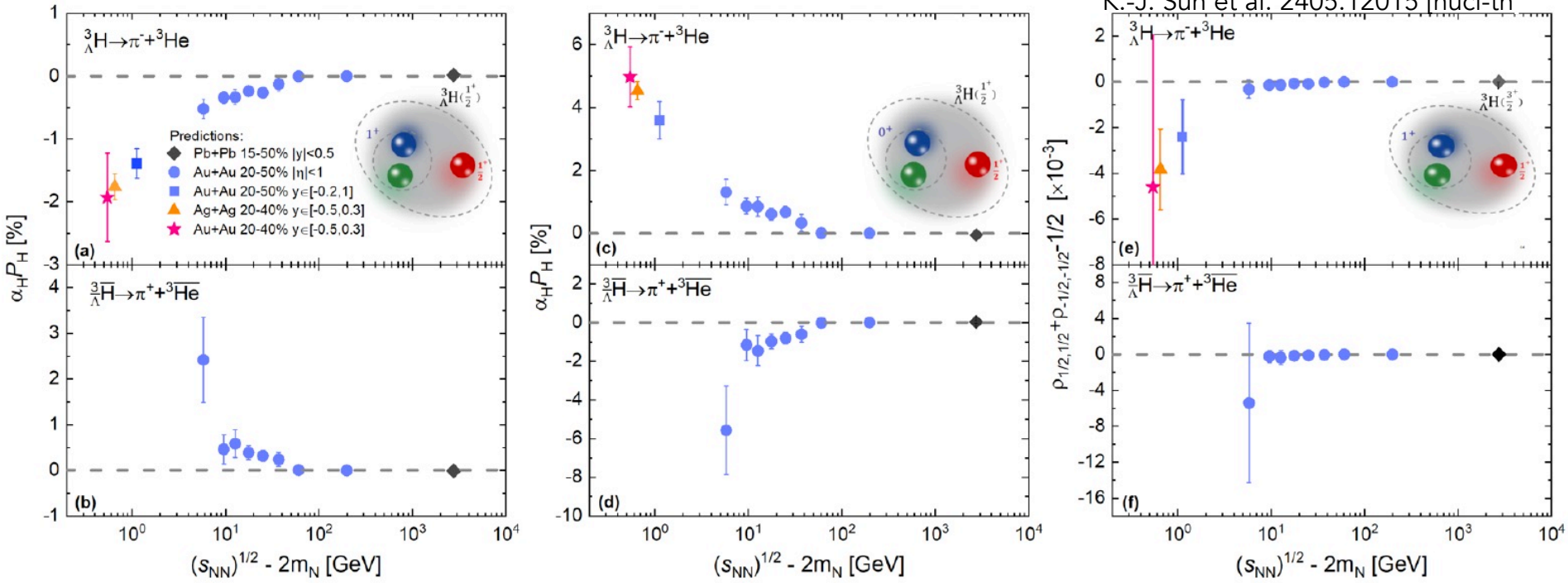
[e] *University of Wrocław, 50-204 Wrocław, Poland*

(Dated: November 12, 2025)

We present the first observation of $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H in Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV, emitted around mid-rapidity. The hypernuclei are reconstructed via their two-body decay channels and identified through their weak-decay topology, employing an artificial neural network for enhanced discrimination. The analysis methodology is validated using Λ hyperons. The resulting rapidity distributions, dN/dy, exhibit a bell shape centered at mid-rapidity. The yield of $^{3}_{\Lambda}$H is equal to or exceeds that of $^{4}_{\Lambda}$H, which contrasts the measurement from the STAR collaboration at $\sqrt{s_{NN}} = 3$ GeV and is consistent with a scenario in which hypernuclei receive feed-down from excited states. The data enable a high-precision measurement of the hypernuclei lifetimes. For the $^{3}_{\Lambda}$H, a lifetime of $\tau_{^{3}_{\Lambda}H} = (239 \pm 23(\text{stat}) \pm 18(\text{sys}))$ ps, is extracted, consistent on the 1σ level with that of the free Λ. In contrast, the $^{4}_{\Lambda}$H lifetime of $\tau_{^{4}_{\Lambda}H} = (209 \pm 7(\text{stat}) \pm 10(\text{sys}))$ ps, shows a 4.5 σ deviation from the free Λ lifetime. The results are compared to the available world data.

At the sweet spot: Hypernuclei at CBM

K.-J. Sun et al. 2405.12015 [nucl-th



Extraction of spin composition of hypertriton by polarization measurement

Out of the Box thinking: Look for the unexpected

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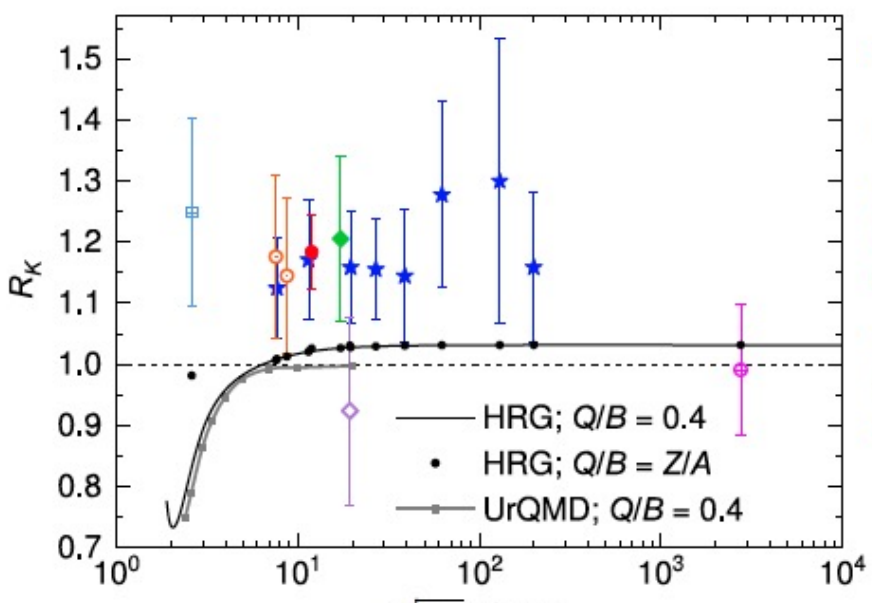
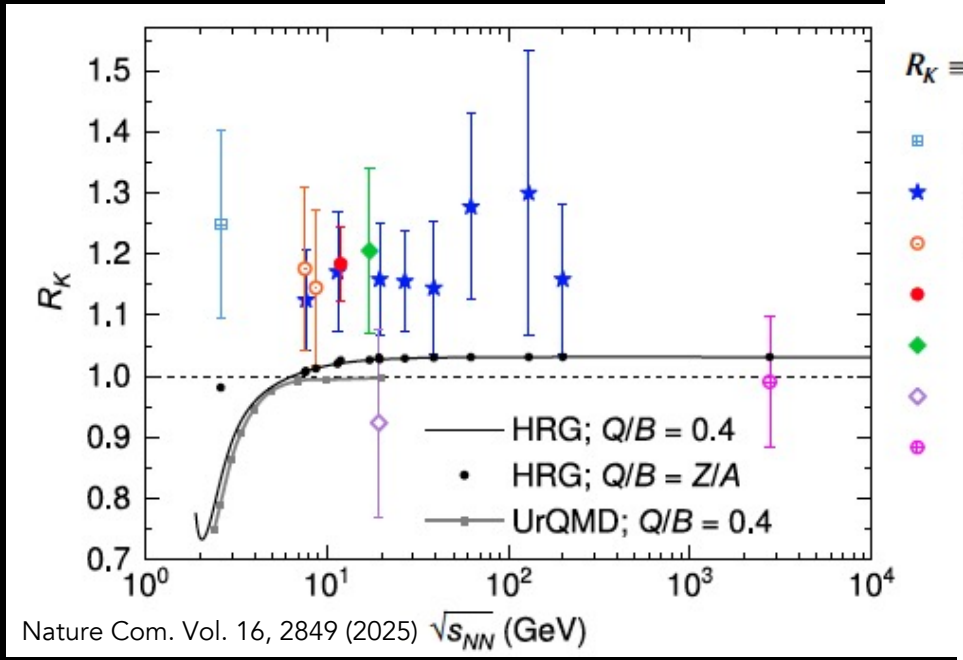


Nature Com. Vol. 16, 2849 (2025)

$$R_K \equiv \frac{\langle K^+ \rangle + \langle K^- \rangle}{\langle K^0 \rangle + \langle \overline{K}^0 \rangle} = \frac{\langle K^+ \rangle + \langle K^- \rangle}{2\langle K^0_S \rangle} = 1.$$

- HADES; Ar+KCl; 4π
- STAR; Au+Au; $y \approx 0$
- NA49; Pb+Pb; 4π
- NA61/SHINE; Ar+Sc; $y \approx 0$
- CERES; Pb+Au; $y \approx 0$
- NA35; S+S; 4π
- ALICE; Pb+Pb; $y \approx 0$

Out of the Box thinking: Look for the unexpected



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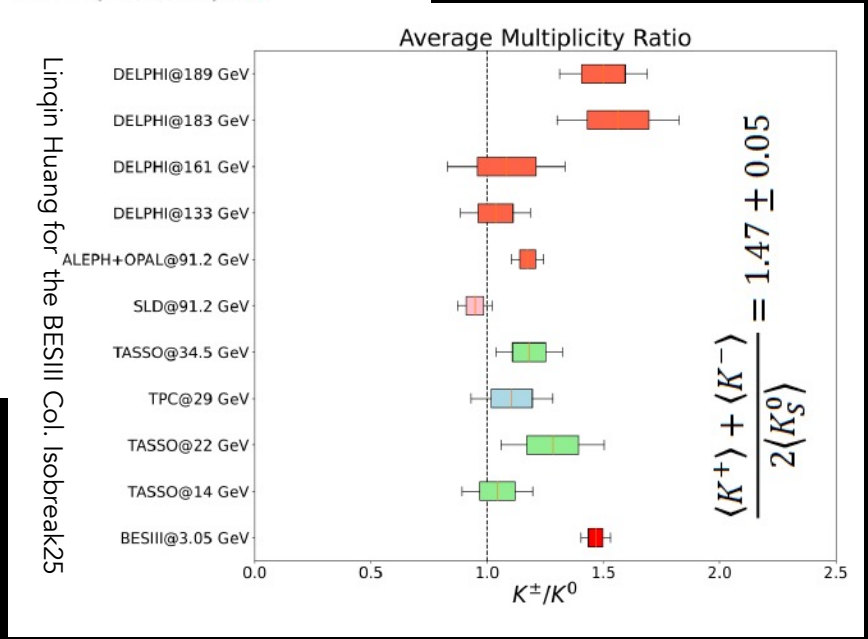
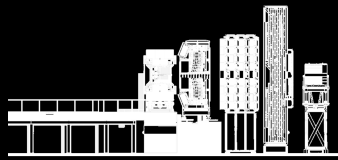


Linqin Huang for the BESIII Col. Isobreak25

→ Effect discovered in HIC, already present in e^+e^-!

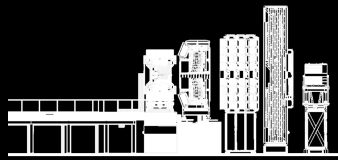
Summary



CBM Compressed Baryonic Matter experiment at FAIR

Summary

CBM is coming!



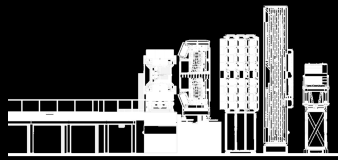
CBM Compressed Baryonic Matter experiment at FAIR

Physics case

- Landmarks of the QCD phase diagram (phase transitions, critical point) are still open → discovery potential
- Likely no single smoking gun → focus on solid baselines and high-quality measurements

Summary

CBM is coming!



CBM Compressed Baryonic Matter experiment at FAIR

Physics case

- Landmarks of the QCD phase diagram (phase transitions, critical point) are still open
  → discovery potential
- Likely no single smoking gun → focus on solid baselines and high-quality measurements

Strategic context

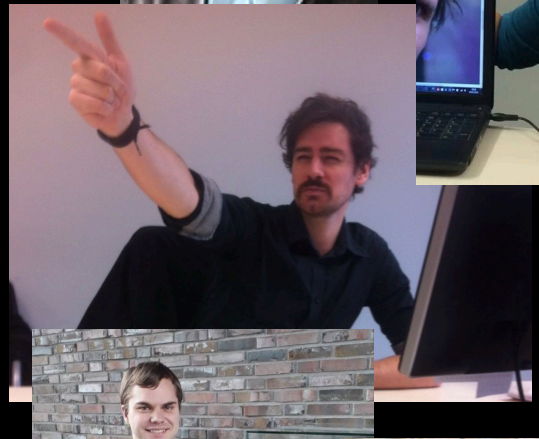
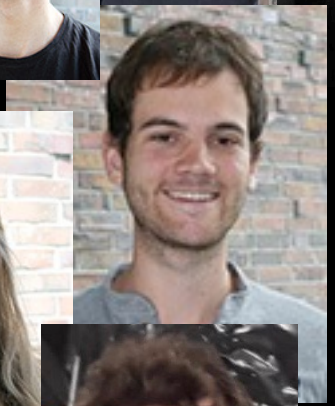
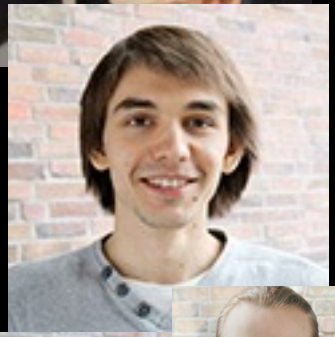
- Lab is moving from survival to science mode
  → cultural reset by generation change in leadership

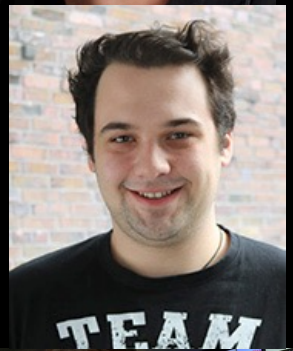
Execution (< 3 years)

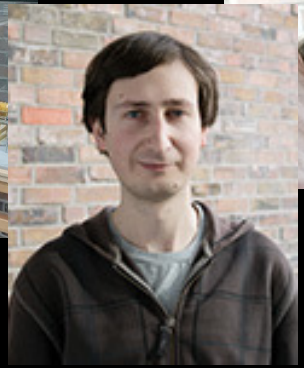
- Full focus on the group and deliverables
- No overcommitment of responsible persons

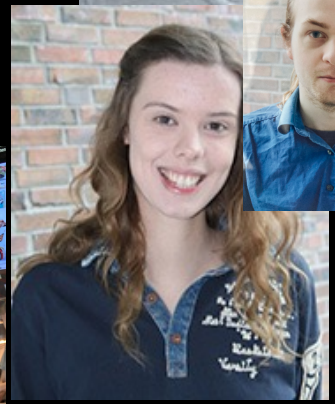






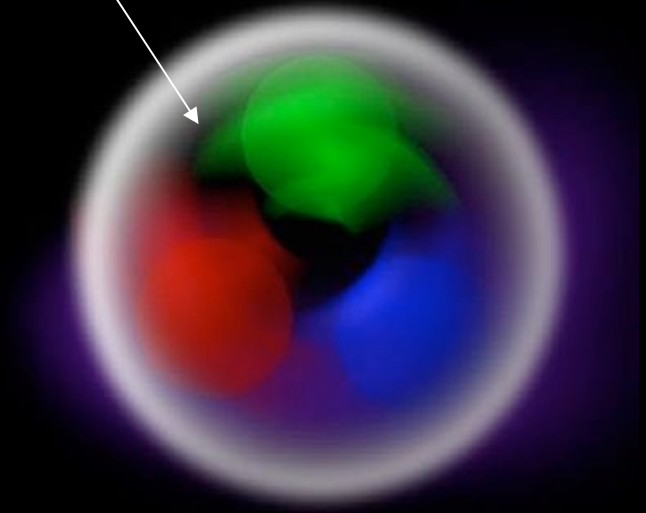


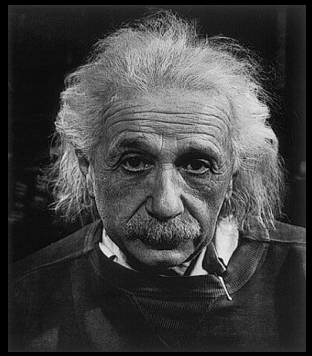

Back Up

The generation of mass

Distortion of color neutrality



Only few % of the nucleon mass result from the interaction with the Higgs-field.



