FXT in BES II

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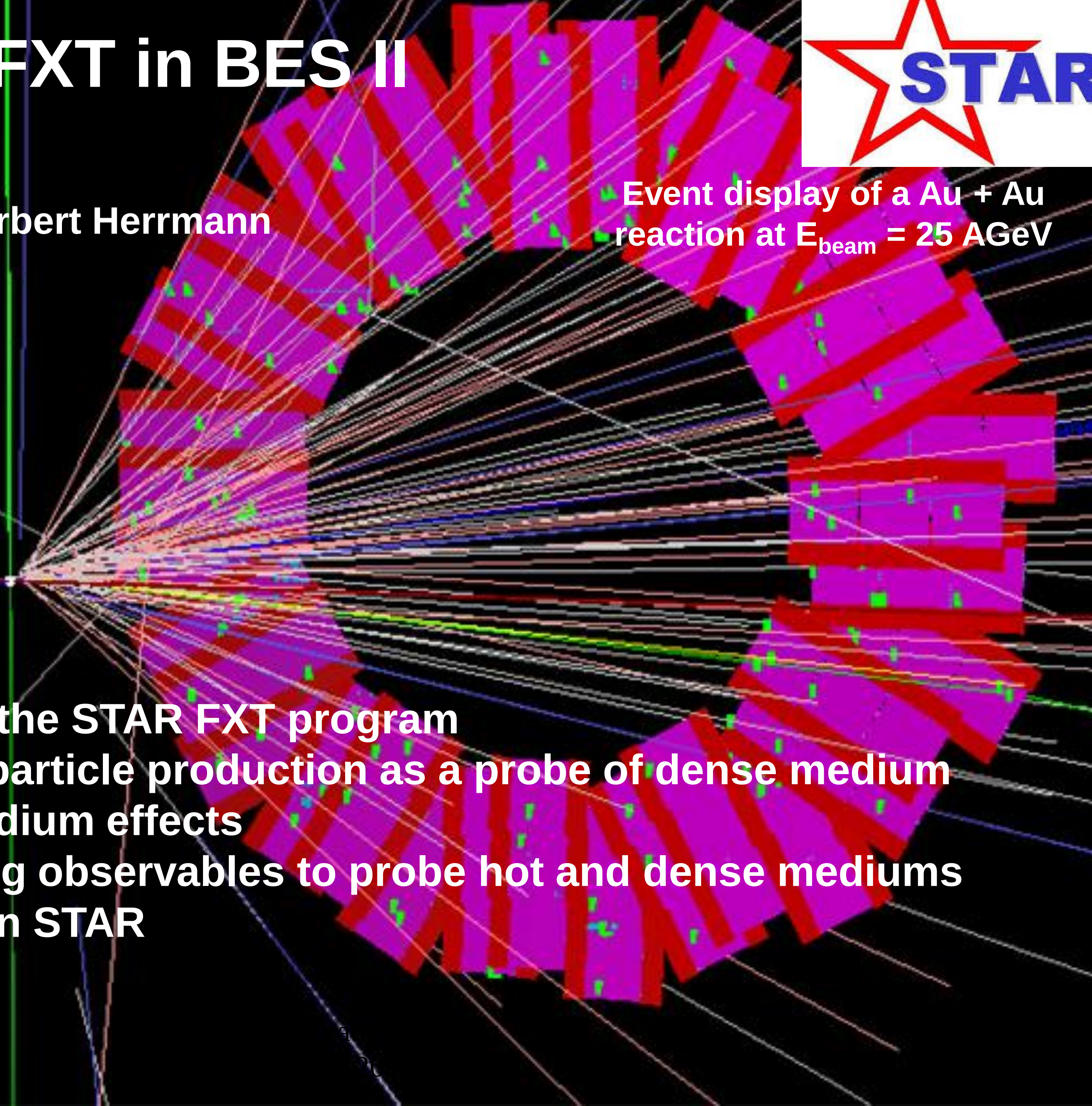


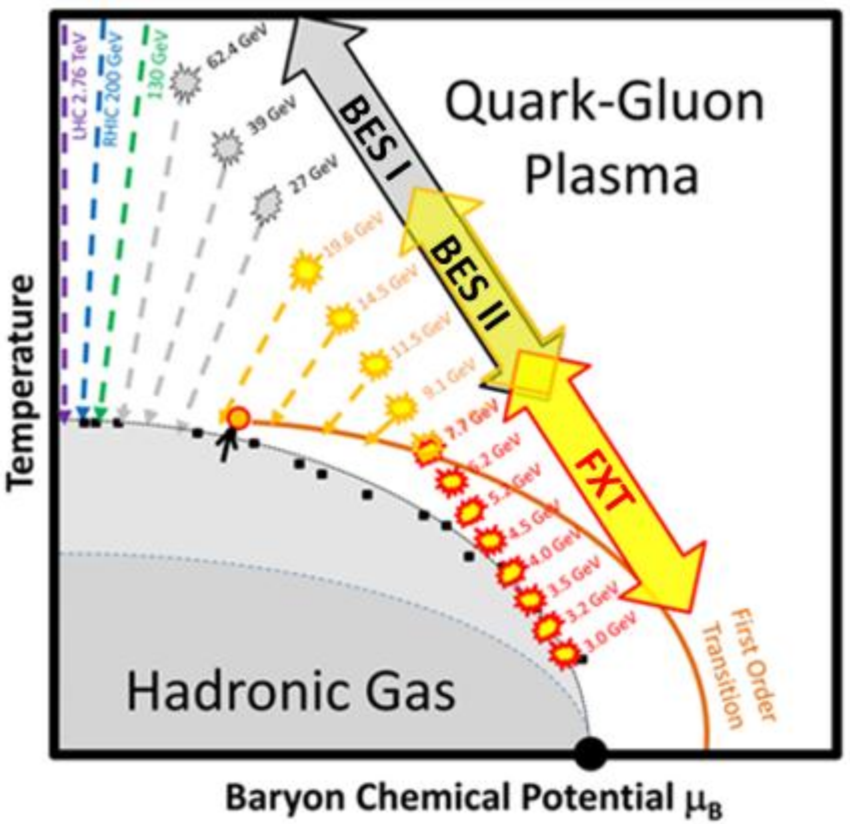
Event display of a Au + Au reaction at E_{beam} = 25 AGeV

Outline

- Introduction to the STAR FXT program
- Sub-threshold particle production as a probe of dense medium
- Flow and in-medium effects
- Other interesting observables to probe hot and dense mediums
- eTOF upgrade in STAR
- Summary

Beam Energy Scan II and FXT

Kathryn Meehan et al. (STAR), Nuclear Physics A 00 (2017) 1



- Onset of deconfinement
- 1st order phase transition
- Strange states of matter
- Chiral symmetry restoration
- Critical point

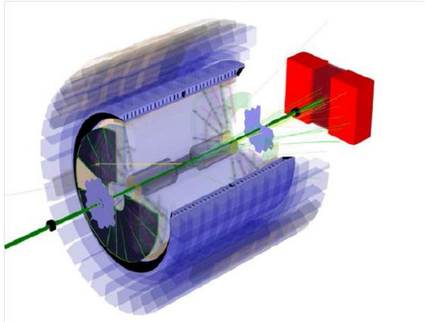
Physics observables

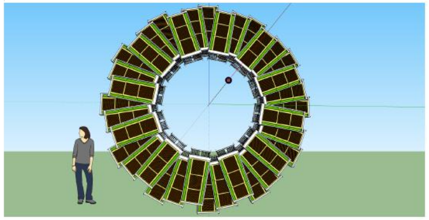
- Rapidity dependence
- Hyperons
- Directed flow
- Elliptic flow
- Hypernuclei
- Di-lepton
- Fluctuations

arXiv:1609.05102v

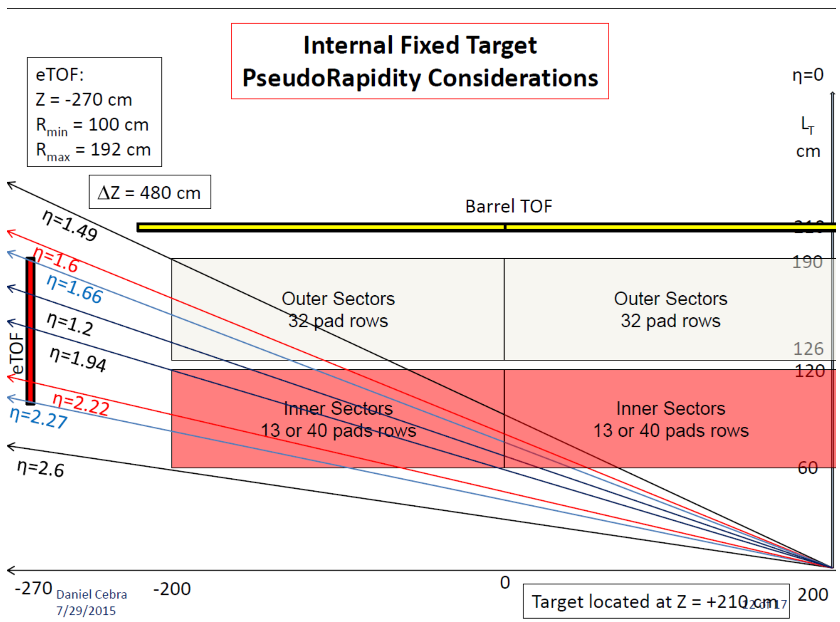
Physics Program for the STAR/CBM eTOF Upgrade - version 2.1

The STAR/CBM eTOF Group
(Dated: March 29, 2016)

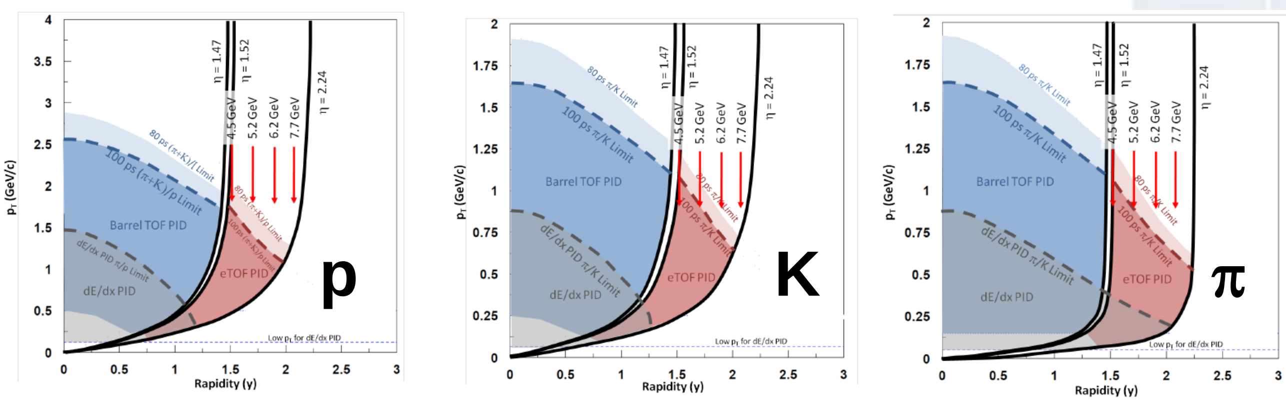


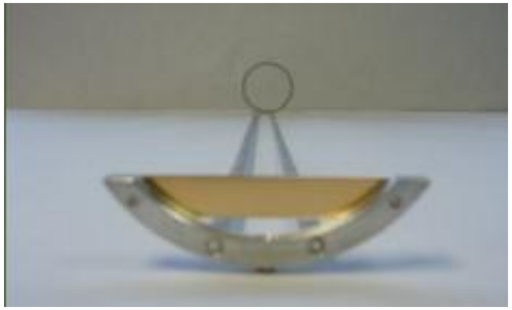


Acceptance in fixed target mode



Collider Energy	Fixed-Target Energy	Single beam AGeV	Center-of-mass Rapidity	μ_B (MeV)
62.4	7.7	30.3	2.10	420
39	6.2	18.6	1.87	487
27	5.2	12.6	1.68	541
19.6	4.5	8.9	1.52	589
14.5	3.9	6.3	1.37	633
11.5	3.5	4.8	1.25	666
9.1	3.2	3.6	1.13	699
7.7	3.0	2.9	1.05	721