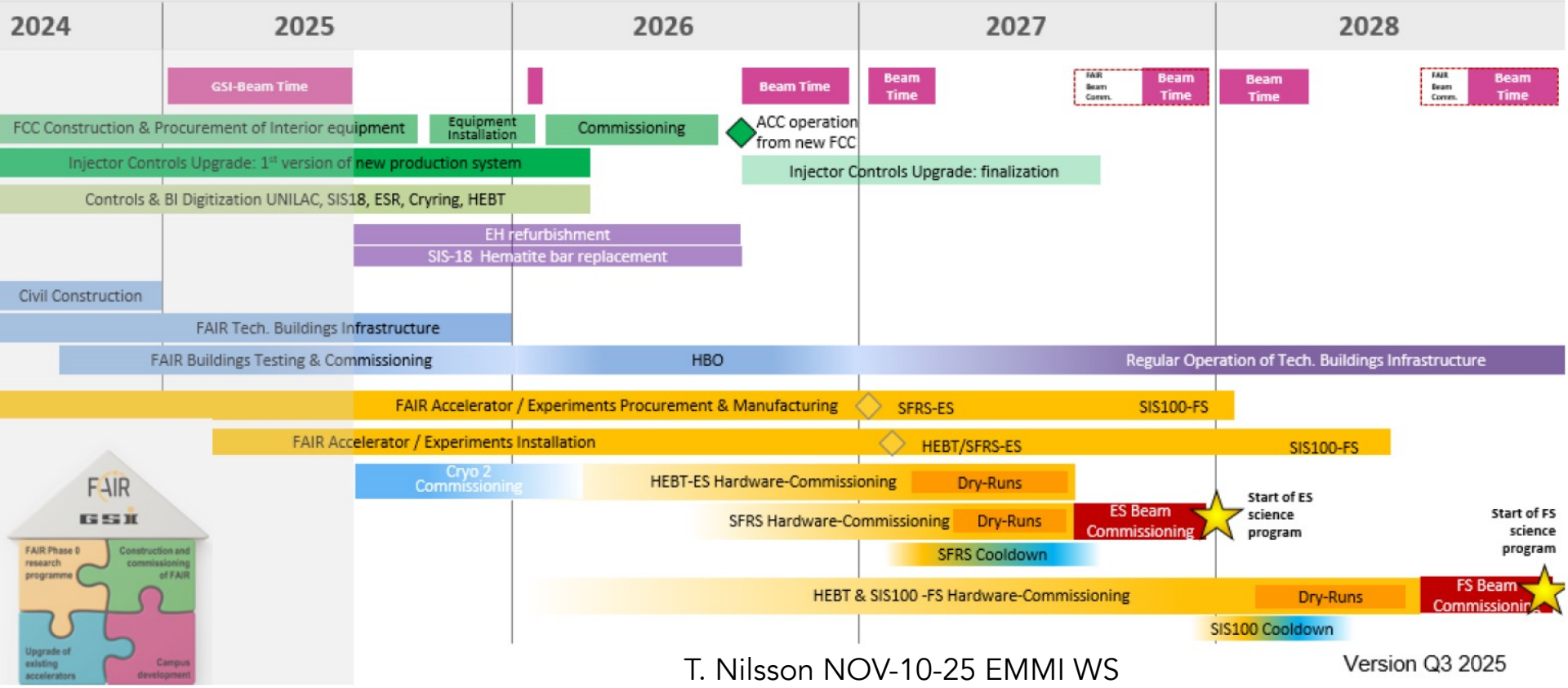
Localization “costs” energy!

$\Delta x \Delta p \geq \hbar$ $E^2=(pc)^2+(mc^2)^2$

“Observed hadron masses are nature's compromise between distortion of the vacuum and localization!”
F. Wilczek

→ Dynamical generation of hadron mass.

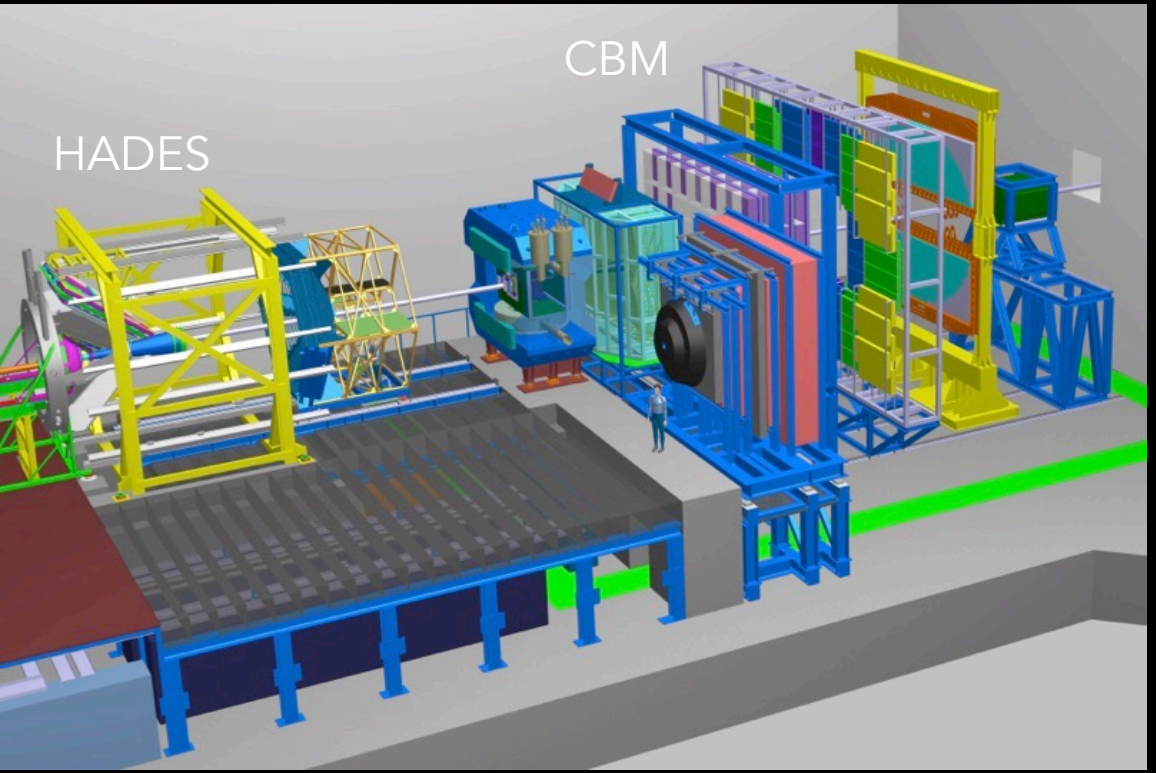
FAIR & GSI Integrated Schedule



T. Nilsson NOV-10-25 EMMI WS

Version Q3 2025

CBM Setup



- Interaction rates of up to 10 MHz
  - → high statistic measurements of rare probes
- Free-streaming
  - → nearly dead-time free data taking
- Tracking based entirely on silicon
  - → fast and precise track reconstruction
  - → 4D Tracking
- On-line event selection
  - → high-selective data reduction

Systematic Uncertainties

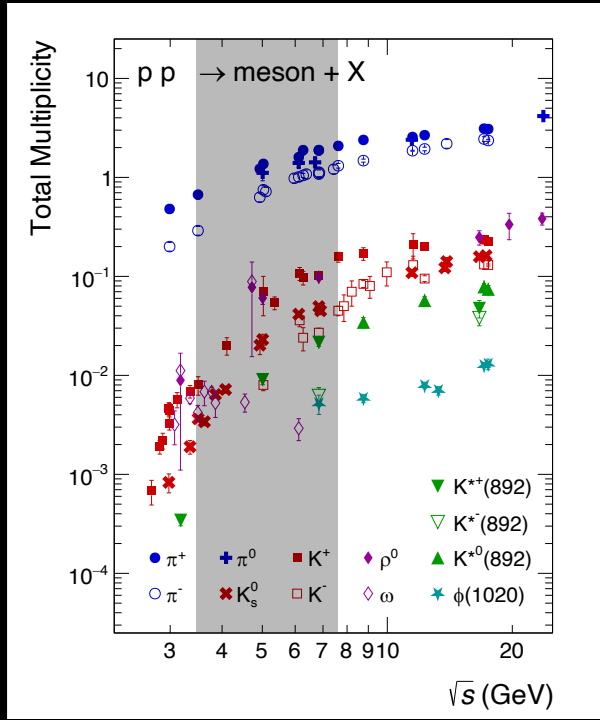
The FAIR energy range

Theory situation:
complicated region for phenomenological models:

- transition from resonance production mechanisms (2 →2, 2→ 3) to multiparticle production (2 → n)
- transition from nuclear resonance models (3d phase space) to string formation and decay (longitudinal phase space) is not well known

Experimental situation:

- poor data on (light and strange) hadron multiplicities in p+p reactions
- practically NO data on hadron production in p+n reactions
- little information on differential spectra, correlations etc.
- no elastic scattering data for p_{Lab} > 1GeV (urgently needed for transport approaches)
- little information about multi-step processes



Reference measurements are basis for solid interpretation of heavy-ion data!

2004: David J. Gross; H. David Politzer; Frank Wilczek — asymptotic freedom in QCD. Strong Interaction

2006: John C. Mather; George F. Smoot — CMB blackbody spectrum & anisotropies (COBE). Cosmology

2008: Yoichiro Nambu — spontaneous symmetry breaking; Makoto Kobayashi; Toshihide Maskawa -origin of CP violation (CKM).

Particle Physics

2011: Saul Perlmutter; Brian P. Schmidt; Adam G. Riess — accelerating expansion of the Universe. Cosmology

2013: François Englert; Peter W. Higgs — Higgs mechanism for mass generation. Particle Physics

2015: Takaaki Kajita; Arthur B. McDonald — neutrino oscillations (neutrino mass). Particle Physics

2017: Rainer Weiss; Barry C. Barish; Kip S. Thorne — gravitational waves (LIGO). Cosmology

2019: James Peebles — physical cosmology; Michel Mayor; Didier Queloz — first exoplanet around a Sun-like star. Cosmology

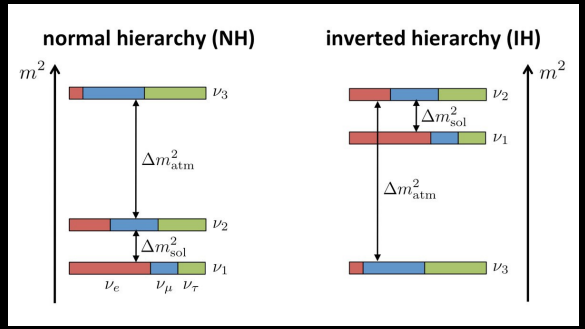
2020: Roger Penrose — black-hole formation; Reinhard Genzel; Andrea Ghez — supermassive black hole at the Galactic Centre.

Cosmolgy

2024: John J. Hopfield; Geoffrey Hinton — foundational discoveries/inventions enabling machine learning with artificial neural
AI

The LBL neutrino experiment story

Neutrino oscillations (2015 Nobel Prize)
→ neutrinos have mass → beyond SM
Mass hierarchy?
Long-baseline (LBL) neutrino experiments (T2K/Dune):



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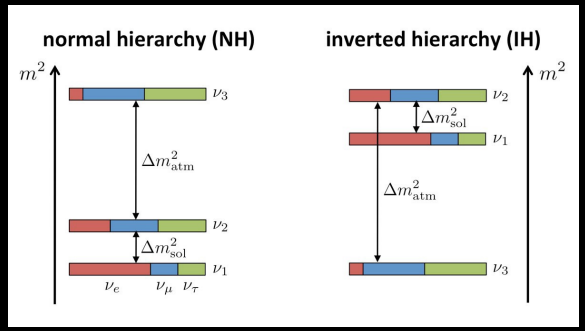

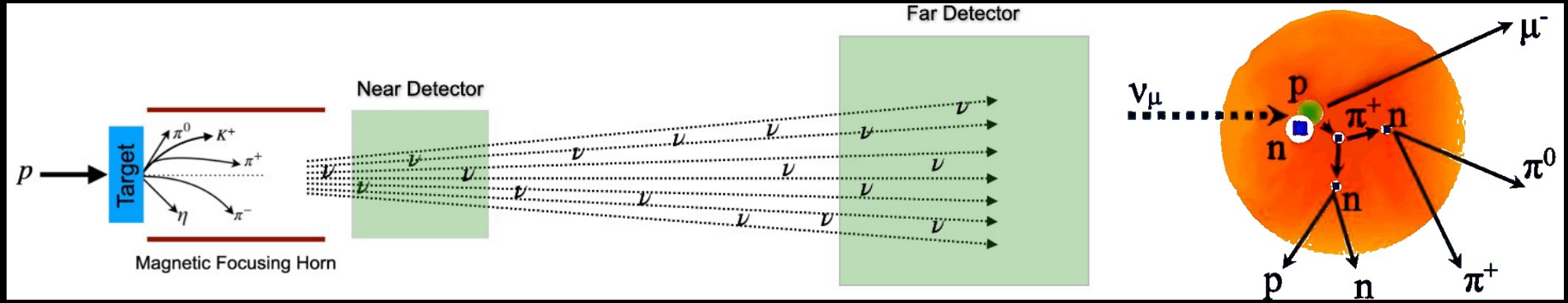

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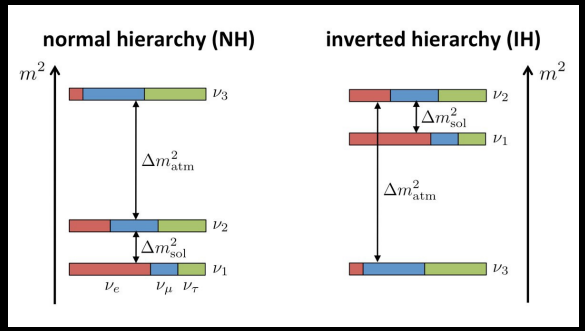

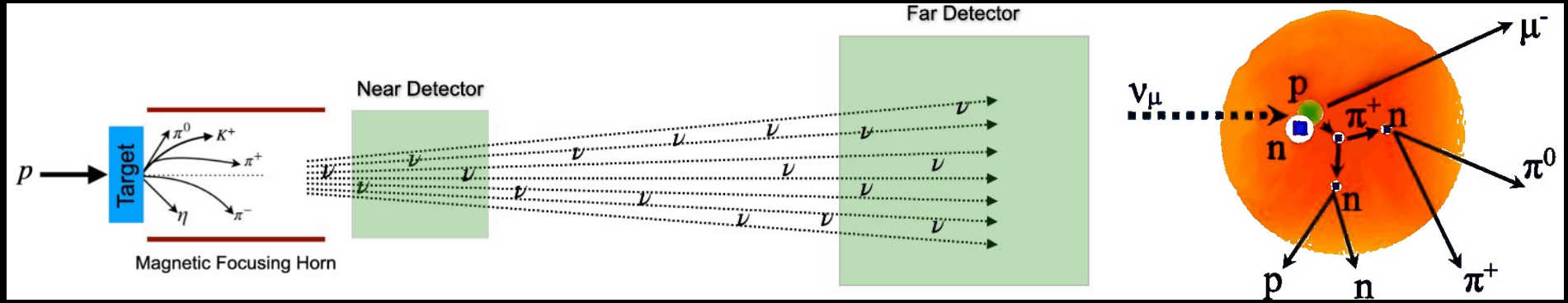

Neutrino energy is not known and is reconstructed from the interaction products measured in the detector:
Calorimetric ('full' deposited energy) method:
relies on visible energy; missing energy from neutrons, detector threshold, pion absorption, etc.