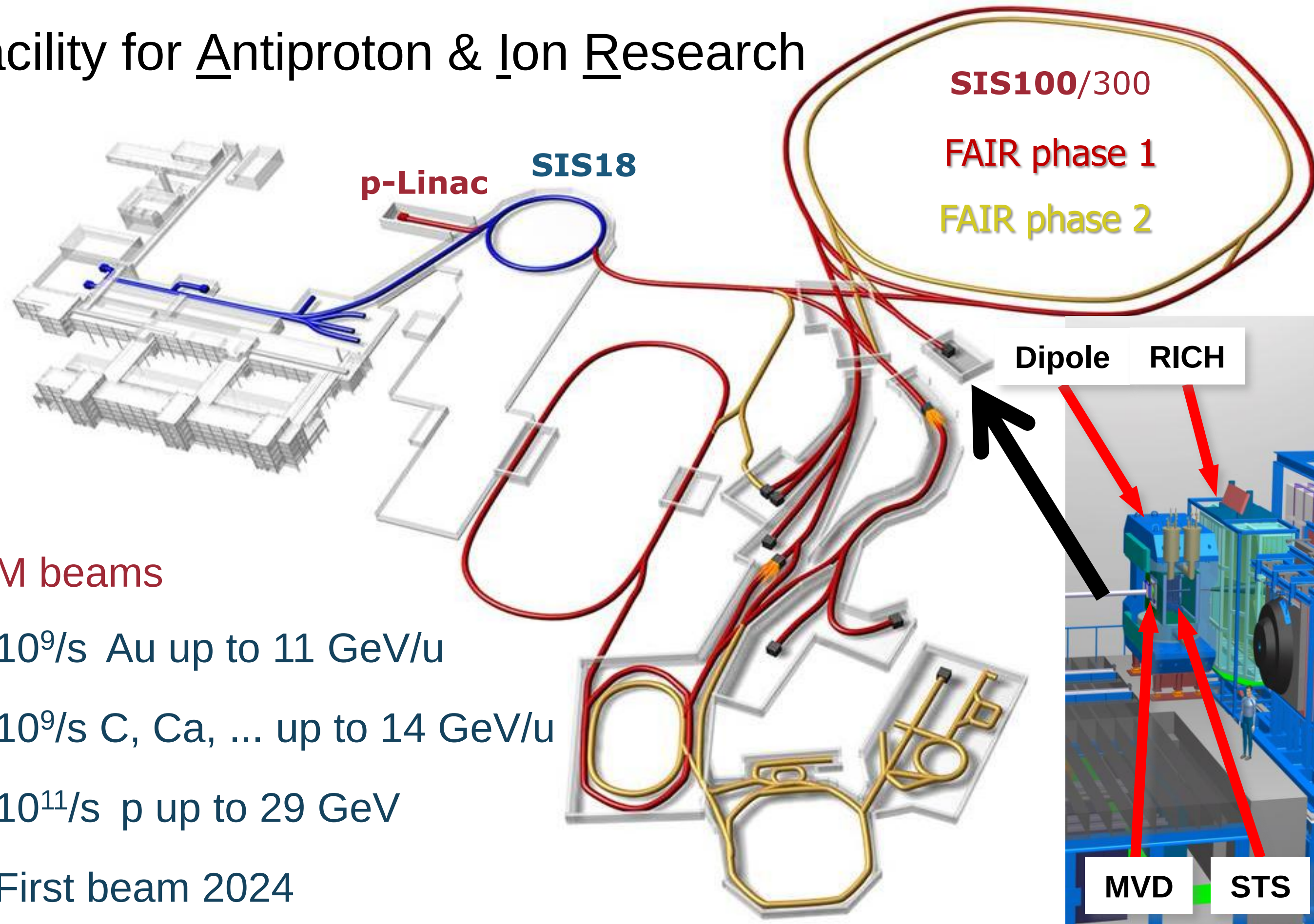




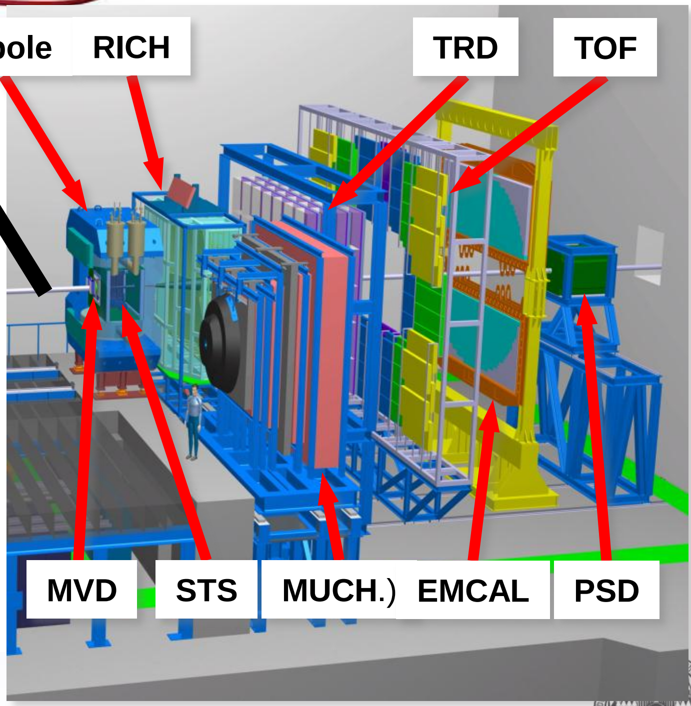
FAIR facility and CBM

The general physics goals are common for STAR and CBM

Facility for Antiproton & Ion Research



CBM

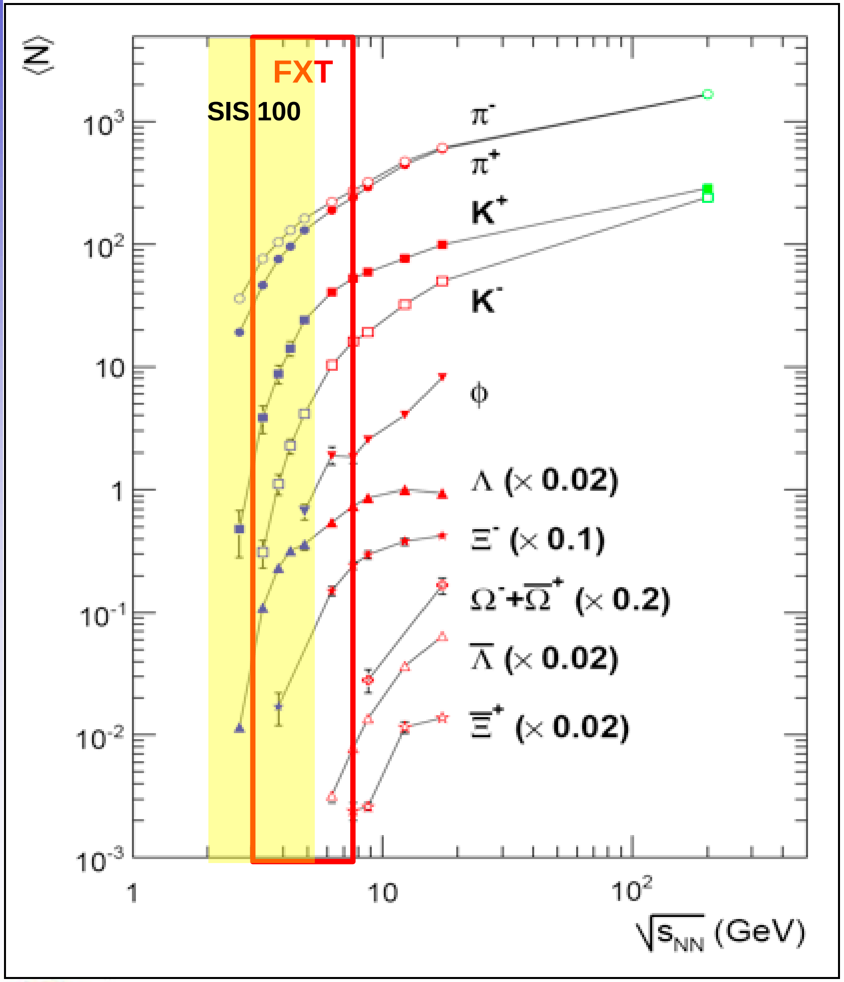


CBM beams

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV
- First beam 2024

Hyperons in FXT

C. Blume, J. Phys. G31, S57 (2005)



Strange and charmed particle production thresholds in pp - collisions

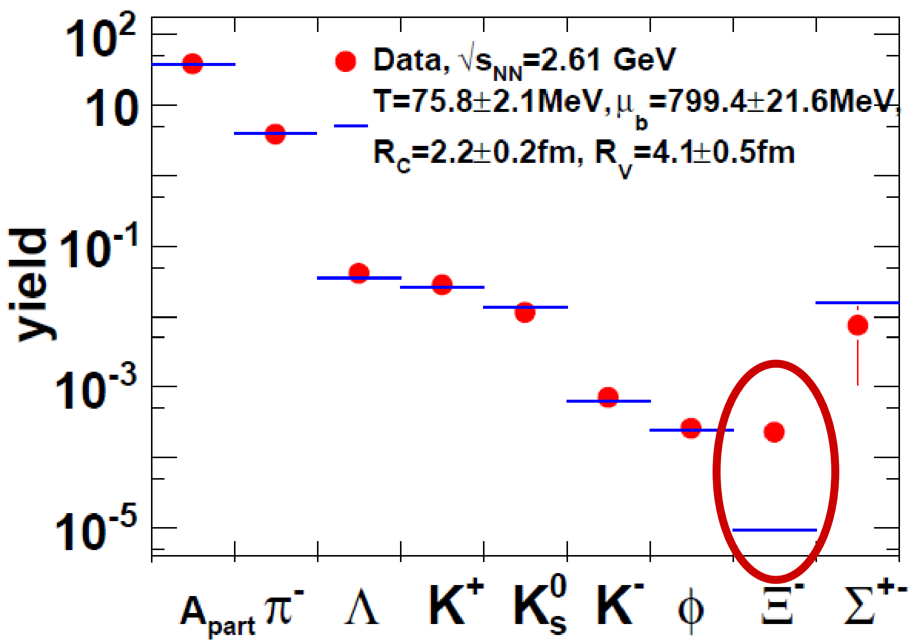
reaction	$\sqrt{s}$ (GeV)	T_{lab}(GeV)
$pp \rightarrow K^+ \Lambda p$	2.548	1.6
$pp \rightarrow K^+ K^- pp$	2.864	2.5
$pp \rightarrow K^+ K^+ \Xi^- p$	3.247	3.7
$pp \rightarrow K^+ K^+ K^+ \Omega^- n$	4.092	7.0
$pp \rightarrow \Lambda \bar{\Lambda} pp$	4.108	7.1
$pp \rightarrow \Xi^- \bar{\Xi}^+ pp$	4.520	9.0
$pp \rightarrow \Omega^- \bar{\Omega}^+ pp$	5.222	12.7
$pp \rightarrow J/\Psi\, pp$	4.973	12.2

- Yield of sub-threshold produced hyperons is sensitive to the medium density (multi step processes)
- In the FXT energy regime very few data available

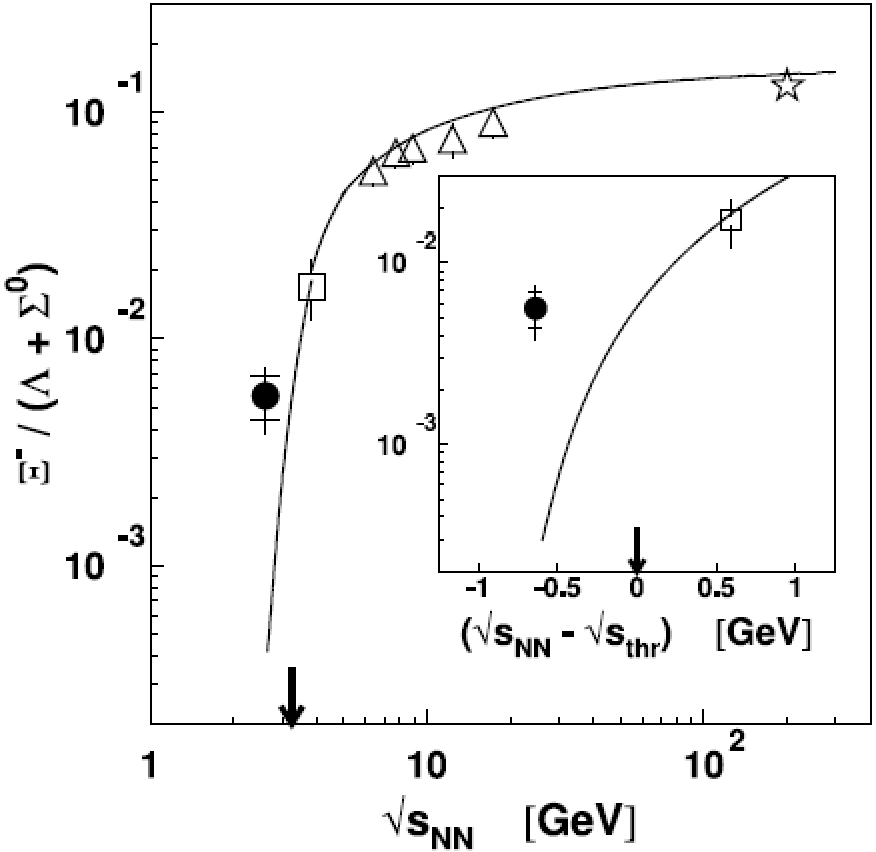
sub-threshold Ξ production

Ar+KCl reactions at 1.76A GeV

- Ξ^- yield by appr. factor 25 higher than thermal yield

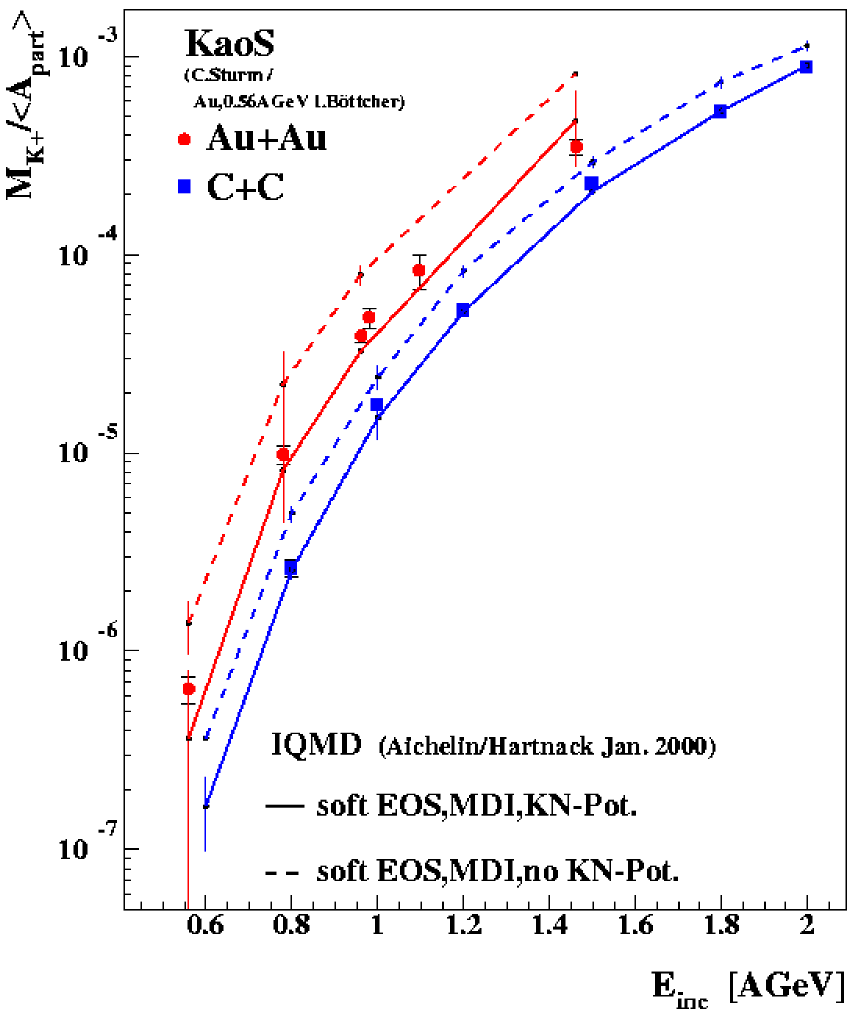


G. Agakishiev et al. (HADES), PRL103, 132301, (2009)

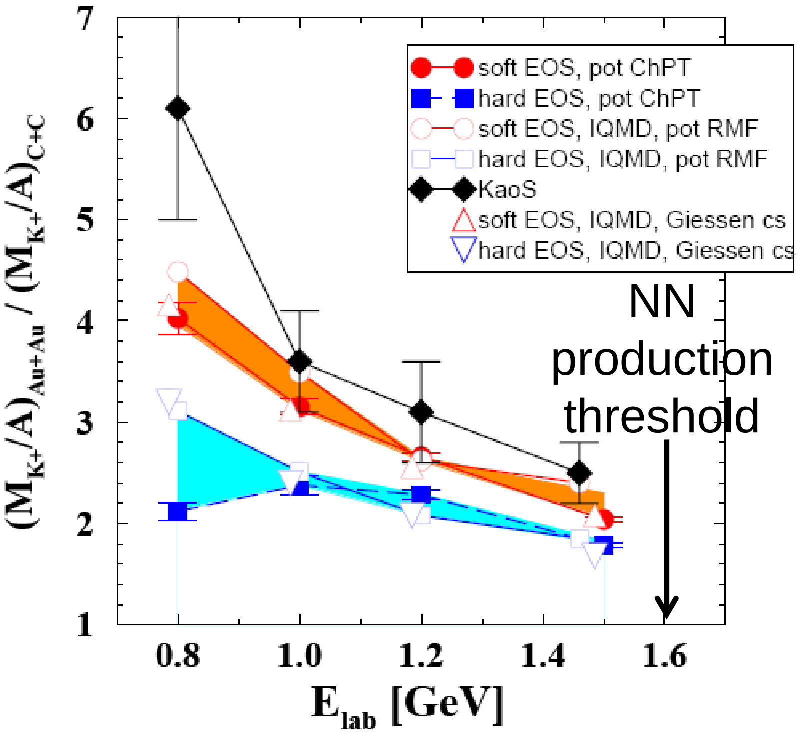


Kaon production at SIS 18

C.Sturm et al. (KaoS), PRL 86 (2001) 39



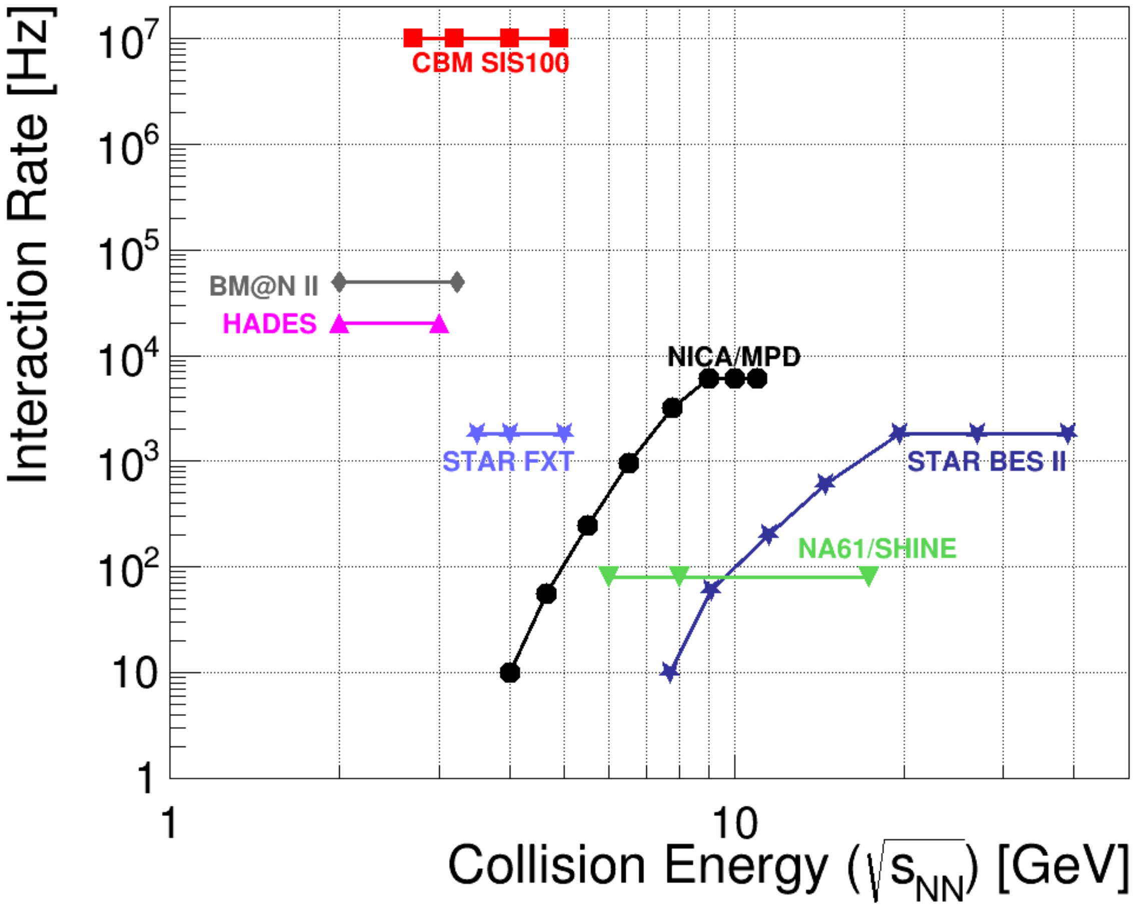
C. Fuchs et al., PRL 86 (2001) 1974



- Strong sensitivity to Equation Of State due to multistep production (formation of nucleon resonances)

=> soft EOS (K=200 MeV)