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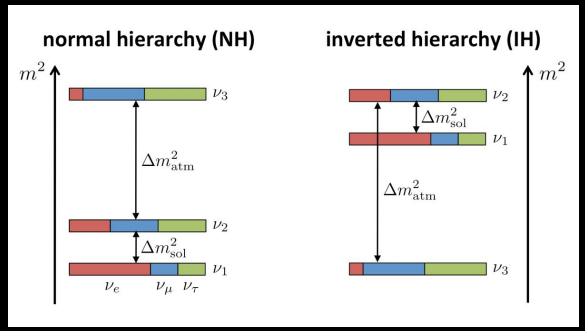

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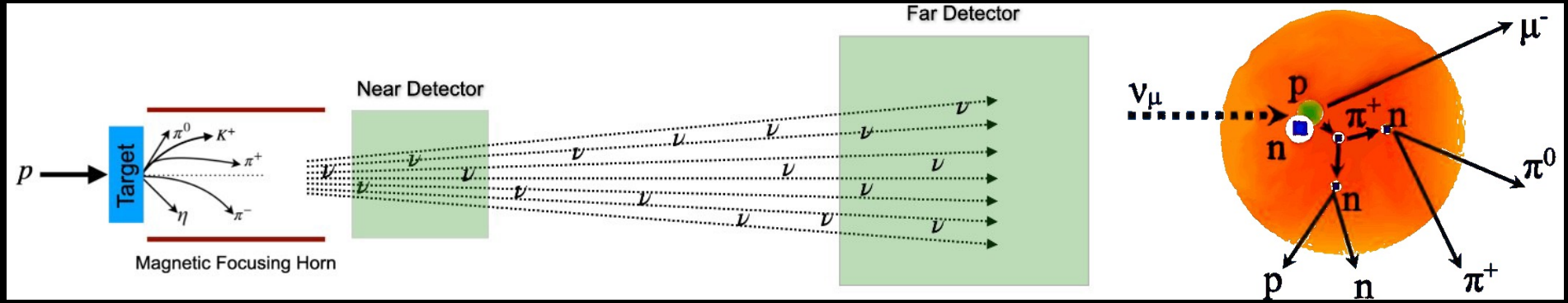

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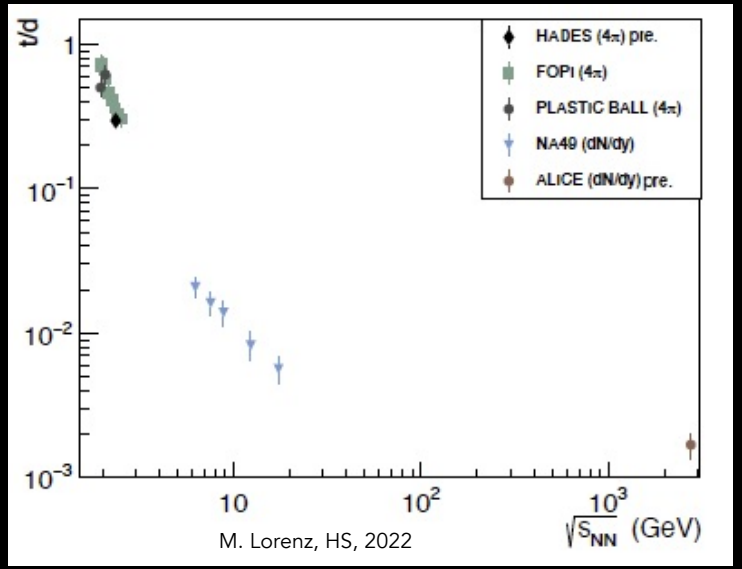
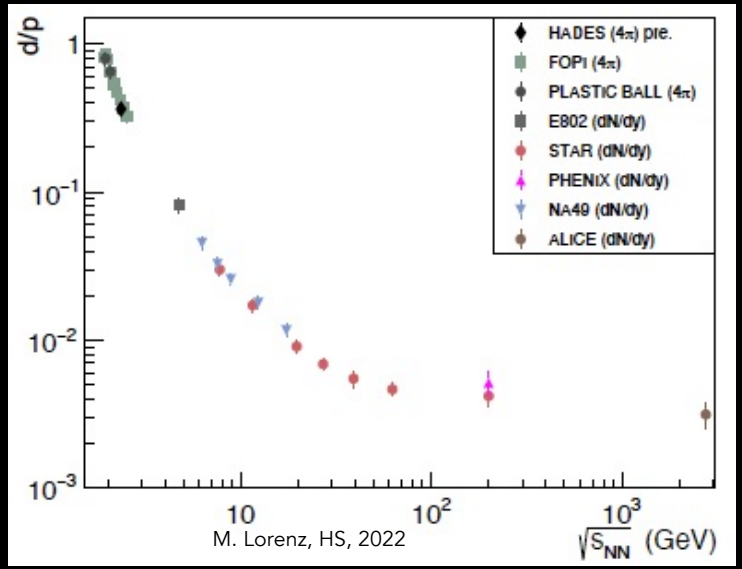
→ CBM baselines reduce **ν**–A model systematics for LBL

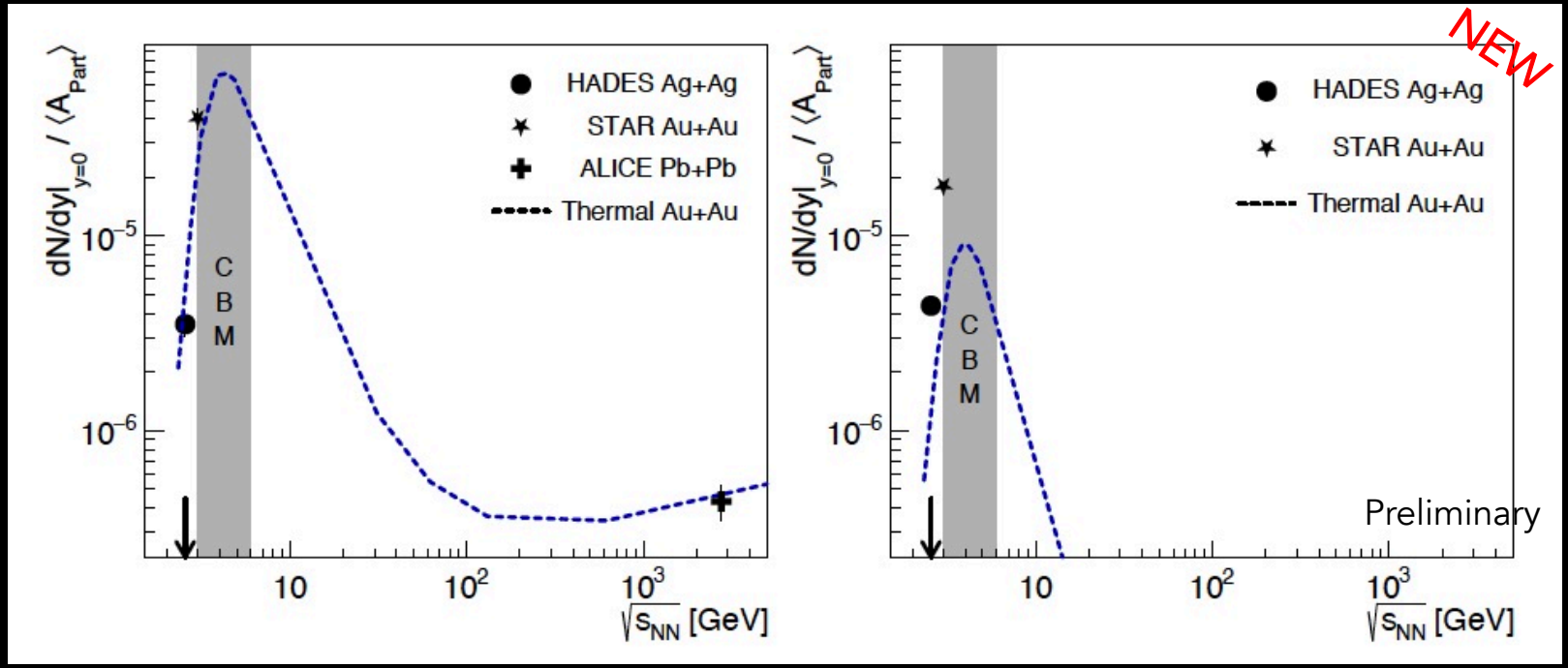
Energy Dependence: Light Nuclei





The fraction of baryons bound in light nuclei increases with decreasing energy.

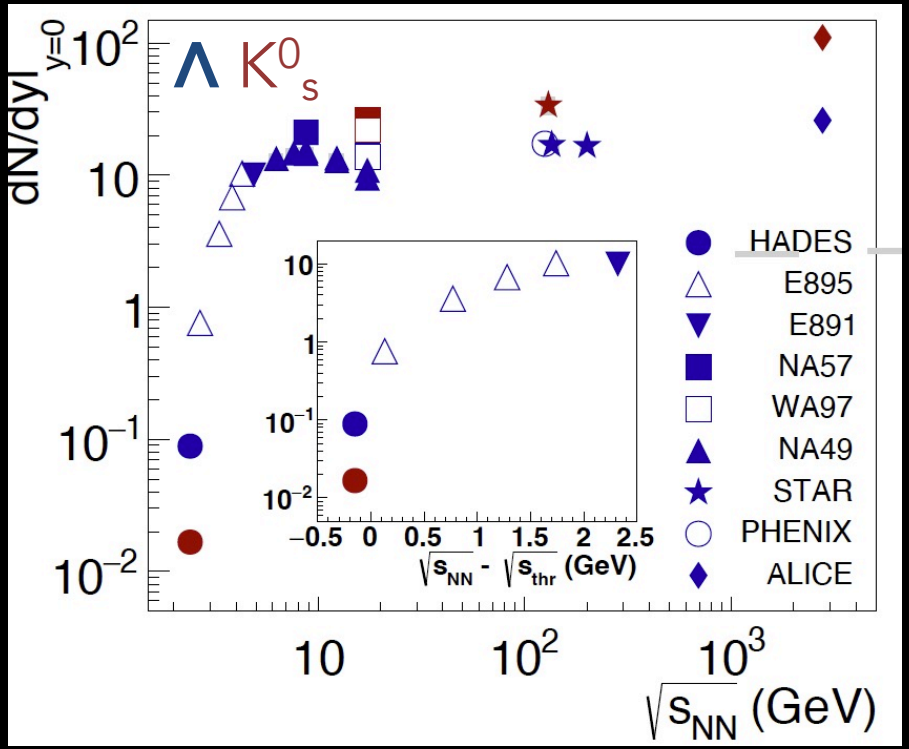
Excitation functions: Energy



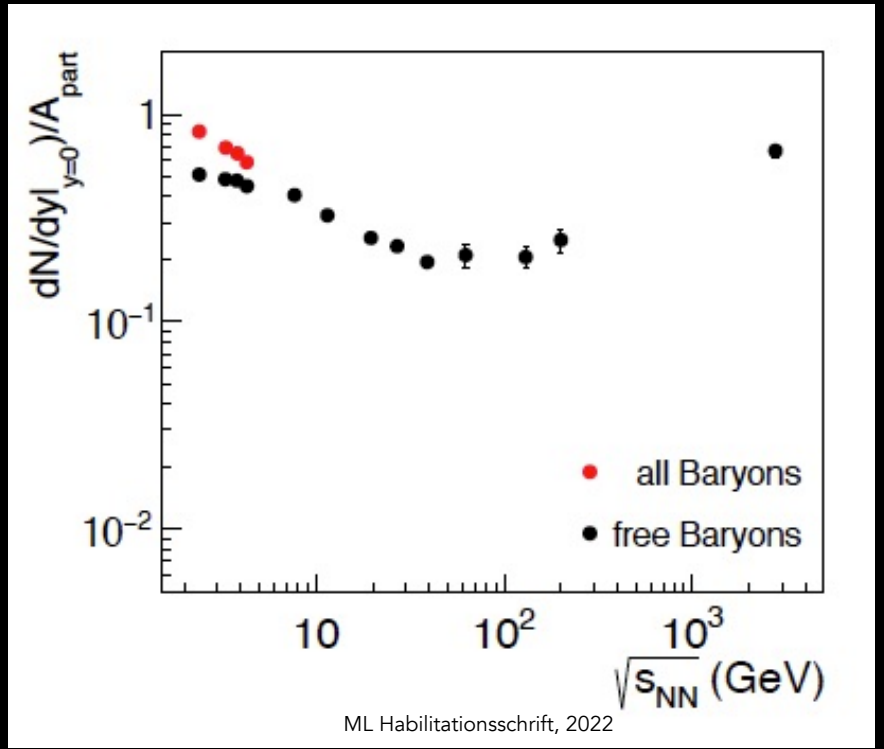
Shift of Hyperhydrogen maximum due to excited ${}^{4}_{\Lambda}H$ states, which are not yet included in the HRG.

Phys. Lett. B, 754:360372, (2016)., Phys. Rev. Lett.,128(20):202301, (2022)., Phys. Lett. B, 697:203207, (2011).

At the sweet spot: Hypernuclei at CBM



Phys.Lett. B778 (2018) 403-407

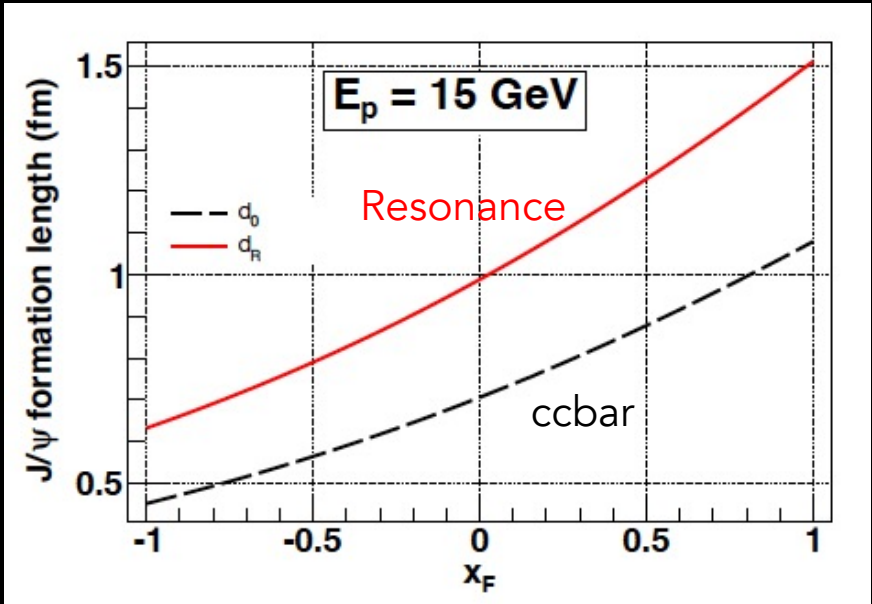


ML Habilitationsschrift, 2022

Steep excitation function, strangeness rare at low energies.

The fraction of baryons bound in light nuclei increases with decreasing energy.

Charm at CBM



P. P. Bhaduri et. al. J. Phys. G 45 (2018)

- Perturbative probe at low energies.
- Cross section and production mechanism unknown at SIS100 energies $\sqrt{s_{NN}} < 8$ GeV.
- Gluon fusion vs. gluon exchange. ω to J/ψ should be suppressed by the OZI rule if gluon exchange is the dominant process.
- J/ψ multiplicities key observable for QGP
  A. Andronic et. Al. Eur.Phys.J.C 76 (2016) 3, 107
- Important reference measurement of J/ψ absorption in cold nuclear matter possible at CBM

π–A world data base

π^++C

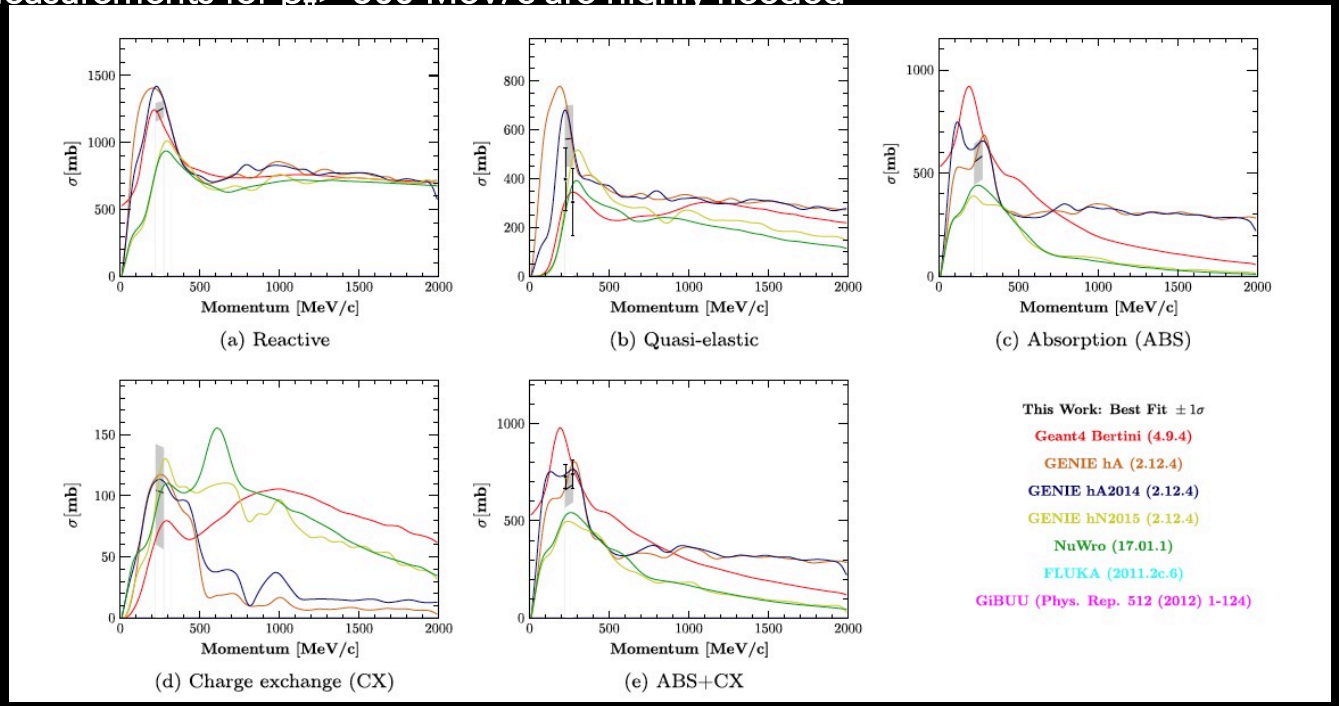
- p_π<250 MeV/c: Δ(1232) resonance region rather well-known.
- 300 < p_π<500 MeV/c : few measurements (π, πx) or (π, ππx) (LAMPF, TRIUMF, KEK).
- p_π>500 MeV/c : only σ_{tot} (Saturne-1, NIMROD, BNL) and differential elastic cross sections (KEK).