Rate capability of HI experiments

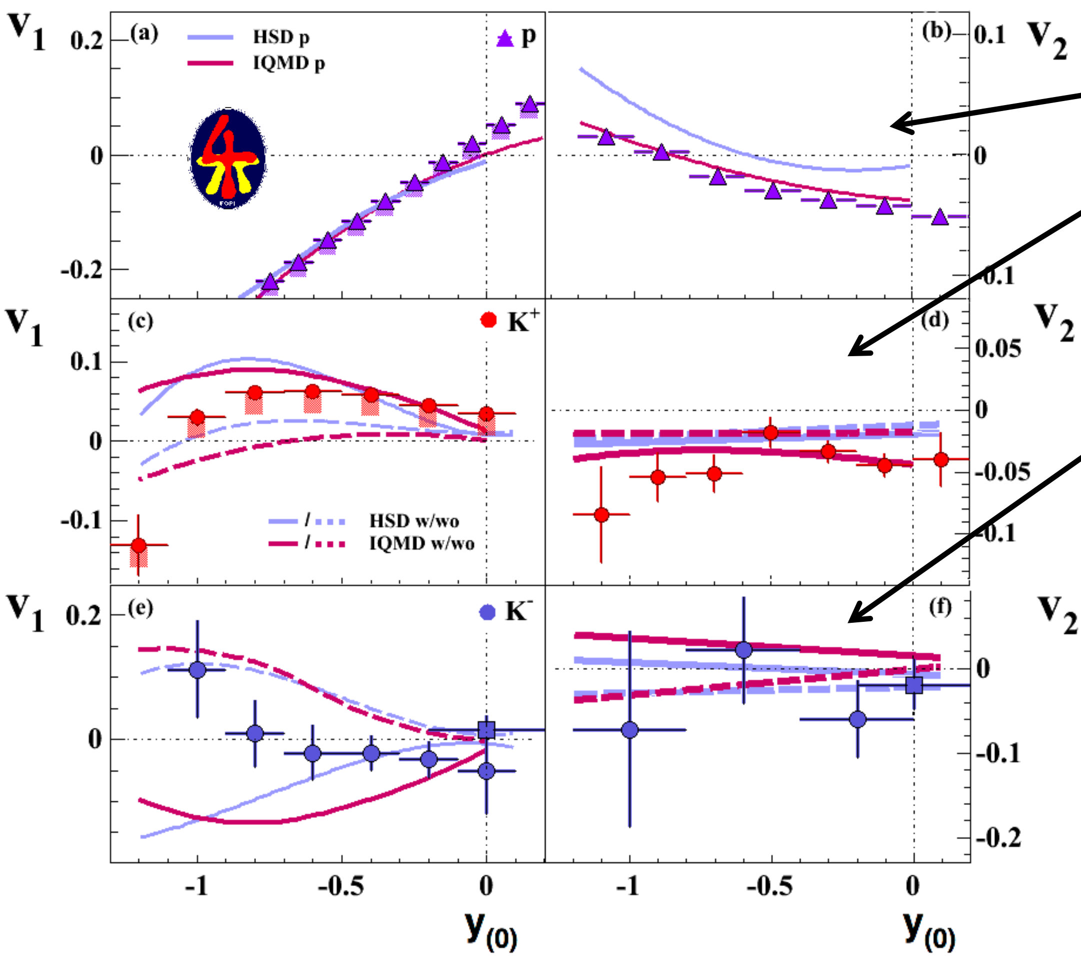


- At least 100 M Events for each energy required in order to do multi-differential measurement
- 2 days for each energy
- Data rate is limited by the DAQ
- For CBM 5 Min of data taking

Flow and in-medium modification

V.Zinyuk et al. (FOPI), PRC 90 (2014) 025210

Ni+Ni at 1.91 AGeV, σ = 1.5 b



Protons

Kaons (K^+)

Potentials with linear density dependence at $r=r_0$:

$U_{HSD}(K^+)$	20 MeV
$U_{IQMD}(K^+)$	40 MeV

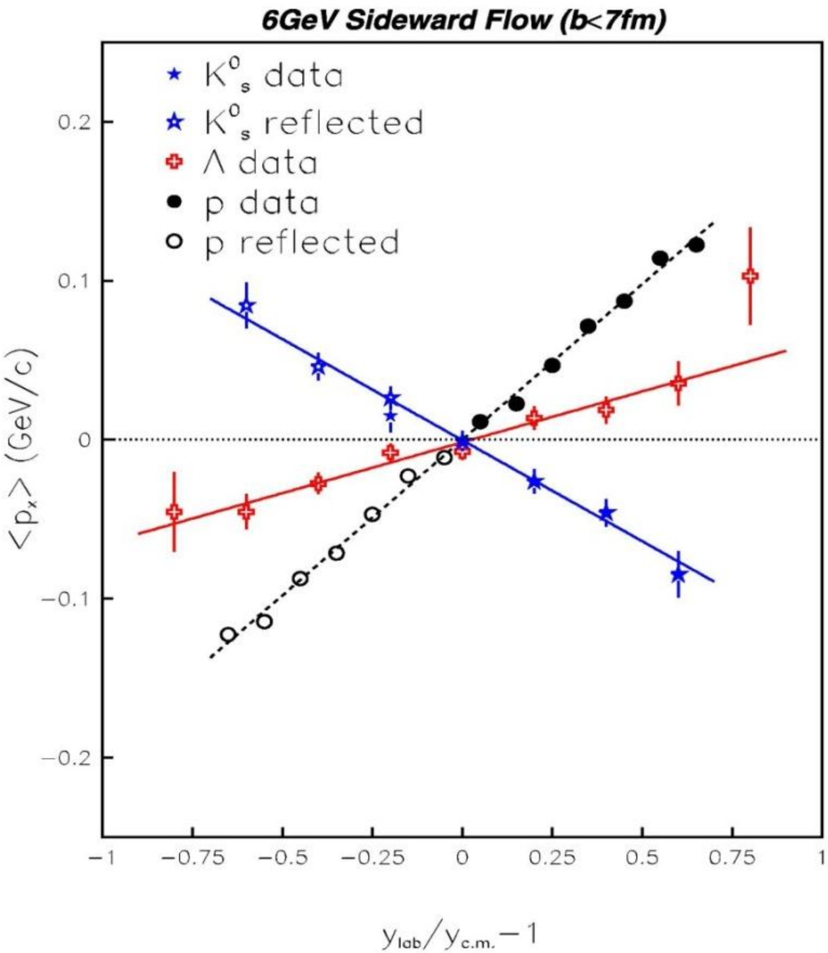
Antikaons (K^-)

$U_{HSD}(K^-)$	-50 MeV
$U_{IQMD}(K^-)$	-90 MeV

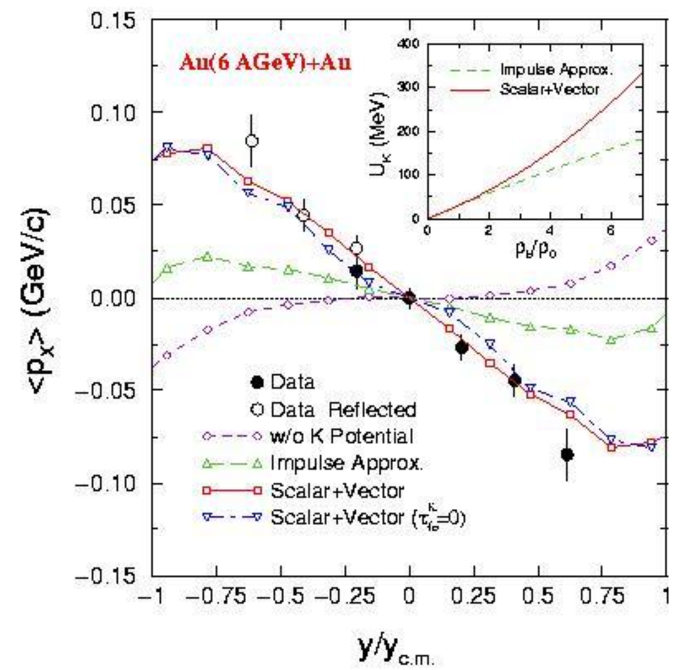
- Transport model calculations need to be refined,
- Exp. data need to be extended, much more statistics needed for K^-.

AGS K⁰-flow

Data: P. Chung et al. (E895), PRL85, 940 (2000)



Theo: S. Pal et al., Phys.Rev.C62:061903, (2000)



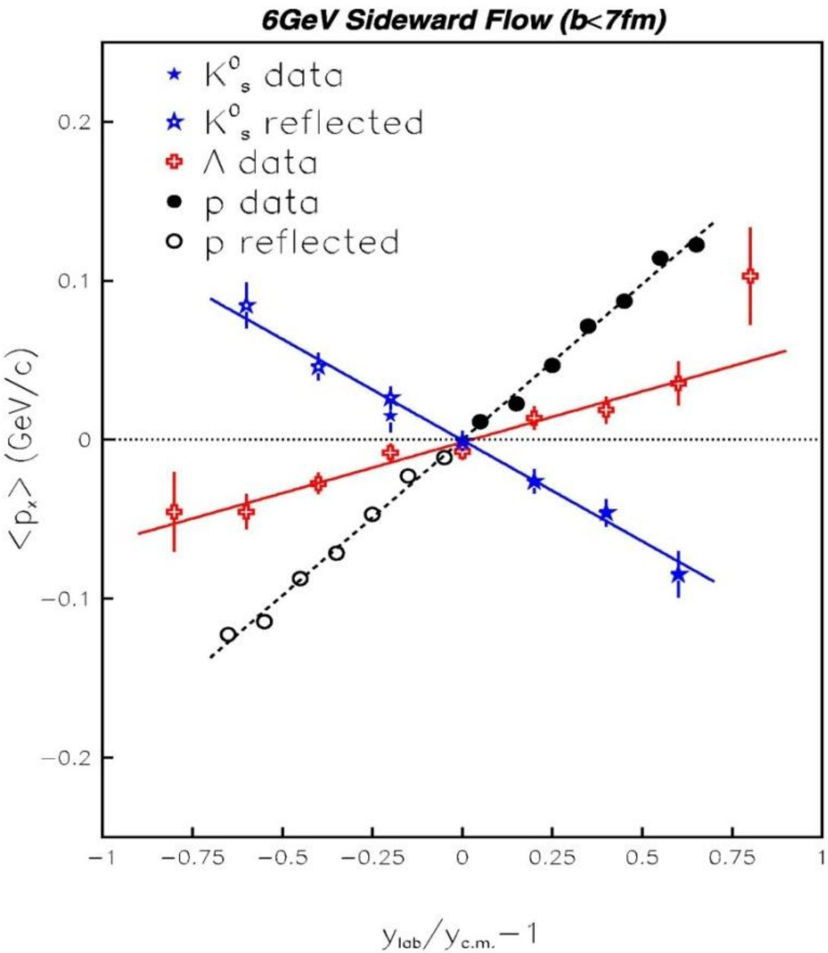
Kaon flow as barometer in HI collisions?

Calibrate probe by systematic measurements

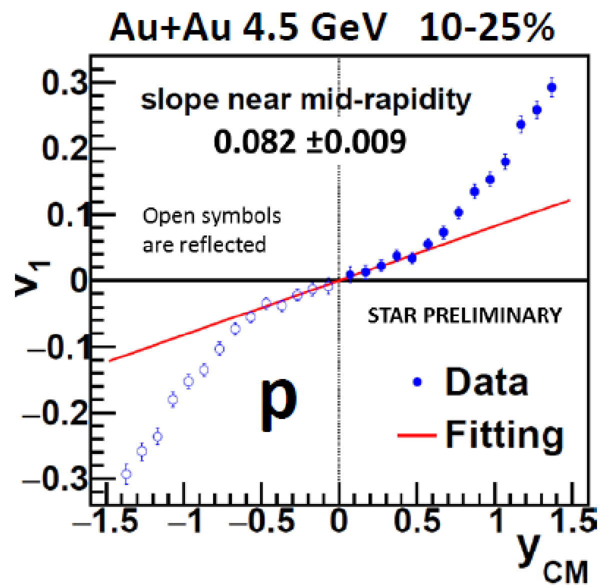
- centrality
- system size
- incident energy

AGS K^0-flow

Data: P. Chung et al. (E895), PRL85, 940 (2000)

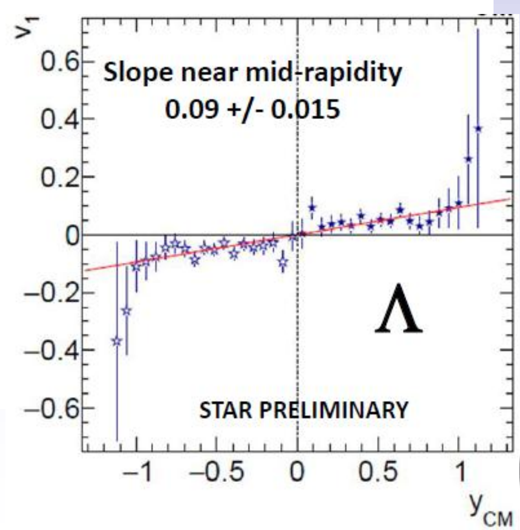


K. Meehan (STAR), QM2017



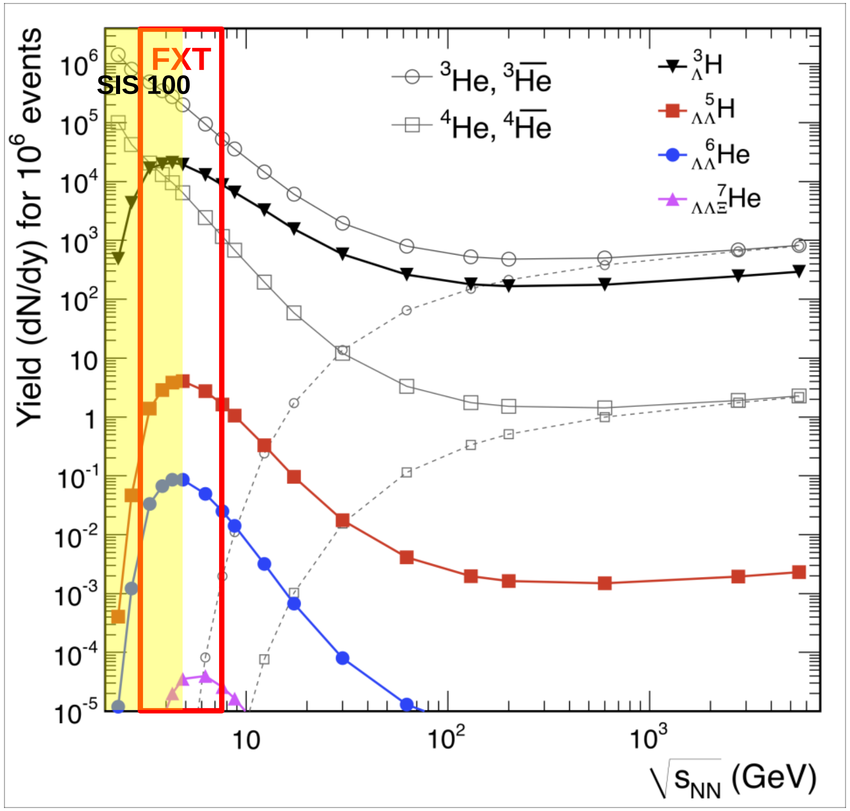
E895 *trend*:
Λ/p flow ratio at
4.5 GeV ➔ 0.2

STAR FXT:
Λ/p flow ratio at
4.5 GeV ➔ 1.1



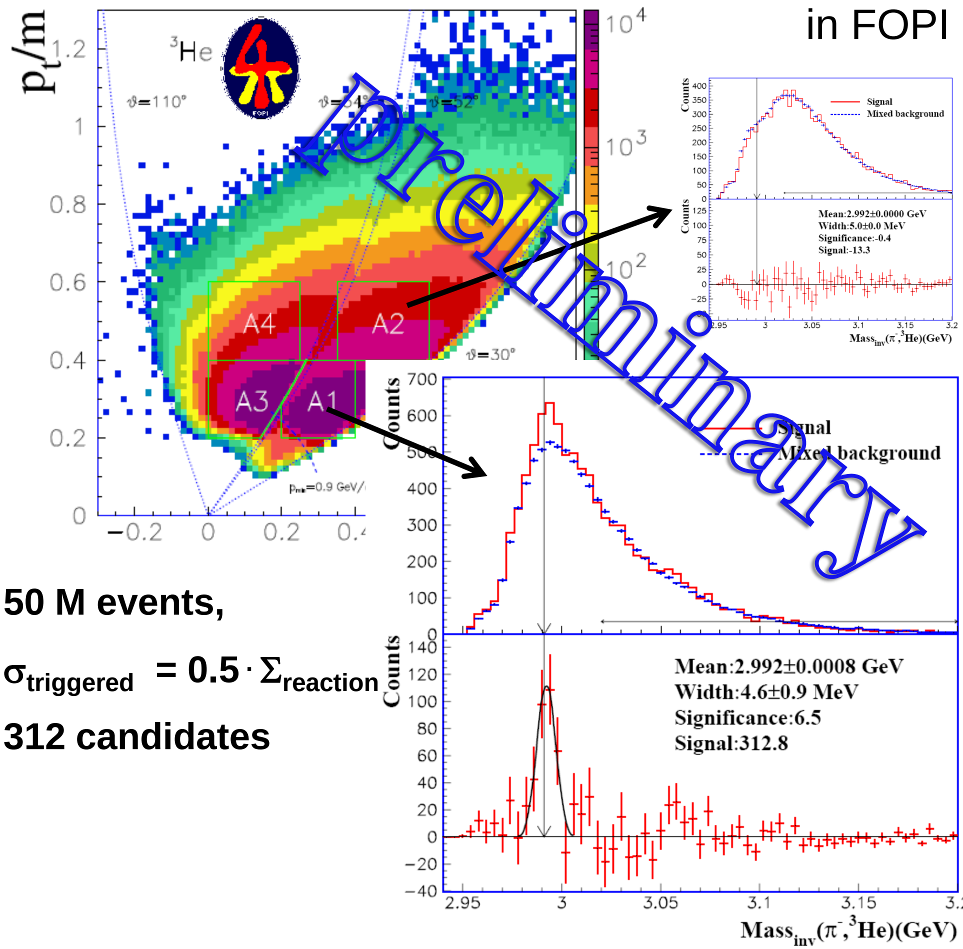
Hypernuclei in FXT

A. Andronic, P. Braun-Munzinger, J. Stachel, and H. Stocker, Phys. Lett. B697, 203 (2011), arXiv:1010.2995 [nucl-th]



- Thermal model predicts a maximal yield at FXT energies

Hypertriton production in Ni + Ni at 2 AGeV in FOPI



50 M events,

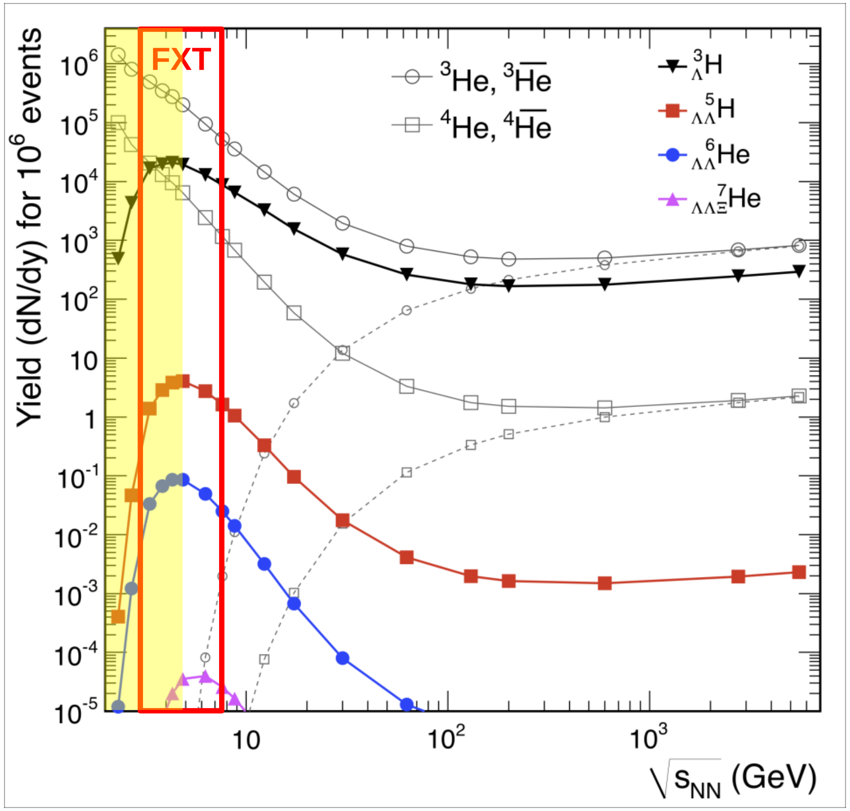
$\sigma_{triggered} = 0.5 \cdot \Sigma_{reaction}$

312 candidates

Y.P. Zhang, PhD thesis, Heidelberg

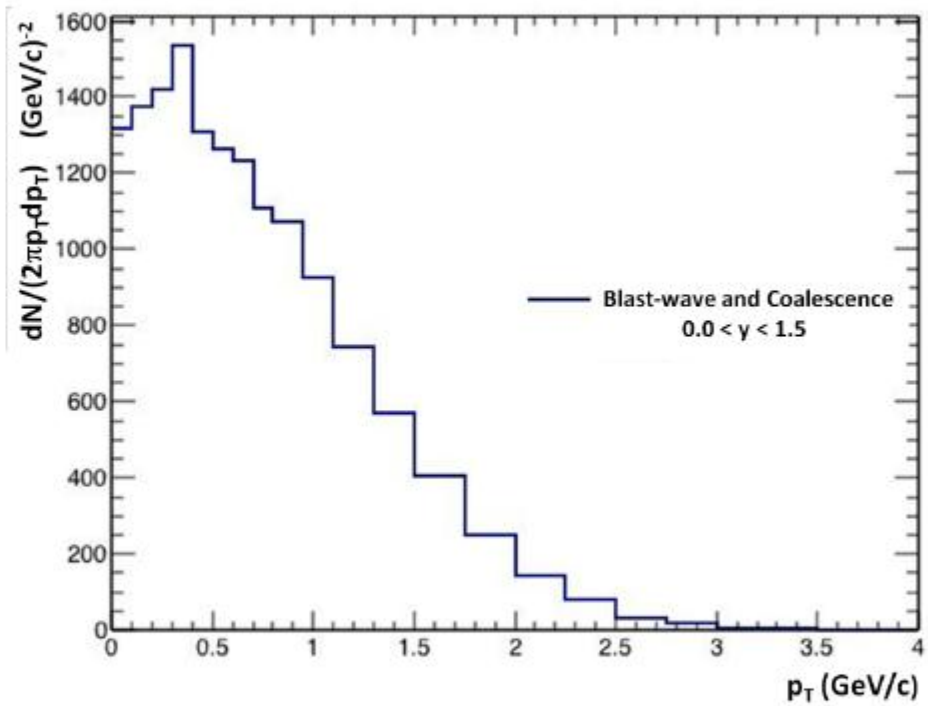
Hypernuclei in FXT

A. Andronic, P. Braun-Munzinger, J. Stachel, and H. Stocker, Phys. Lett. B697, 203 (2011), arXiv:1010.2995 [nucl-th]



- Thermal model predicts a maximal yield at FXT energies

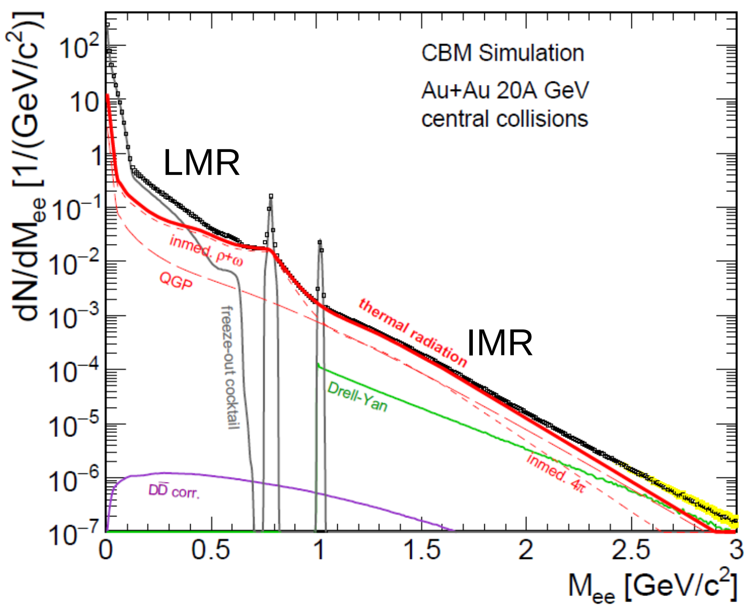
Simulated p_T distribution of hypertritons produced in Au + Au at 4.5 AGeVI