→ Multi-differential measurements for p_π> 500 MeV/c are highly needed

π^-+C: less measurements

π^-+Fe: data very scarce

Relevant for T2K: BabyMIND and INGRID detectors contain Fe.



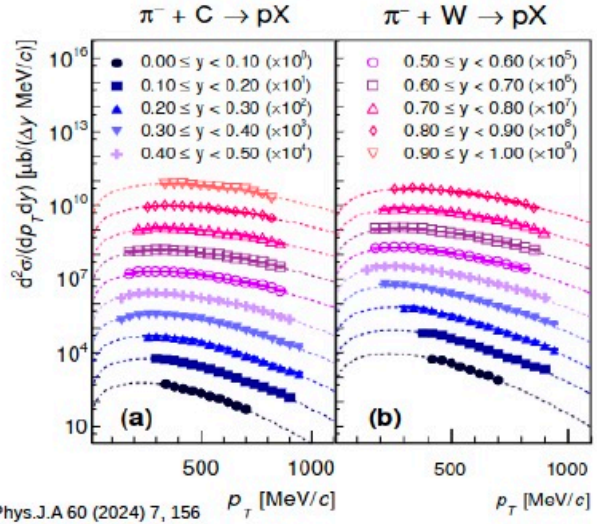
E.S. Pinzon Guerra et al.

~All~ available data only measure the xsec as a function of the incoming pion momentum → we also need differential measurement as a function of the kinematics of the outgoing particles

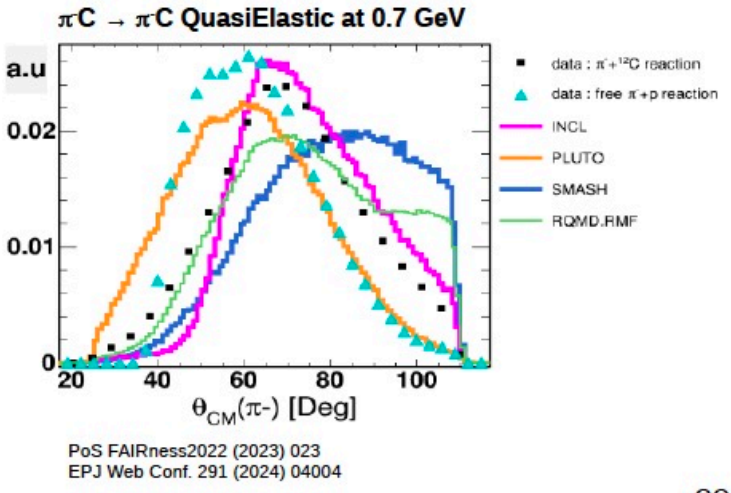
→ **HADES data!**

HADES@GSI exclusive measurements

Hadron production (π, proton, Λ, K) in π^-+C and π^-+W collisions at an incident pion beam momentum of **1.7 GeV/c.**

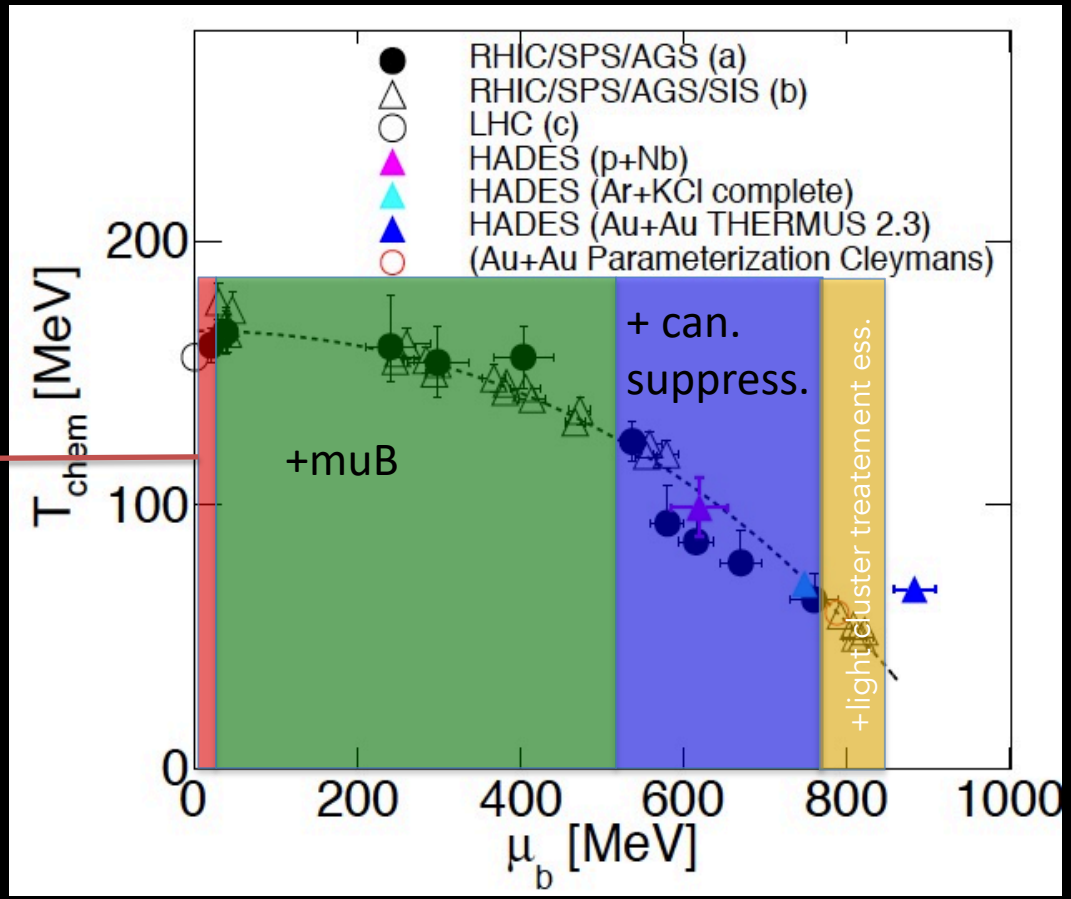


Eur.Phys.J.A 60 (2024) 7, 156

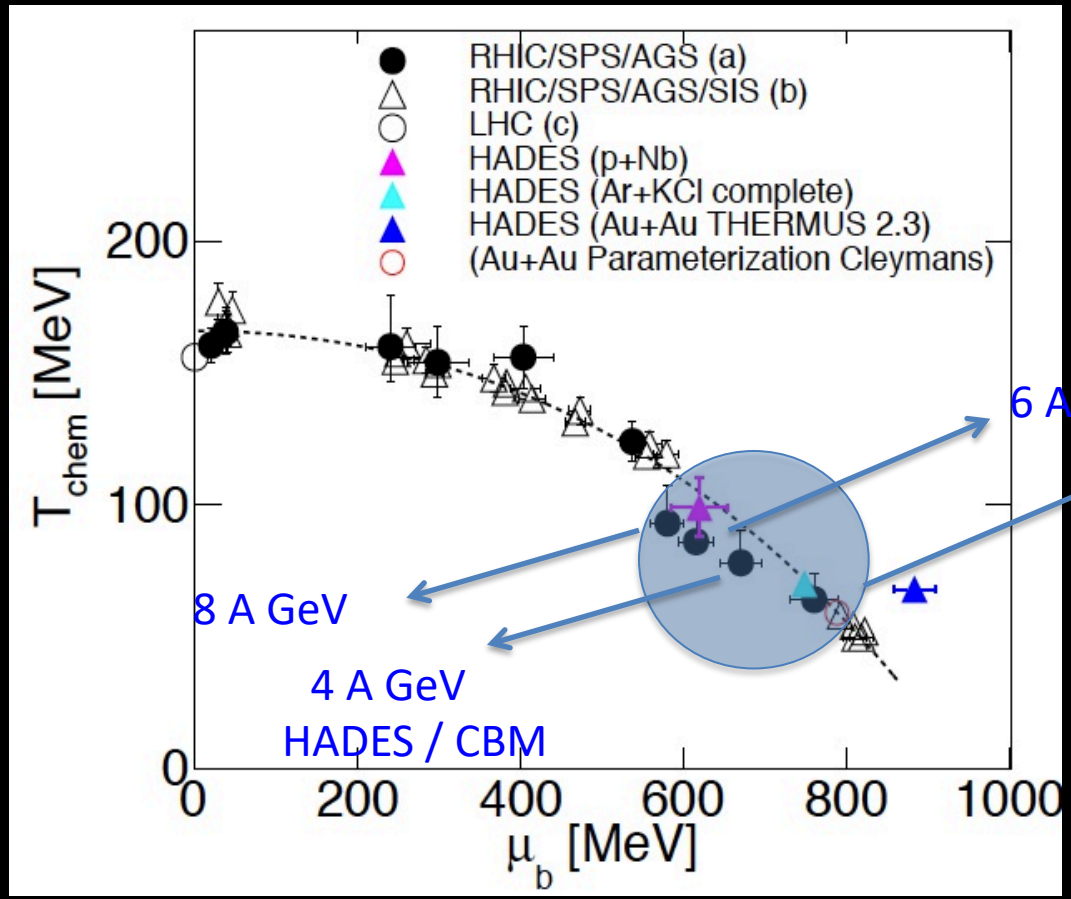


PoS FAIRness2022 (2023) 023
EPJ Web Conf. 291 (2024) 04004

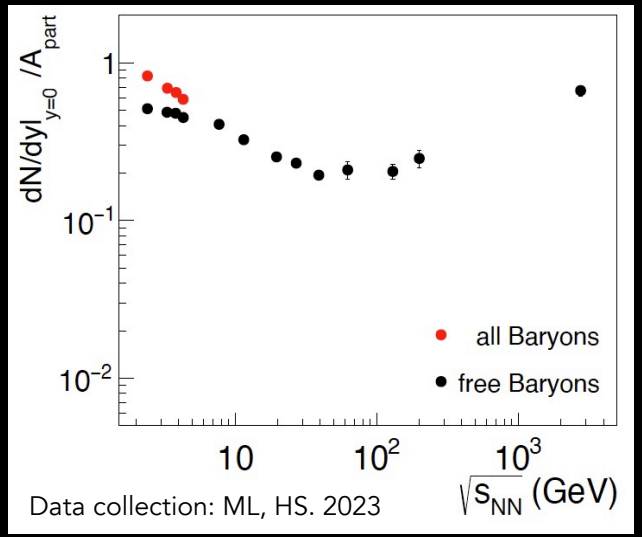
Chemical Freeze-out:

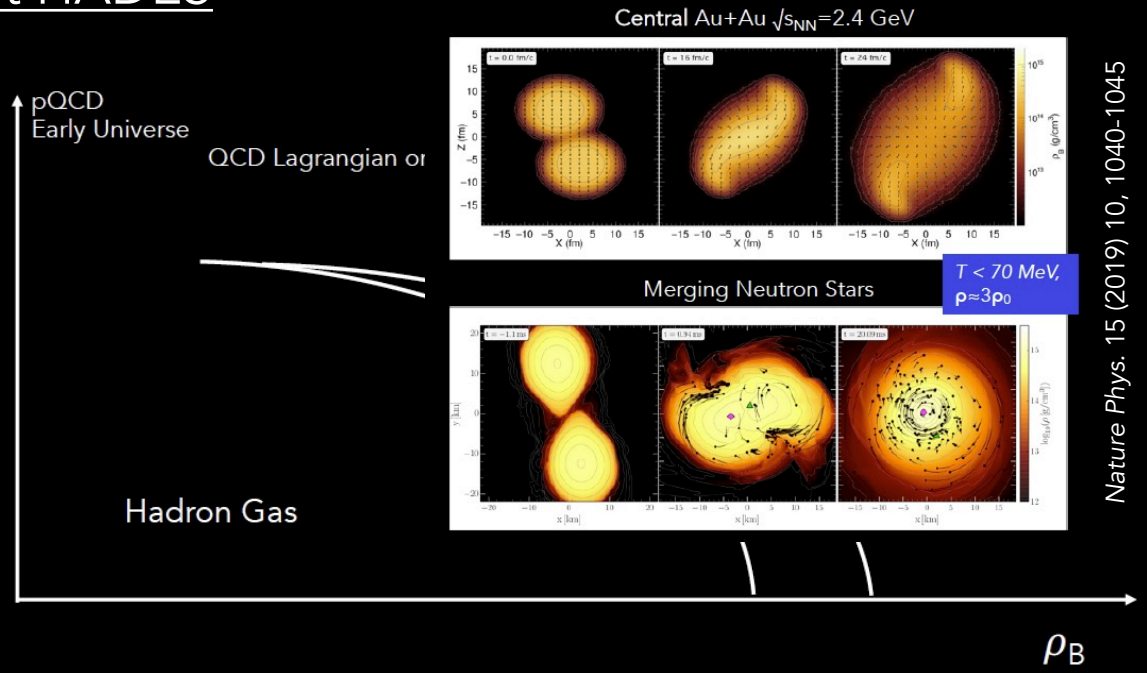


Chemical Freeze-out: Anomaly at SIS100



Baryon dominated matter at HADES





Nature Phys. 15 (2019) 10, 1040-1045

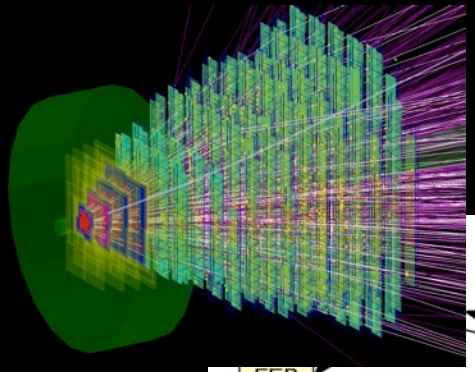
Baryon dominated system,
large amount of bound nucleons.