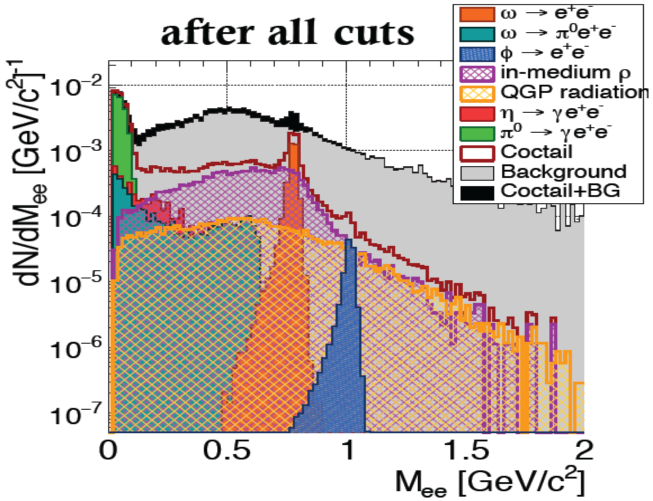


- One day of running
- Mapping out the phase space
- Precise measurement of lifetime

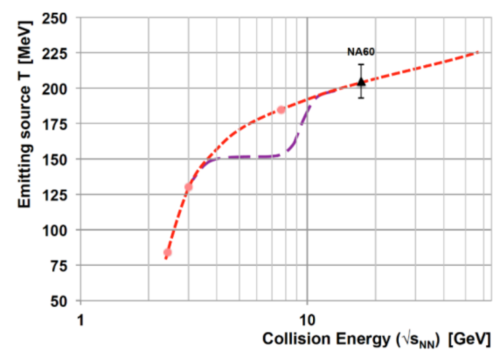
Di-leptons as probe of dense matter

R. Rapp, H. v.Hees, PLB 753 (2016) 586





- 1M Au+Au (b=0 fm), 8 AGeV
- IMR: S/B > 1/100
- Statistical accuracy of 10% requires ~1 week of CBM beamtime at 100 kHz IR

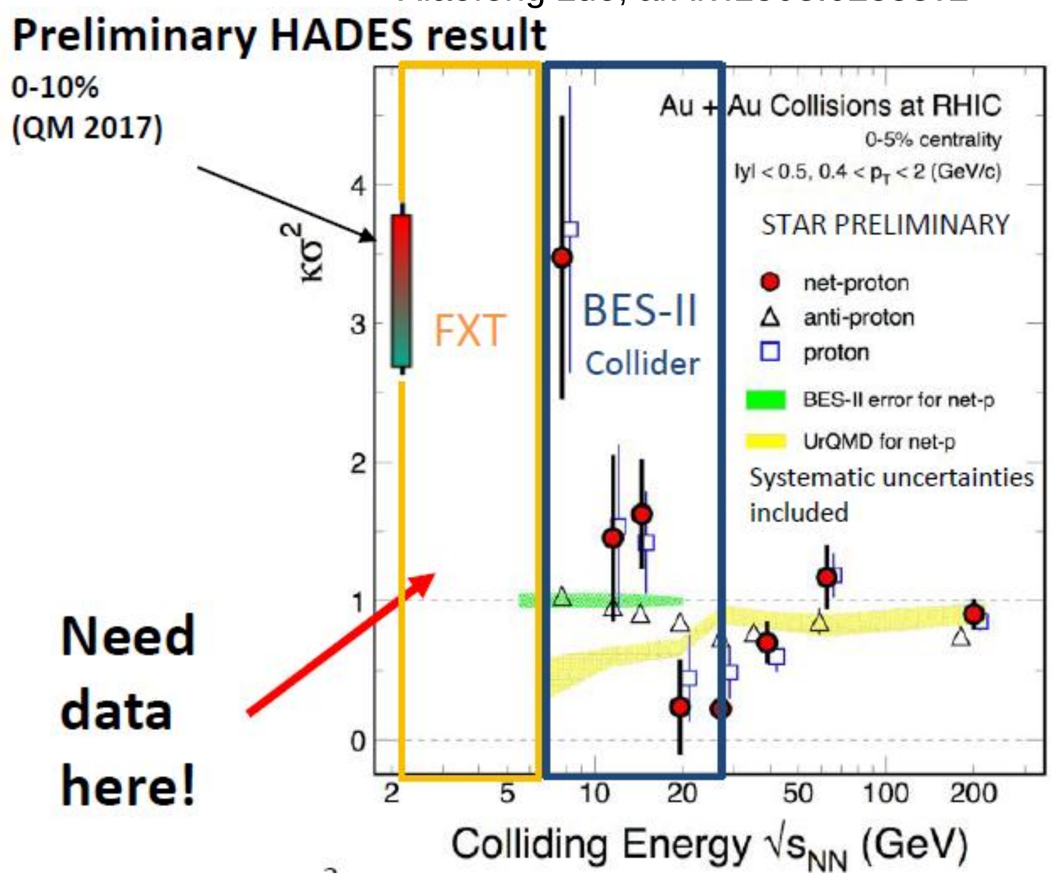


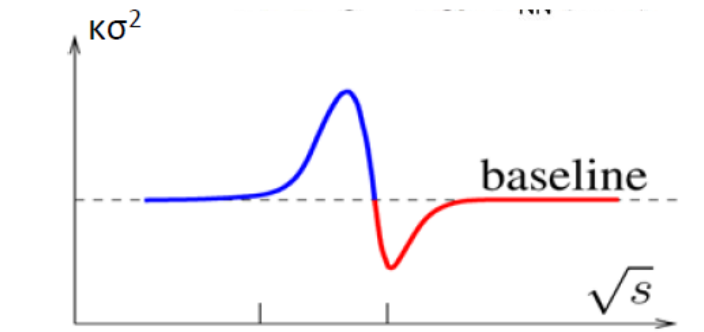
LMR: ρ – chiral symmetry restoration
fireball space – time extension

IMR: access to fireball temperature
ρ-a_1 chiral mixing

Fluctuations

K. Meehan (STAR), QM2017
Xiaofeng Luo, arXiv:1503.02558v2





M. Stephanov. J. Physics G.: Nucl. Part. Phys. ***38*** (2011) 124147

$$\delta N = N - \langle N \rangle$$

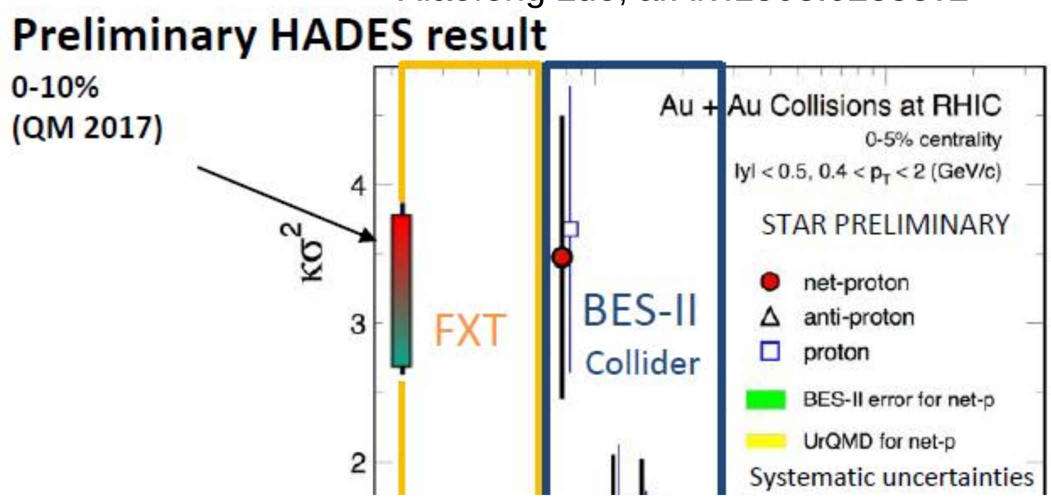
$$C_2 = \langle (\delta N)^2 \rangle ,$$

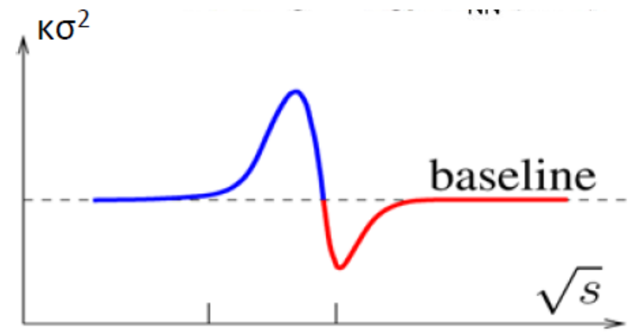
$$C_4 = \langle (\delta N)^4 \rangle - 3 \langle (\delta N)^2 \rangle^2$$