Clear hierarchy in hadron yields:
$p \approx 100$, $p_{bound} \approx 50$, $\pi \approx 10$,
$K^+ \approx 10^{-2}$, $K^- \approx 10^{-4}$
} cent. Au+Au

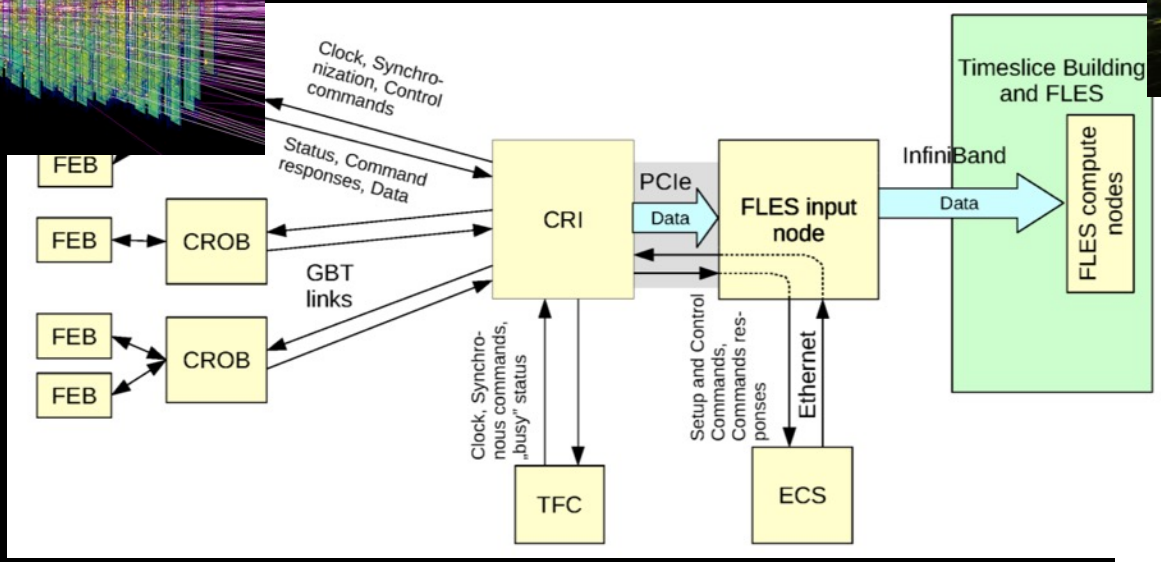
Created matter has similar properties in merging neutron stars.

This talk, focuses on:
1. p, light nuclei and π to characterize bulk properties
2. strangeness as rare probe

CBM data processing system



- Reaction rate Au+Au: 10^7 collisions / s
- Data rate: ~1 TB / s
- Archived data volume 10 - 20 PB/year

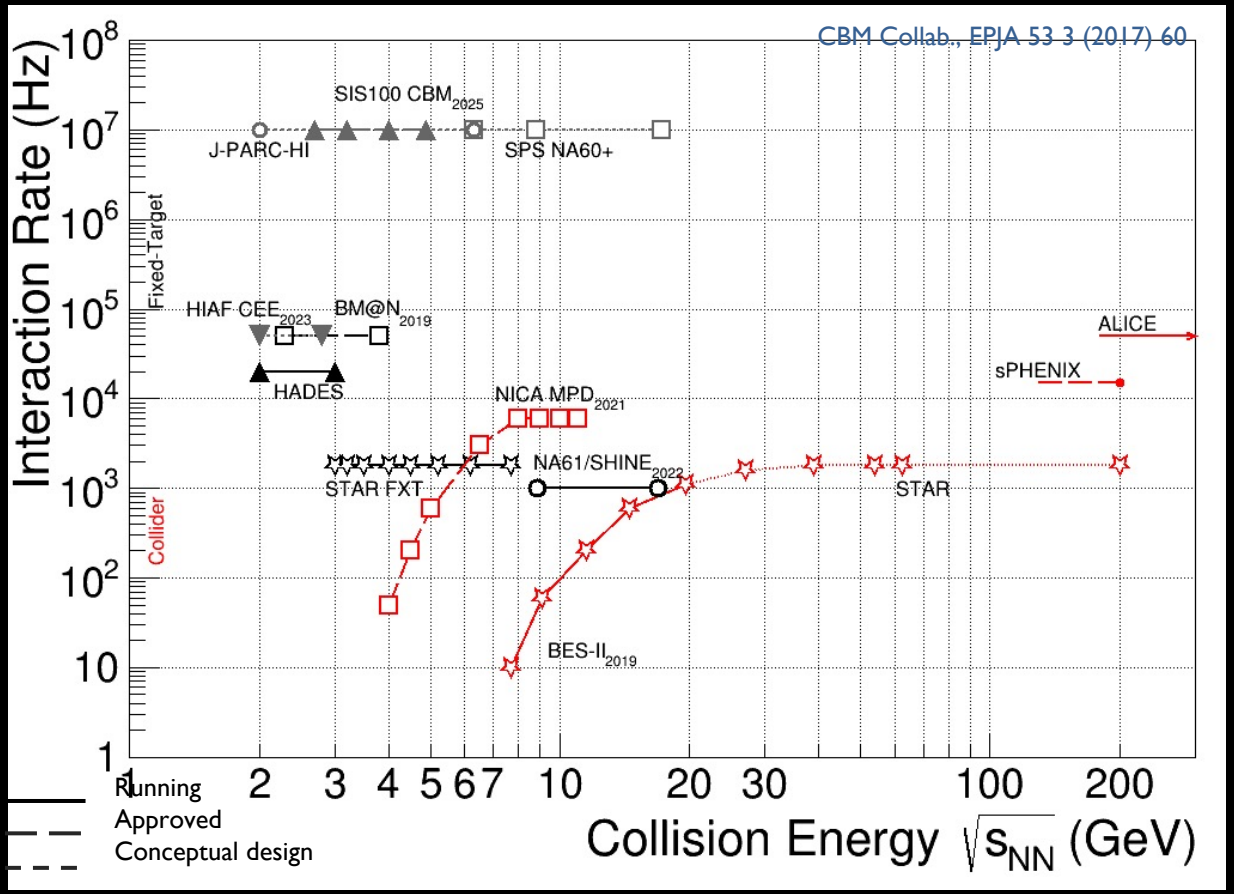


- Radiation tolerant detectors and front-end electronics
- Software based event selection, 4D tracking

ALICE FAIR

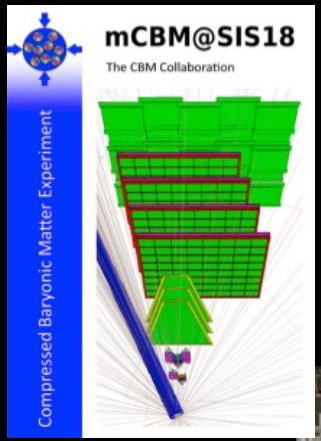
ALFA - a common framework for ALICE and FAIR experiments

Interaction Rate



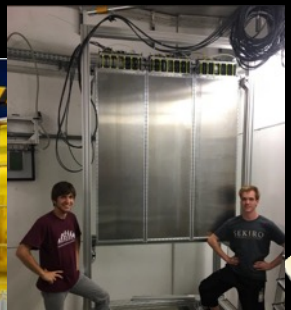
CBM's unique feature – high statistics measurement of rare probes

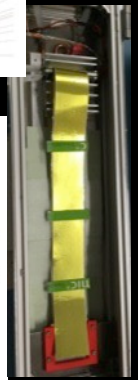
mCBM at SIS18 FAIR Phase0

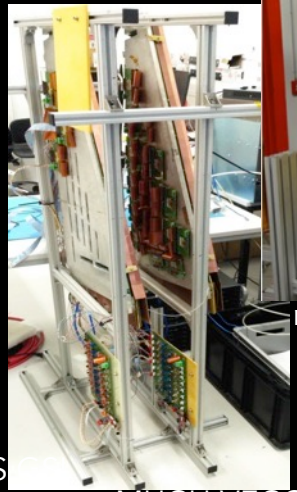


Demonstrator for full CBMdata taking and analysis chain under full load (Au-Au, 10^7 interactions/s)

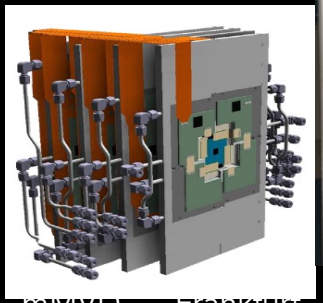
mFLES racks @ Green IT Cube







mTRD Münster, Frankfurt



mMVD$_{2020}$ Frankfurt

mSTS

mMUCH VECC

mRICH Giessen, Wuppertal

mCBM will focus on:

- Free streaming data transport to a computer farm
- Online reconstruction and event selection
- Offline data analysis

Requested beam time was fully granted by G-PAC

Connecting HICs with the Phase Diagram

Simplest assumption (Ockham's favorite):

Statistical particle production from a homogeneous source according to two parameters: temperature **T** and baryo-chemical potential μ_B.

$$\sum_i M_{m_i} = \sum_i g_i V \int \frac{d^3p}{(2\pi)^3} \exp\left(-\frac{E_i}{T}\right) \times F_{Si},$$

$$\sum_j M_{b_j} = \sum_j g_j V \int \frac{d^3p}{(2\pi)^3} \exp\left(-\frac{E_j - \mu_B}{T}\right) \times F_{Sj}$$

Constraining T and μ_B for a given collision system:

→ χ^2 minimization on measured hadron yields.

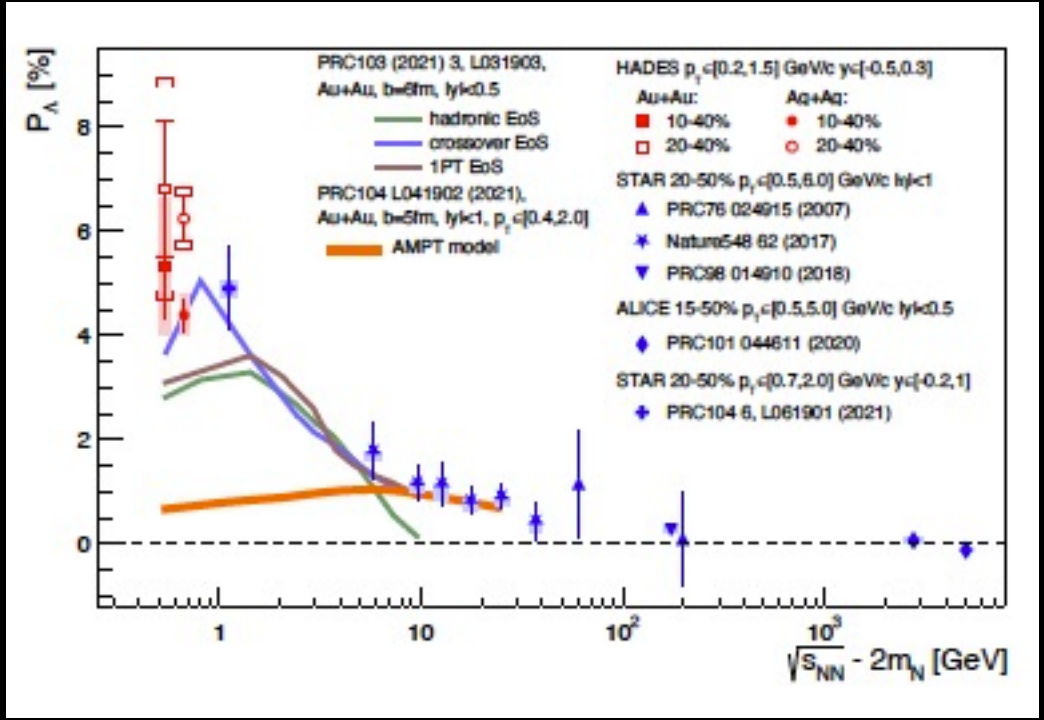
The devil in the detail:

Additional input: hadron states and branching ratio to final states, finite size of baryons and nuclei …

Wilhelm von Ockham
1288-1347,
Christian monk

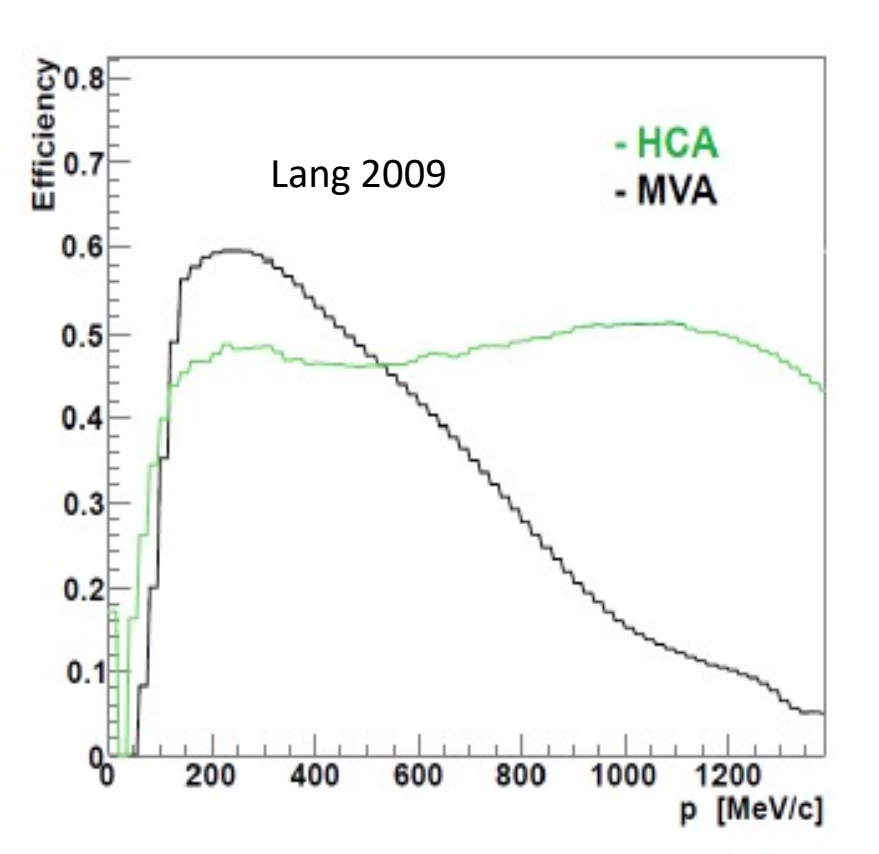
"Among competing hypotheses, the one with the fewest assumptions should be selected."

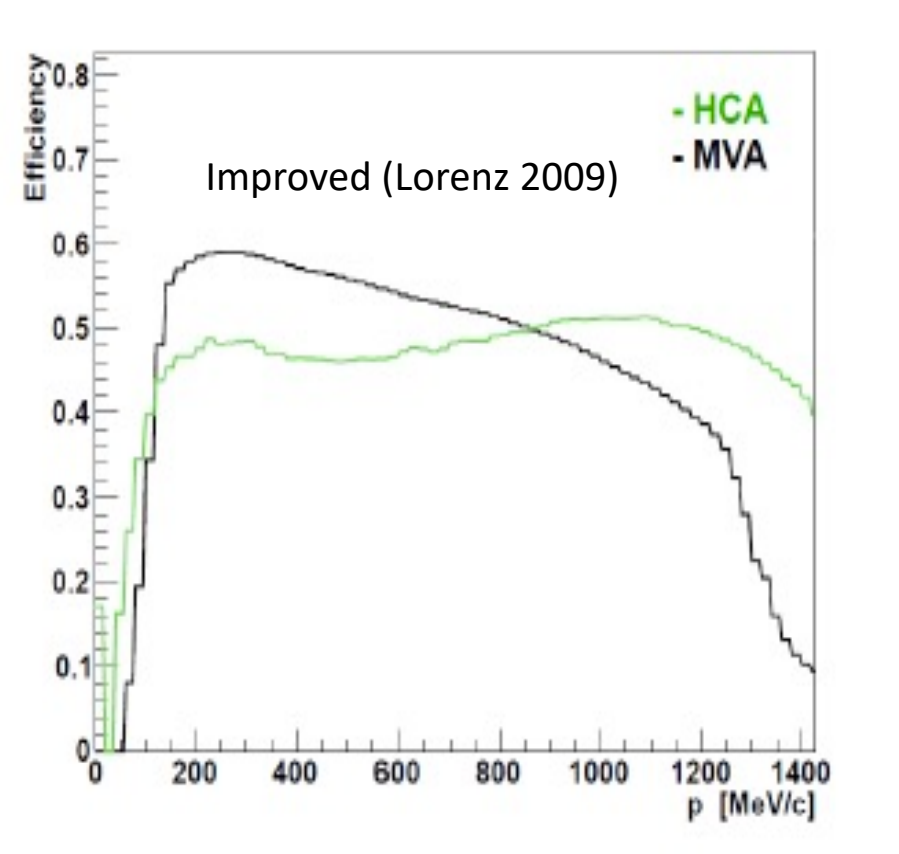
At the sweet spot: Hypernuclei at CBM

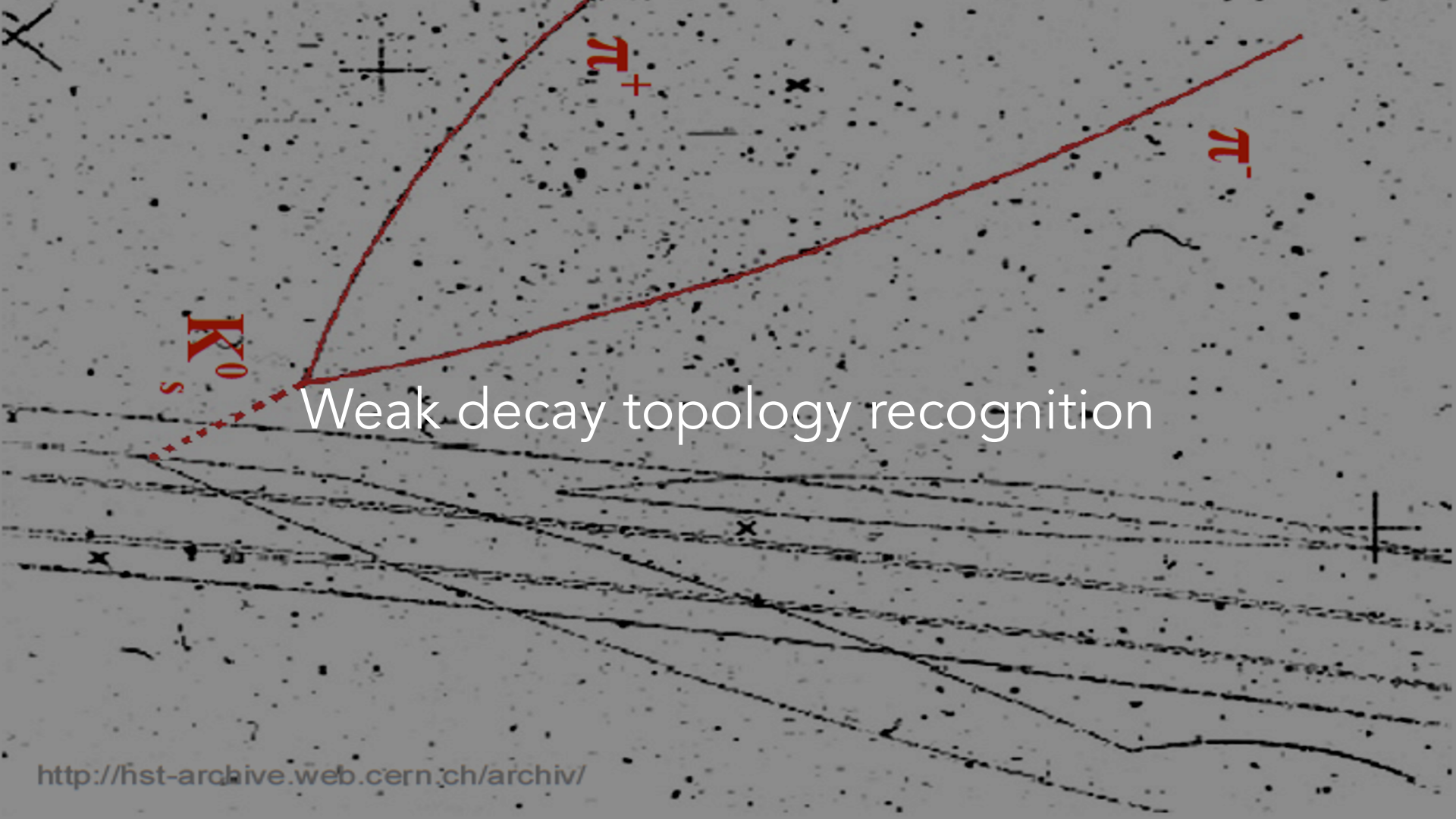


Phys.Lett.B 835 (2022) 137506

Results


Lang 2009
- HCA
- MVA
Efficiency
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
p [MeV/c]

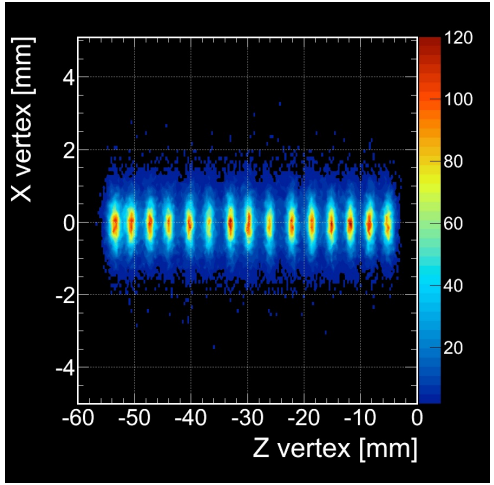

Improved (Lorenz 2009)
- HCA
- MVA
Efficiency
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
p [MeV/c]

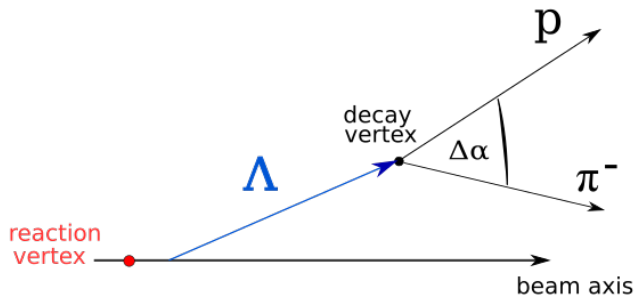


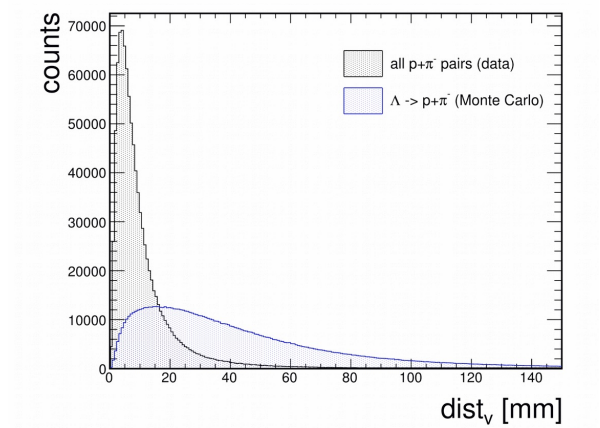
Weak decay topology recognition

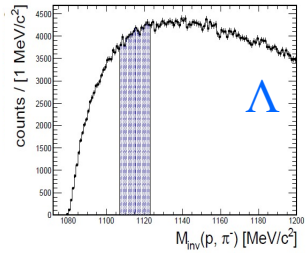
http://hst-archive.web.cern.ch/archiv/

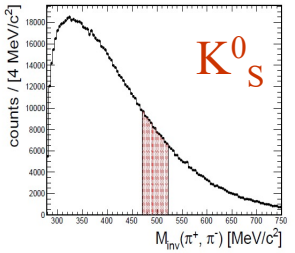
V-Decay topology





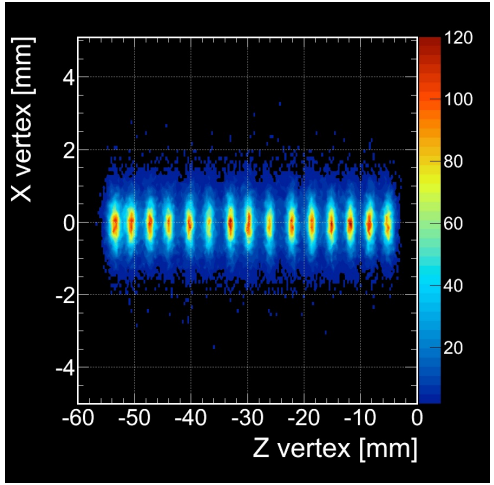


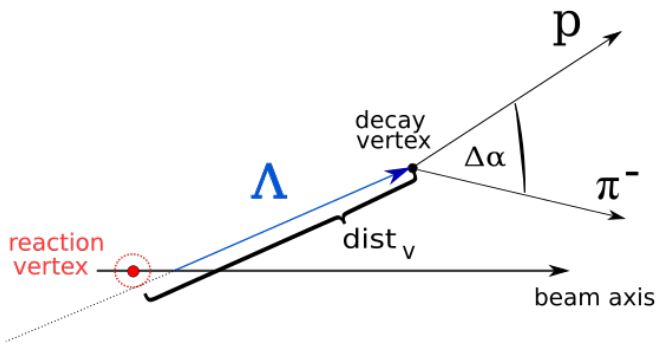


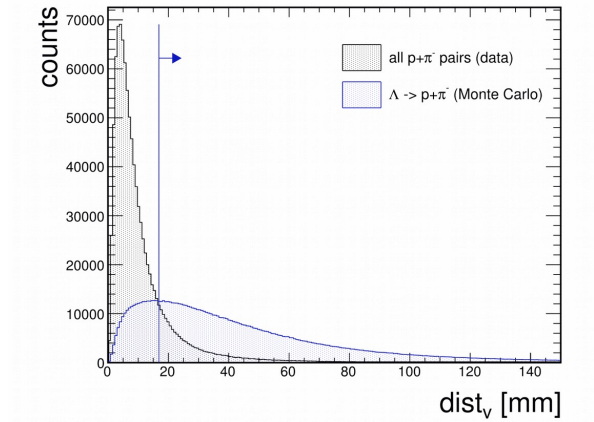


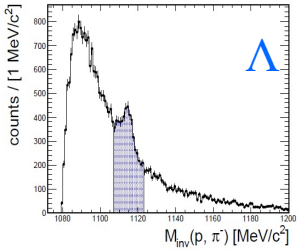
T. Scheib

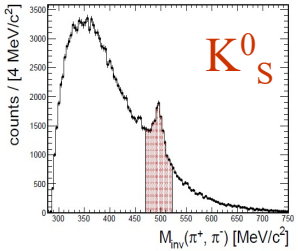
V-Decay topology





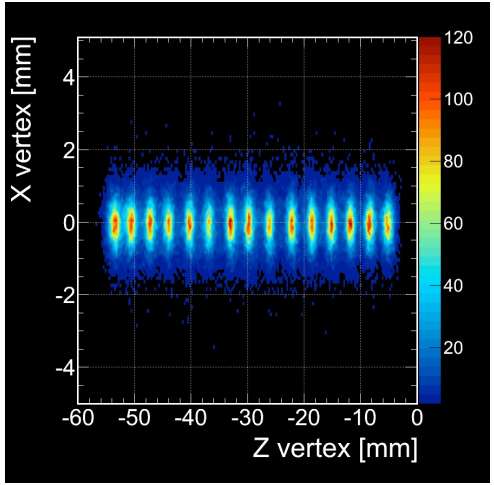


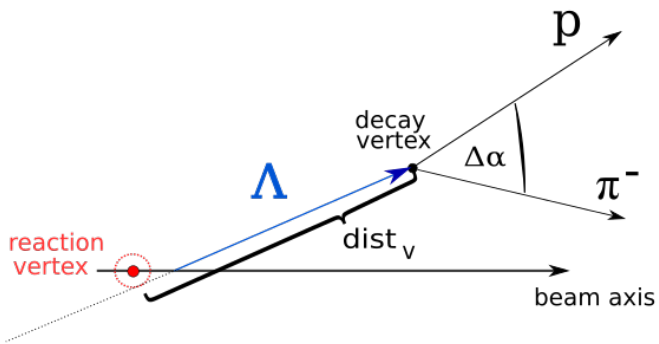


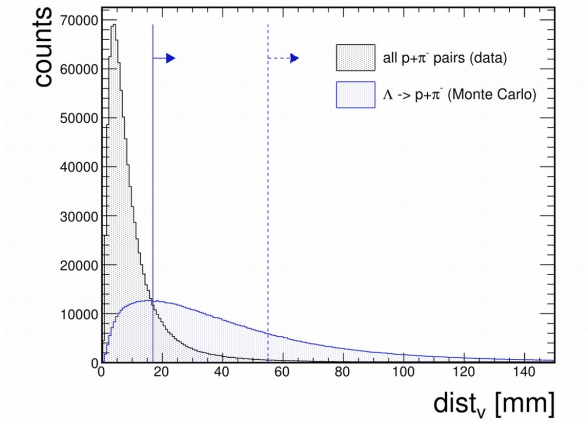


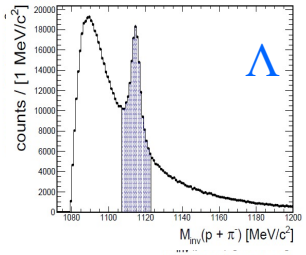
T. Scheib

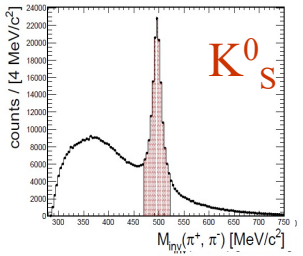
V-Decay topology





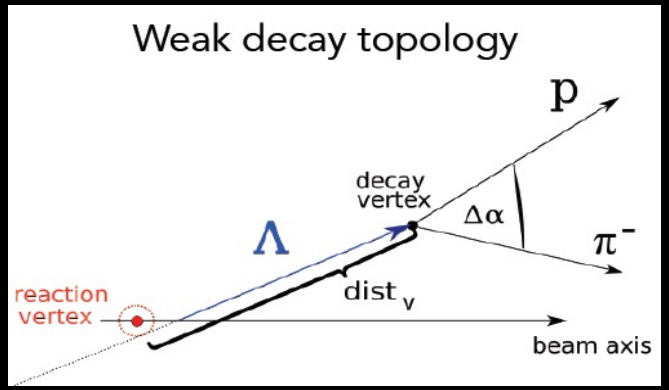




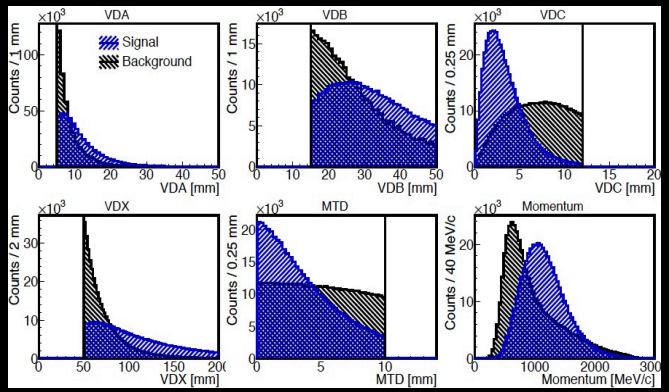


T. Scheib

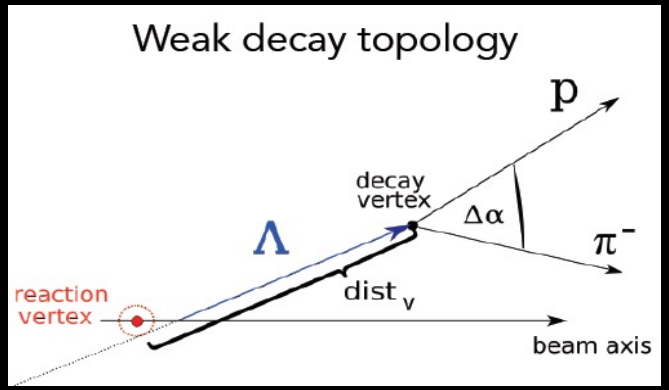
Weak decay topology recognition with neural networks



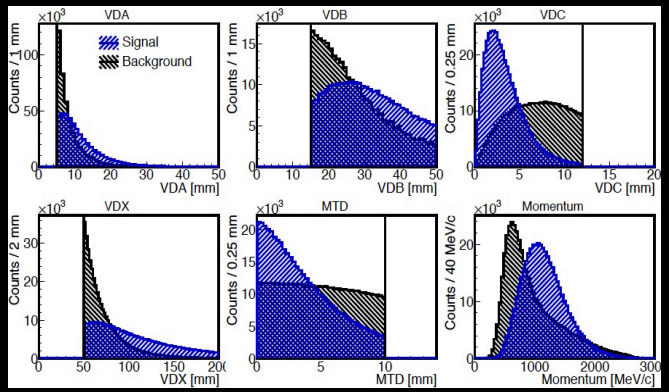
Results in several parameters



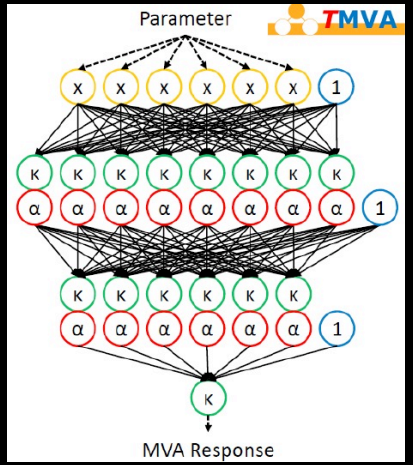
Weak decay topology recognition with neural networks



Results in several parameters

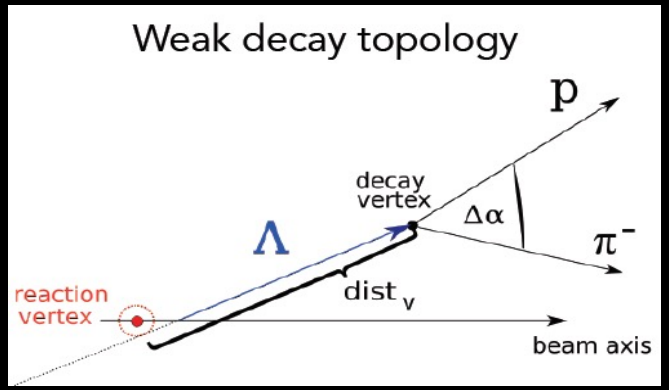


Which can be fed into an ANN

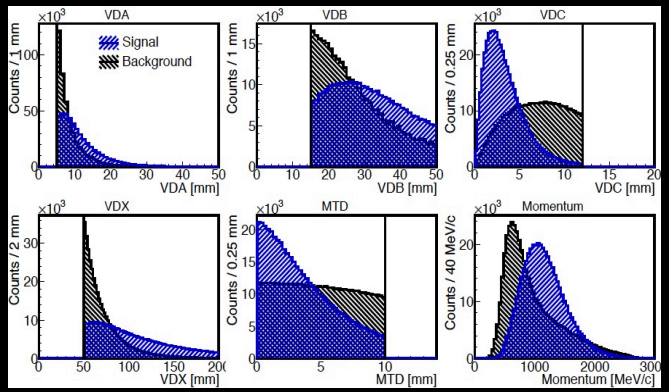


MA S. Spies, Phys.Lett. B793 (2019) 457-463

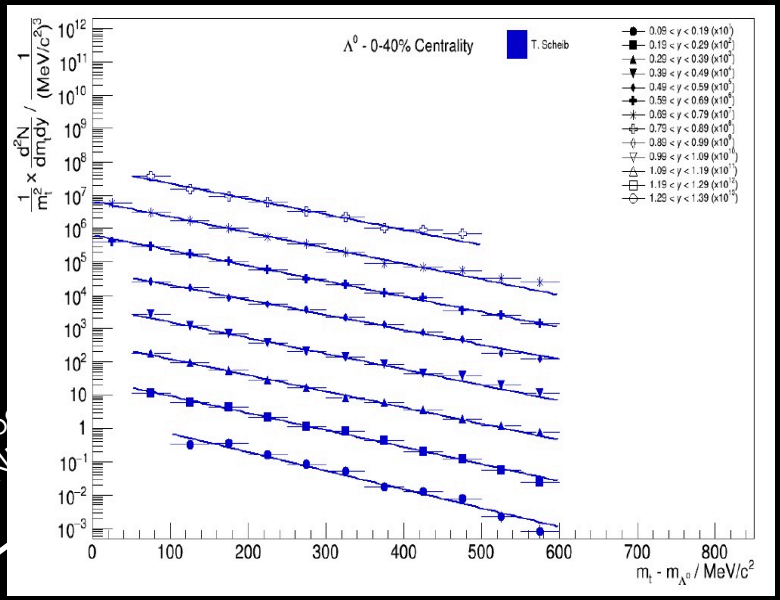
Weak decay topology recognition with neural networks



Results in several parameters

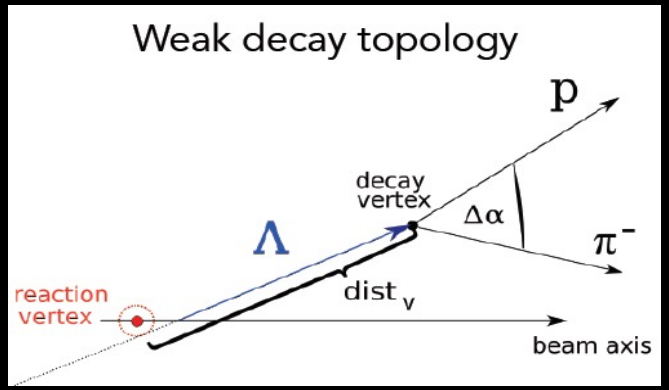


Which can b
into an AN

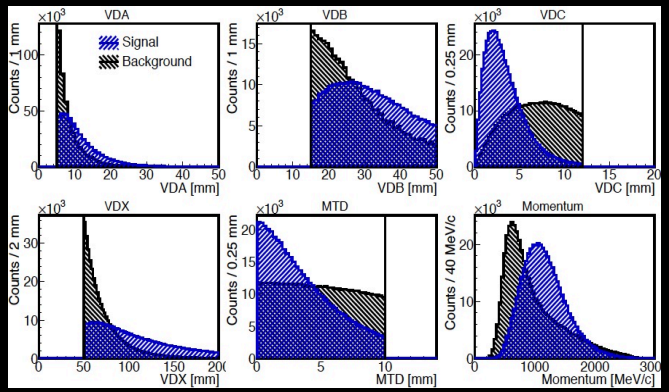


MA S. Spies, Phys.Lett. B793 (2019) 457-463

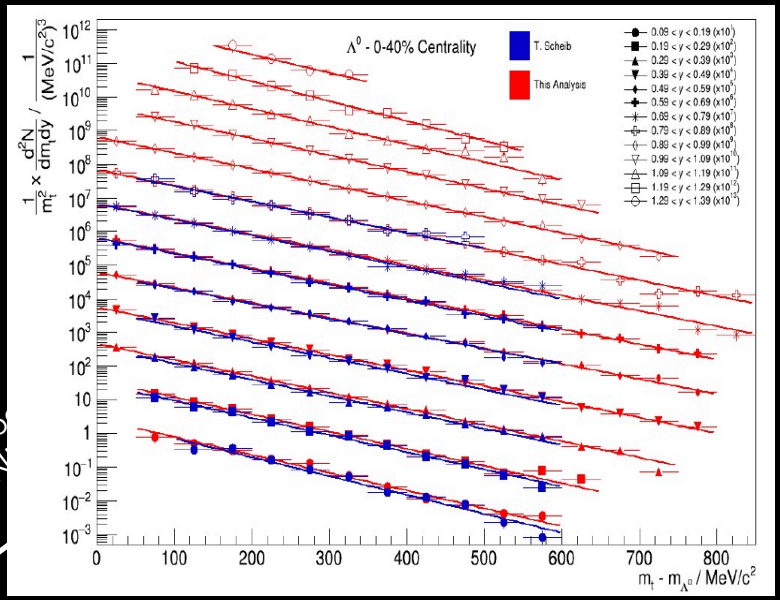
Weak decay topology recognition with neural networks



Results in several parameters



Which can b
into an AN



ANN in combination with pre-selection on topology parameters improves performance
→ reduction of uncertainty for 4π yield extraction.

MA S. Spies, Phys.Lett. B793 (2019) 457-463

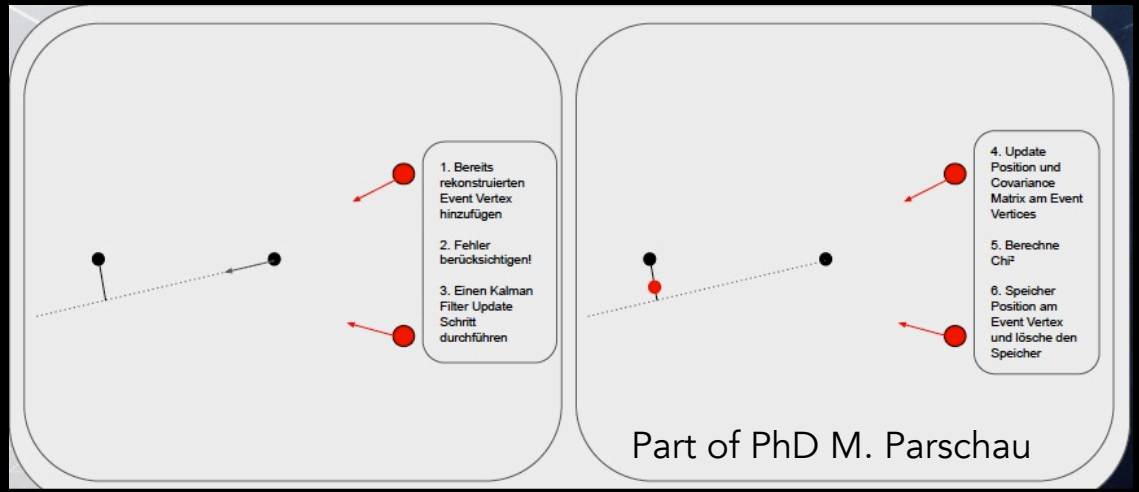
Weak decay topology recognition with neural networks in small system

Strong bias of primary vertex reconstruction by off-vertex tracks

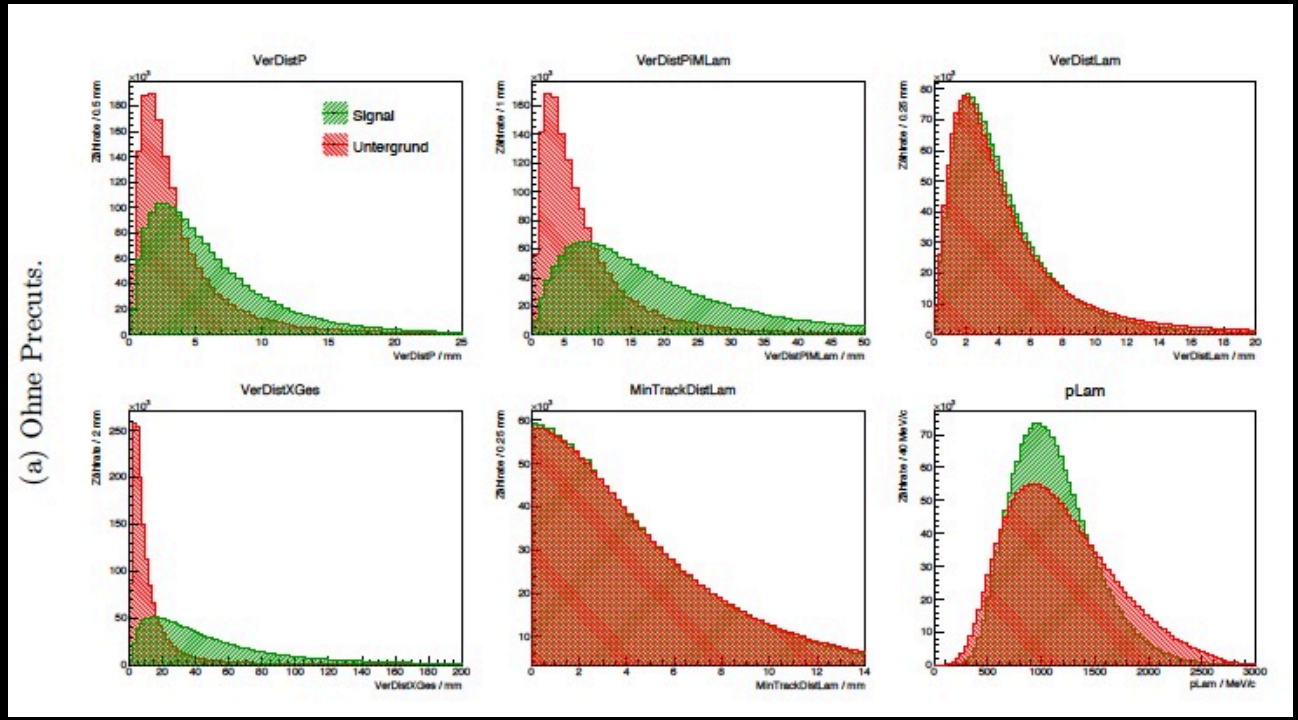
→ Holistic approach by inclusion of PrimaryVertex (PV) in training parameters

→ Make use of KalmanFilter and adjust PV if off-vertex candidates are identified

→ Combination of both



Weak decay topology recognition (S.Spies)



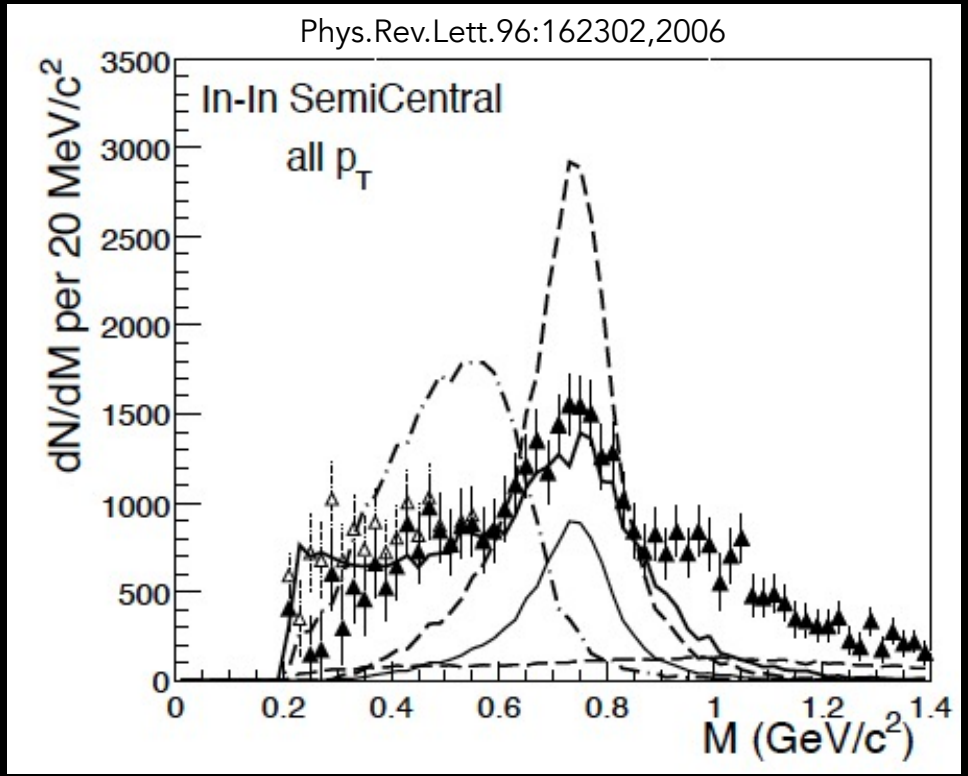
Signal sample: simulations

Background sample: mixed event data

Zeitgeist around 2006/7

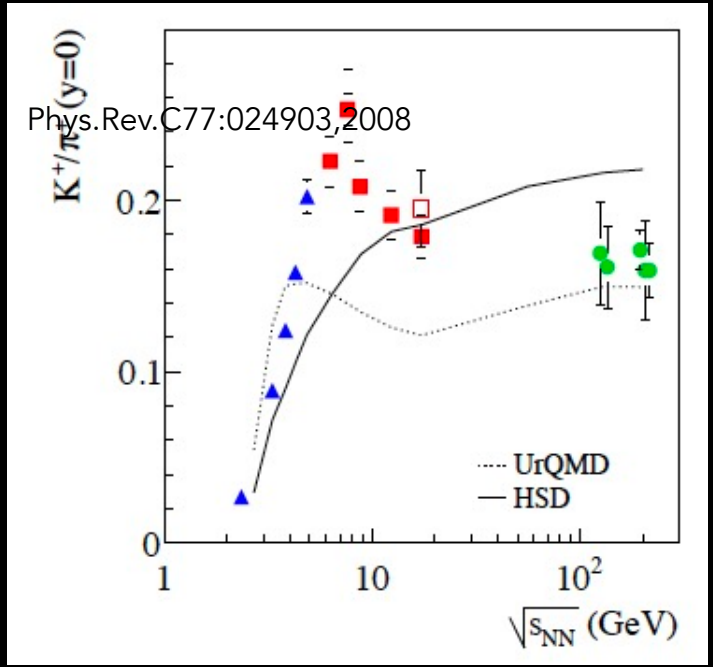
- 2006: NA60 ρ in-medium spectral functions

Phys.Rev.Lett.96:162302,2006

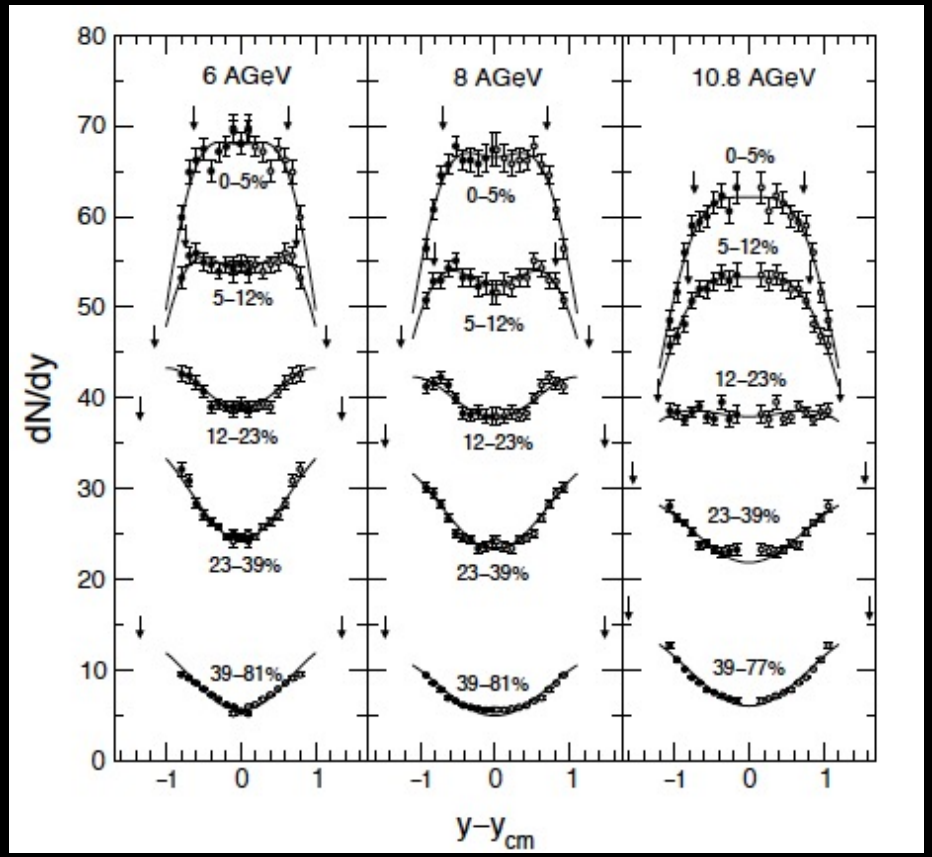


Zeitgeist around 2006/7

- 2005: RHICs “perfect liquid”: strong coupling, tiny **η**/s.
- 2006: NA60 ρ in-medium spectral functions
- 2008: NA49 horn and onset of deconfinement



Rapidity coverage: size matters



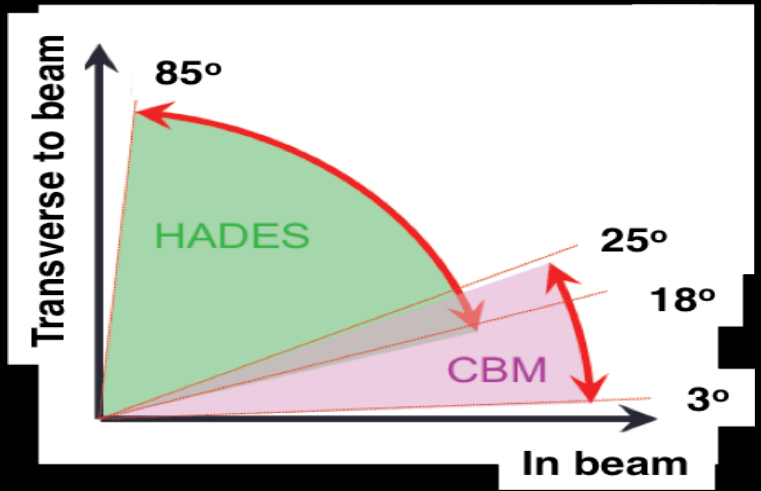
E917 Collaboration Phys.Rev.Lett.86:1970-1973,2001

Rapidity distributions of baryons develop complicated form, difficult to extrapolate.

HADES and CBM are very fast, hadron yields dominated by systematic errors.

Y-symmetry: very efficient estimate of systematic errors:

Perfect synergy between HADES and CBM!



Medium Modification of Hadrons

Direct line shape measurements:

Vector mesons

- Short lived in order to enhance the fraction of decays inside the medium (**ρ**,**ω**)

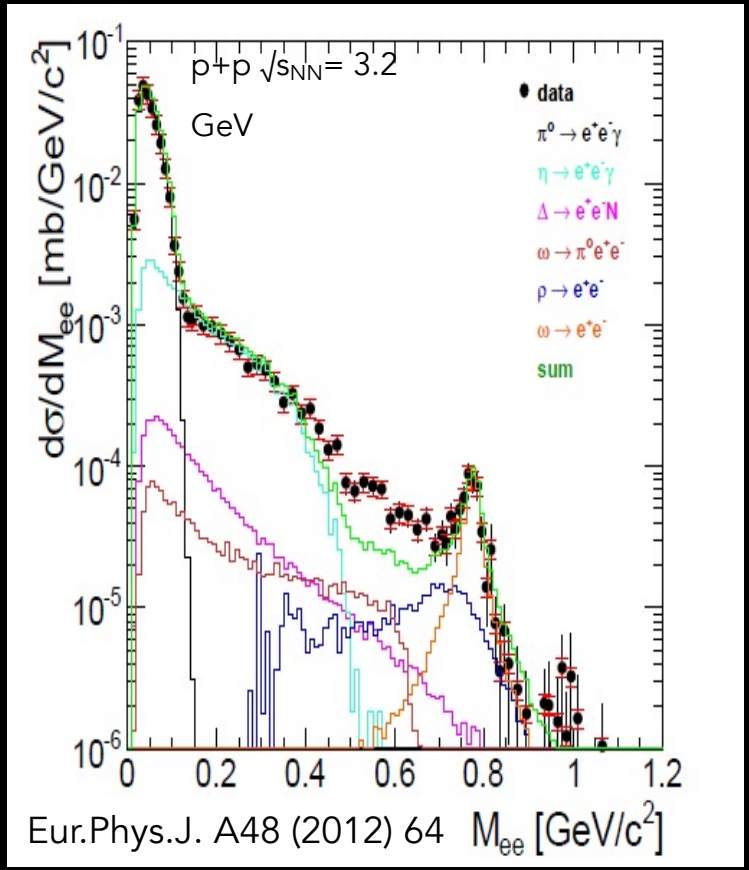
- undistorted information needed
  → dilepton decay channel

- **ω**-meson:
  subthreshold + electromagnetic decay channel:

50 million events for one **ω**!

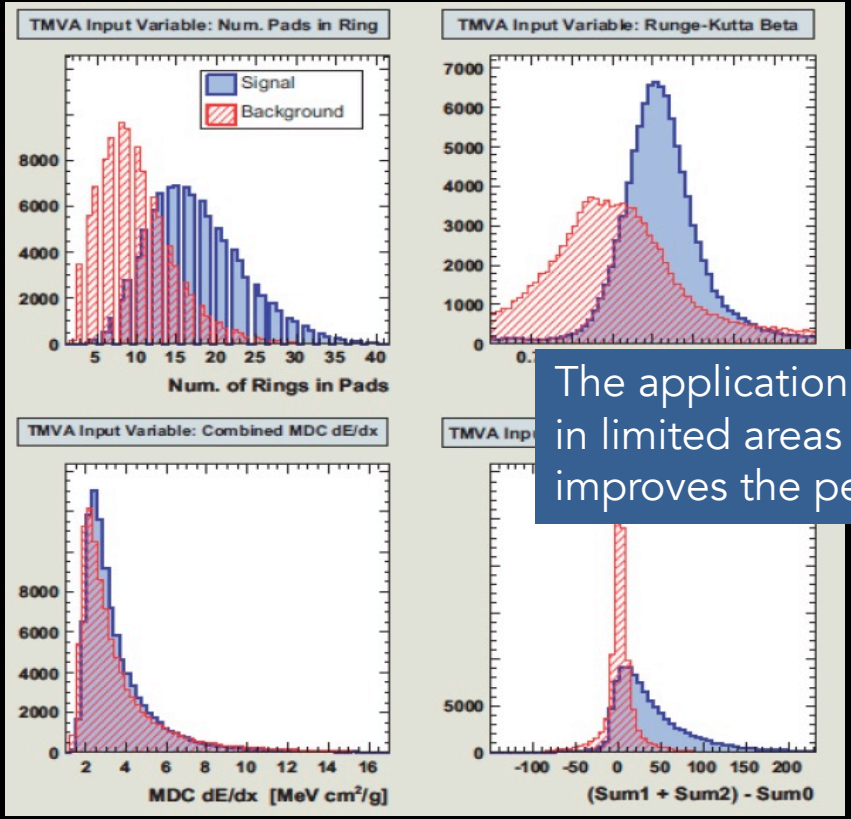
- various broad overlapping contributions

Cold matter and small collision systems:
Ar+KCl @ $\sqrt{s_{NN}}$= 2.6 GeV **and p+Nb @** $\sqrt{s_{NN}}$= 3.2 GeV

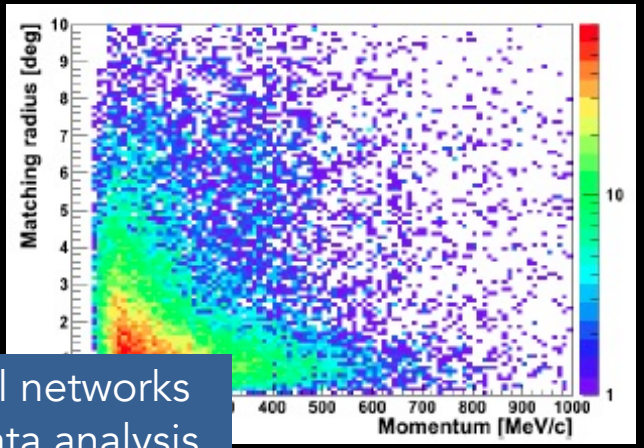


Neural Network for e^+e^- Id

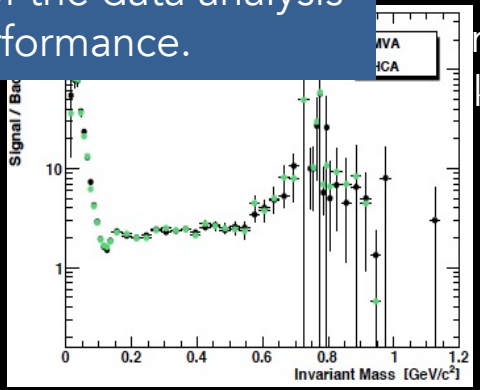
TMVA: Toolkit for Multivariate Data Analysis

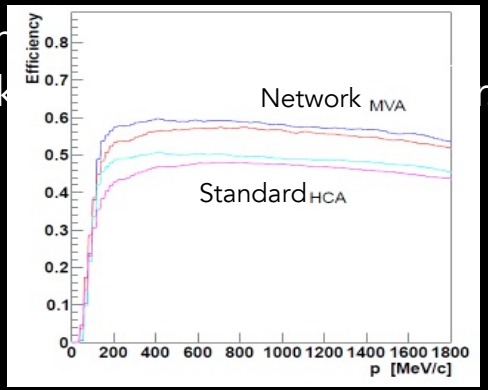


Signal and Background sample:



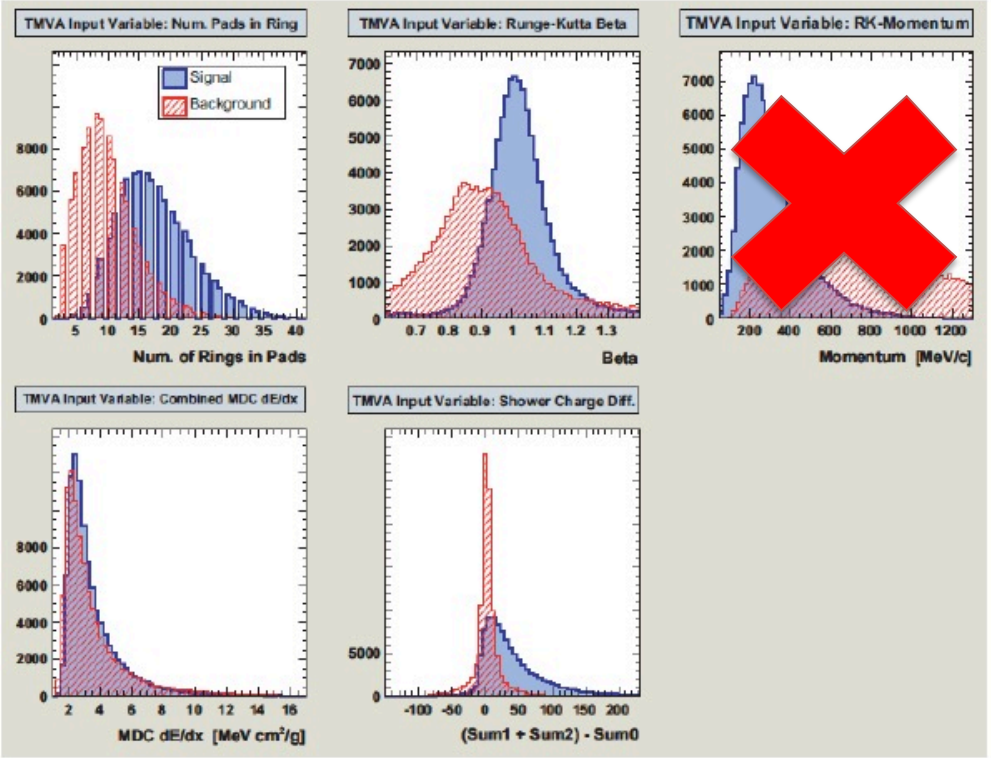
The application of neural networks in limited areas of the data analysis improves the performance.

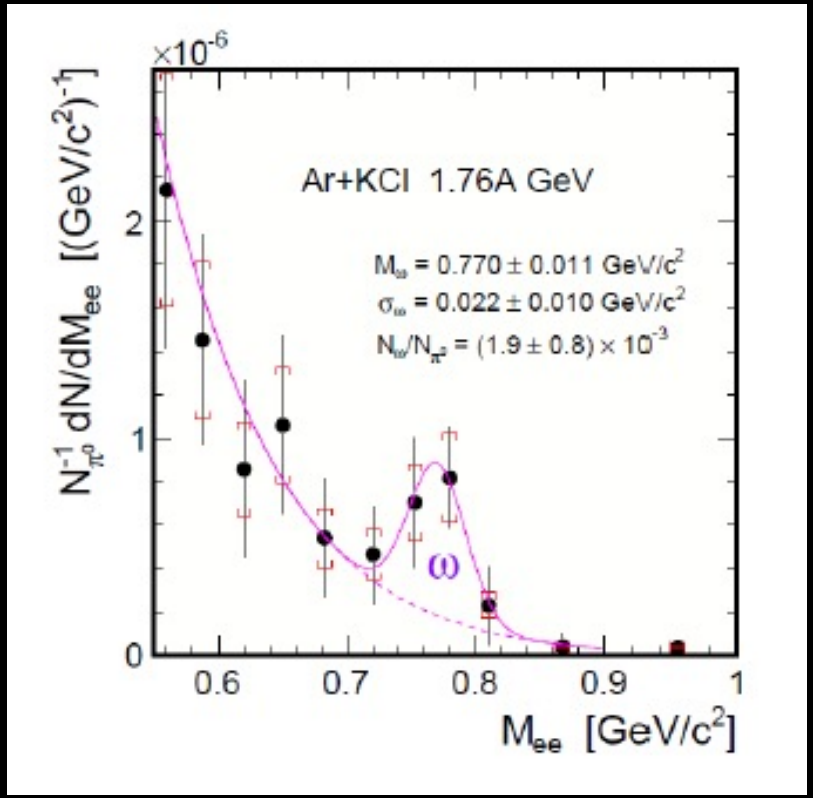




Introduced in PhD S. Lang 2009 optimized in PhD M.Lorenz 2012

Improvements





Phys.Rev. C84 (2011) 014902