$$\kappa\sigma^2 = \frac{C_4}{C_2} \qquad C_4 \propto \xi^7$$

Fluctuations

K. Meehan (STAR), QM2017
Xiaofeng Luo, arXiv:1503.02558v2



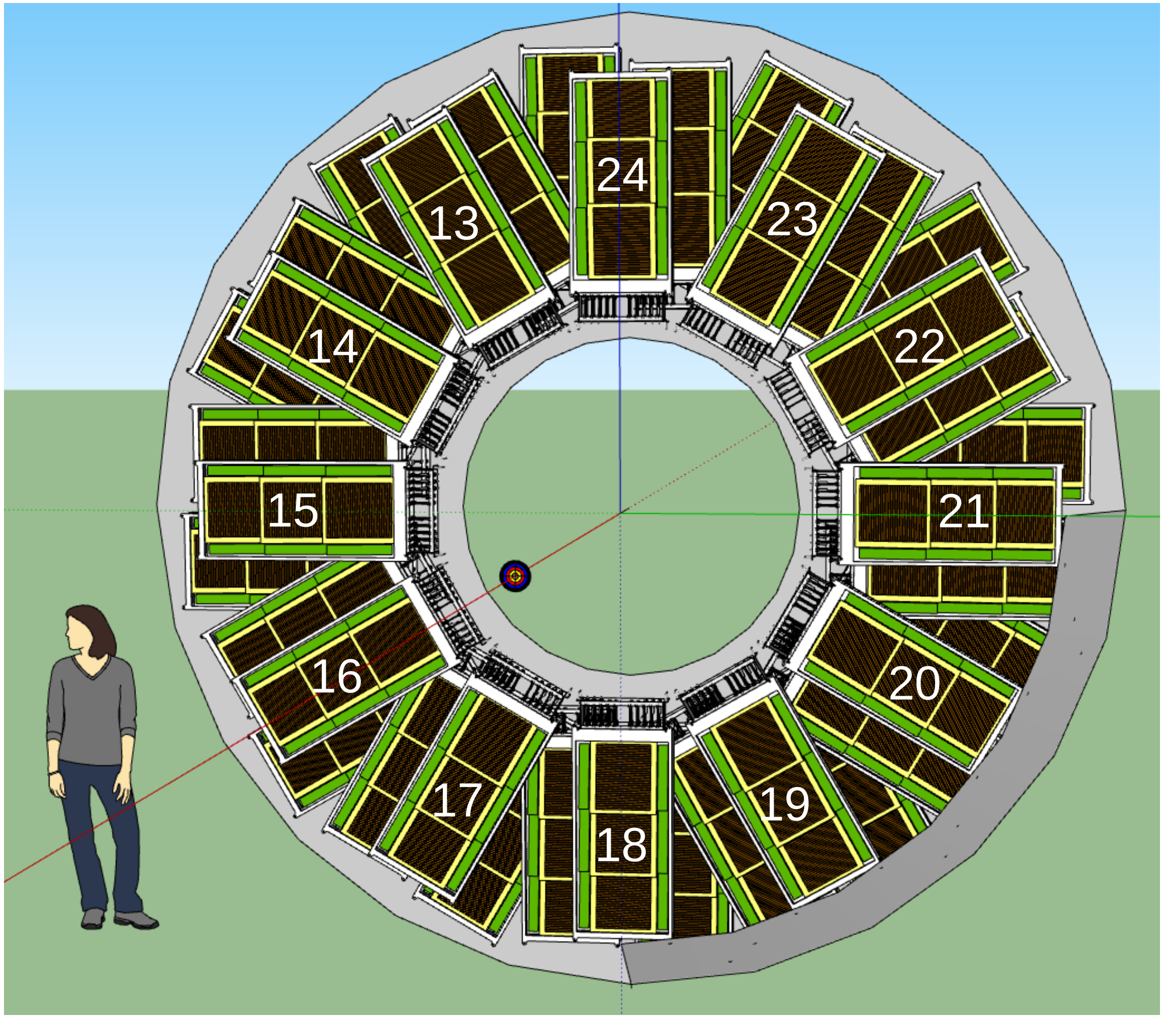


M. Stephanov. J. Physics G.: Nucl. Part. Phys. ***38*** (2011) 124147

critical region instead of a point [16, 18]. Assuming the data in the figure is related to the critical region, one must study the net-proton fluctuations at even higher baryon density region, i.e. at lower collision energies. At energy below 7.7 GeV, the collider mode experiments become inefficient so the fixed-target (FXT) mode is the way out.

Xiaofeng Luo and Nu Xu, arXiv:1701.02105v1

eTOF wheel

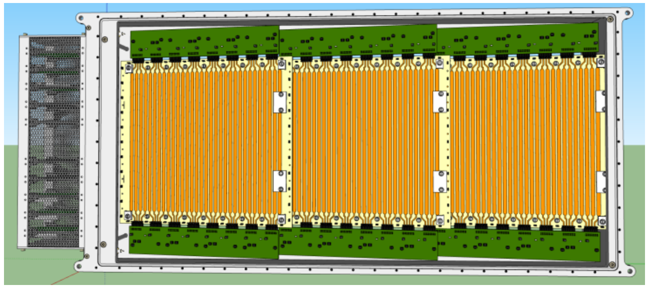


A conceptual design

- 36 modules
- 3 layers
- 12 sectors
- 6912 channels

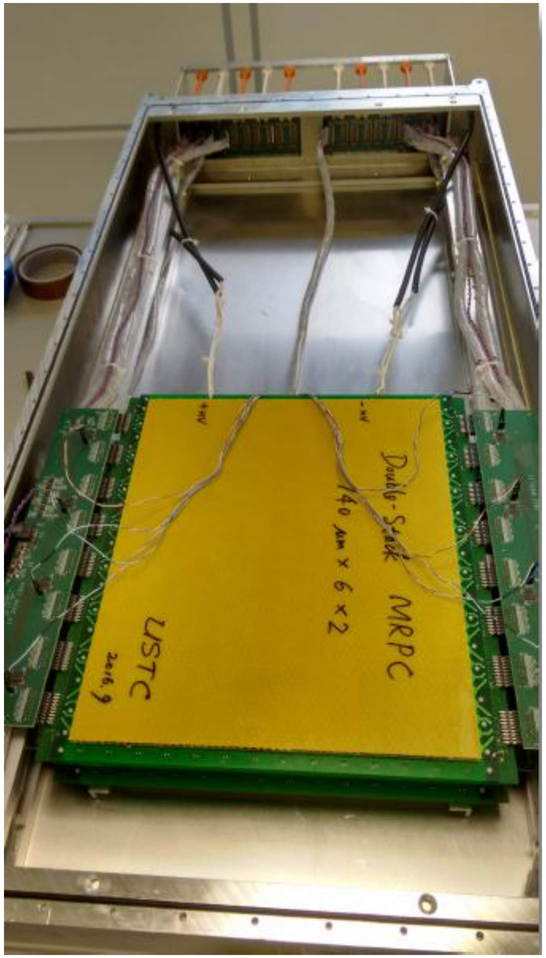
- Sector counting matches the TPC sectors

- Total depth about 14.2” (36 cm)

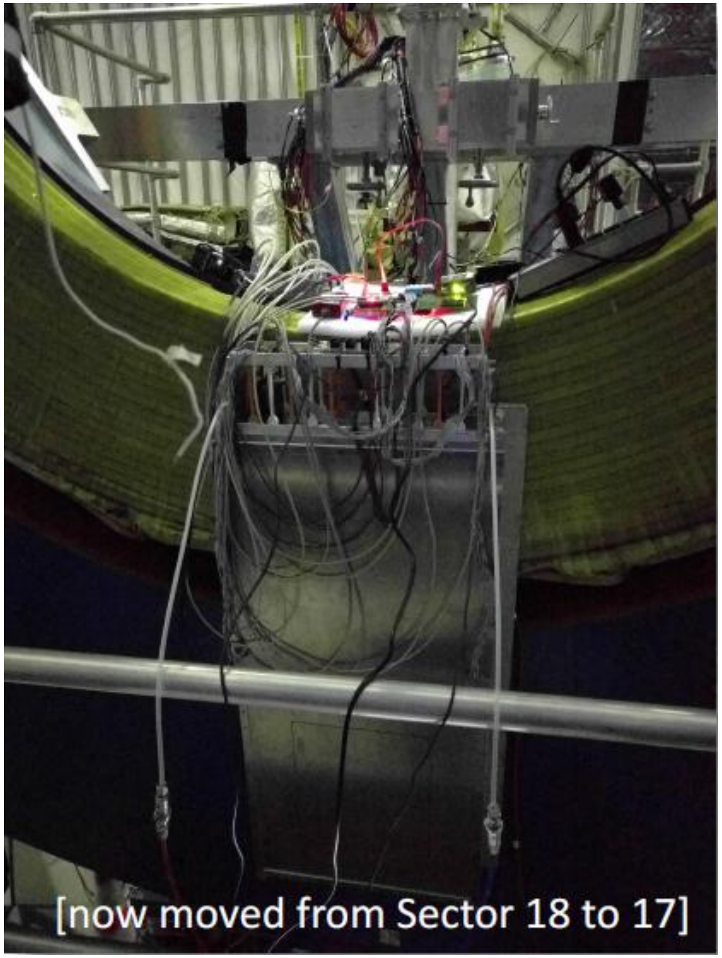


Setup in Jan 2017

Open module



Module fixed at the pole-tip



eTOF timeline

✓	December 2015	submit the physics proposal to GSI and BNL for approval
✓	Summer 2016	shipping a real size module to BNL and installing it on the east side pole of STAR
✓	Feb. 2017	1st system integration test with one module by participating in the Run17 beam time in STAR
➢	Fall 2017	shipping and installation of one sector
➢	Feb. 2018	2nd system integration test with one sector by participating in the Run18 beam time in STAR
➢	Summer 2018	shipping all 36 modules including infrastructure (gas system, LV-, HV-power supply) to BNL
➢	Fall 2018	Installation and commissioning
➢	Feb 2019	Start of the BES II campaign
➢	Summer 2021	Decommissioning and shipping of all modules including infrastructure to FAIR

Summary

- The FXT program will allow to extend the BES-II down to $\sqrt{s_{NN}}$ =3.0 GeV
- Successful FXT test run in June 2015 with Au + Au $\sqrt{s_{NN}}$ = 4.5 GeV and Al + Au $\sqrt{s_{NN}}$ = 4.9 GeV, 2 h -> 3 M triggers
- At least 100 M Events for each energy is required in order to do multi-differential measurement -> about 2 days of data taking for each energy
- Sub-threshold produced baryons (Hyperons) probe the medium density (multi step processes)
- Flow measurement as an indication on pressure and in-medium effects
- Di-leptons can act as thermometer and chronometer – no data available in the FXT energy range
- Much more interesting observable like HBT, High-p_T suppression, …
- eTOF upgrade (in combination with iTPC) opens the PID capability toward higher rapidity's and facilitates FXT program at higher energies up to $\sqrt{s_{NN}}$ = 7.7 GeV

Thank you for your attention

Backup Slides

Benefits

Benefit for STAR:

- providing critical TOF coverage for BES II
  - PID extension to y = 1.2 in collider mode
  - access to energies from 4.5 to 7.7 GeV in the fixed target program

Benefit for CBM:

- providing a large-scale integration test of the CBM TOF system, including PID and calibration of the detectors (hardware and software)
- preparation for day one experiment at SIS 100

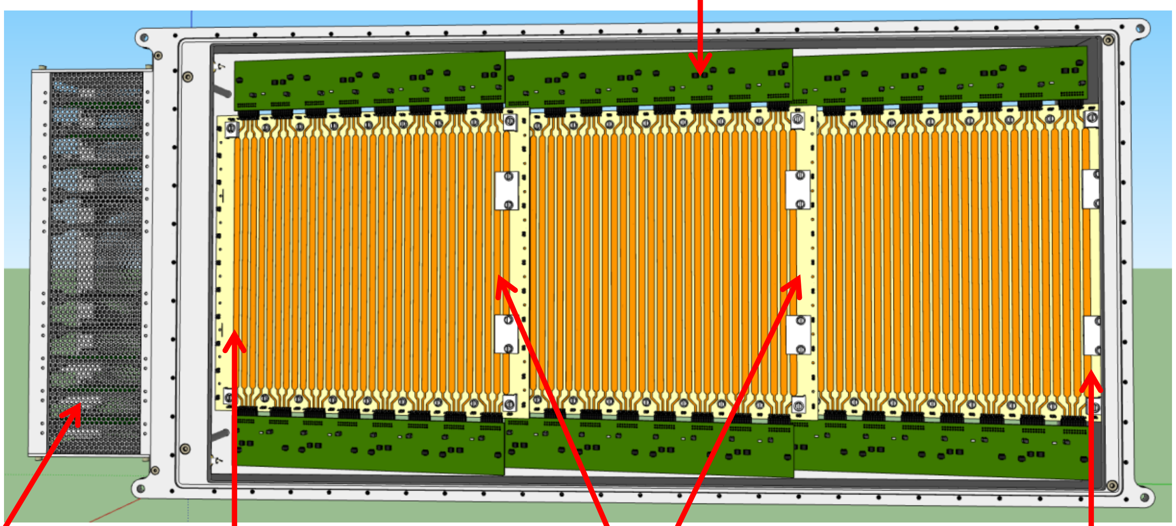
Benefit for CBM-TOF group members:

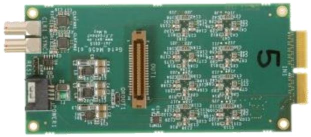
- participation in the analysis of the physics data provided by the CBM TOF detectors, including authorship of any publications from this data.

eTOF module

- 3 MRPCs (MRPC3a/b) – tilted by ≈7°
- 32 strips/MRPC with a pitch of 1 cm
- 27 cm strip length
- Active area about 92 cm x 27 cm
- 192 read out channels

Preamplifier PADI boards





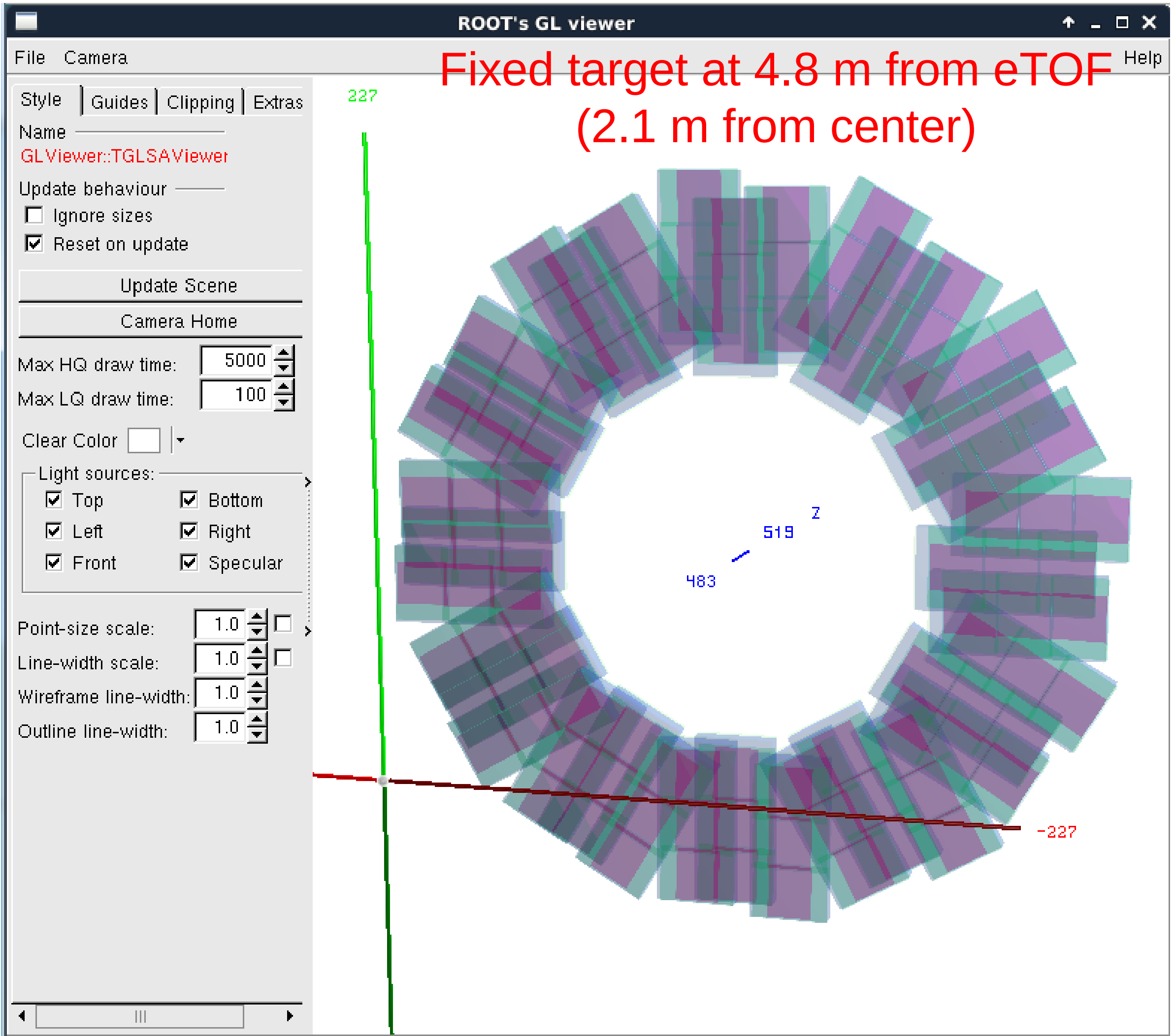
TDC GET4 boards

Strip 1

overlapping strips

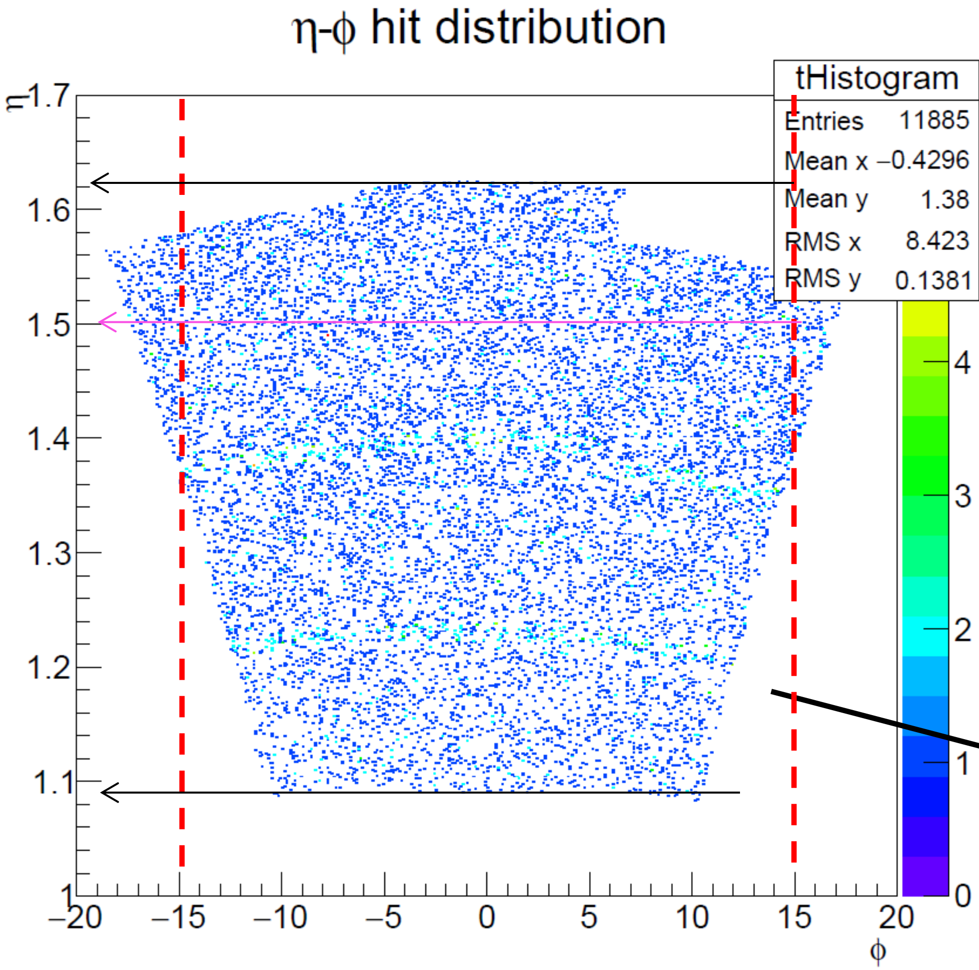
Strip 96

eTOF geometry in CBM ROOT



- MRPC
  - Active gas
  - Glass
- Electronics
- Aluminum box

Acceptance of one sector

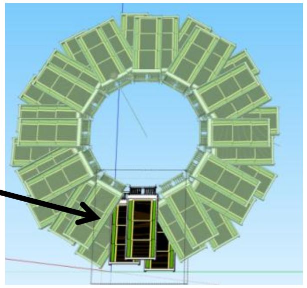


Collider mode

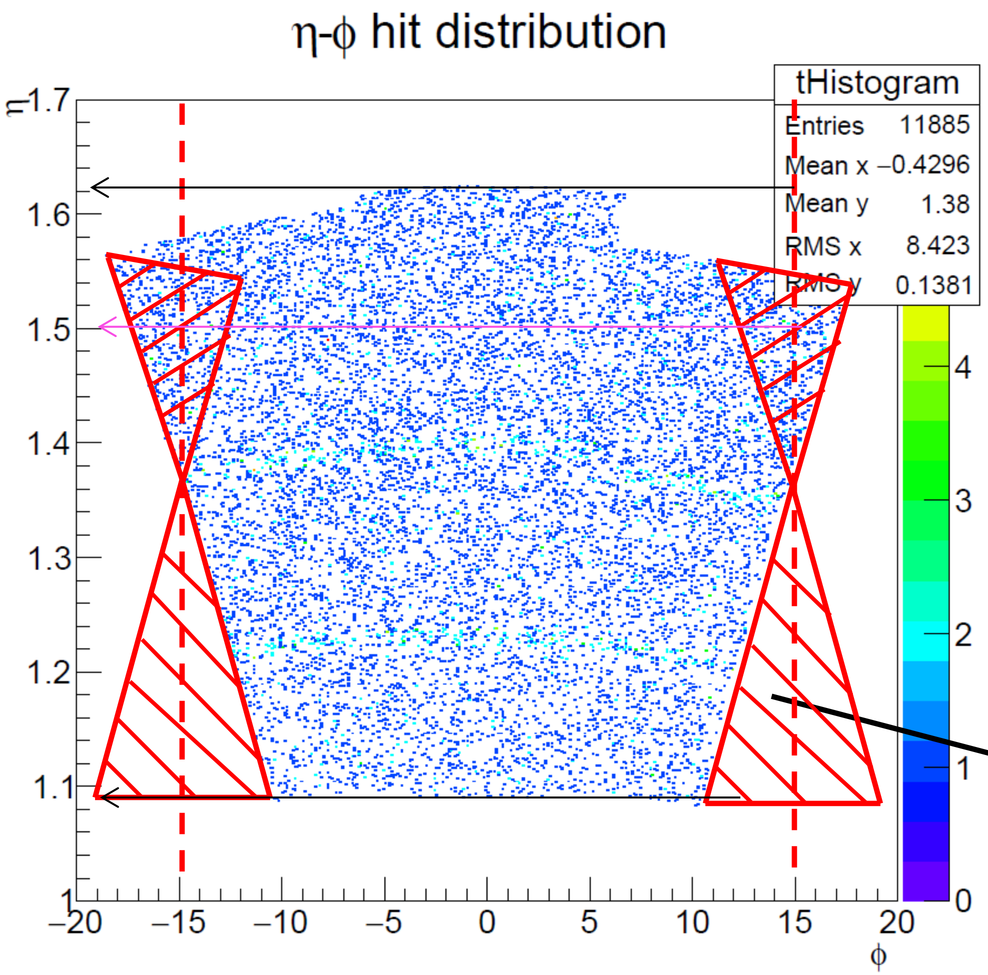
Interaction point 2.7 m

1.09 < eta < 1.62

Good tracks - iTPC



Acceptance of one sector



Collider mode

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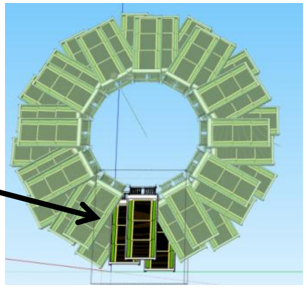
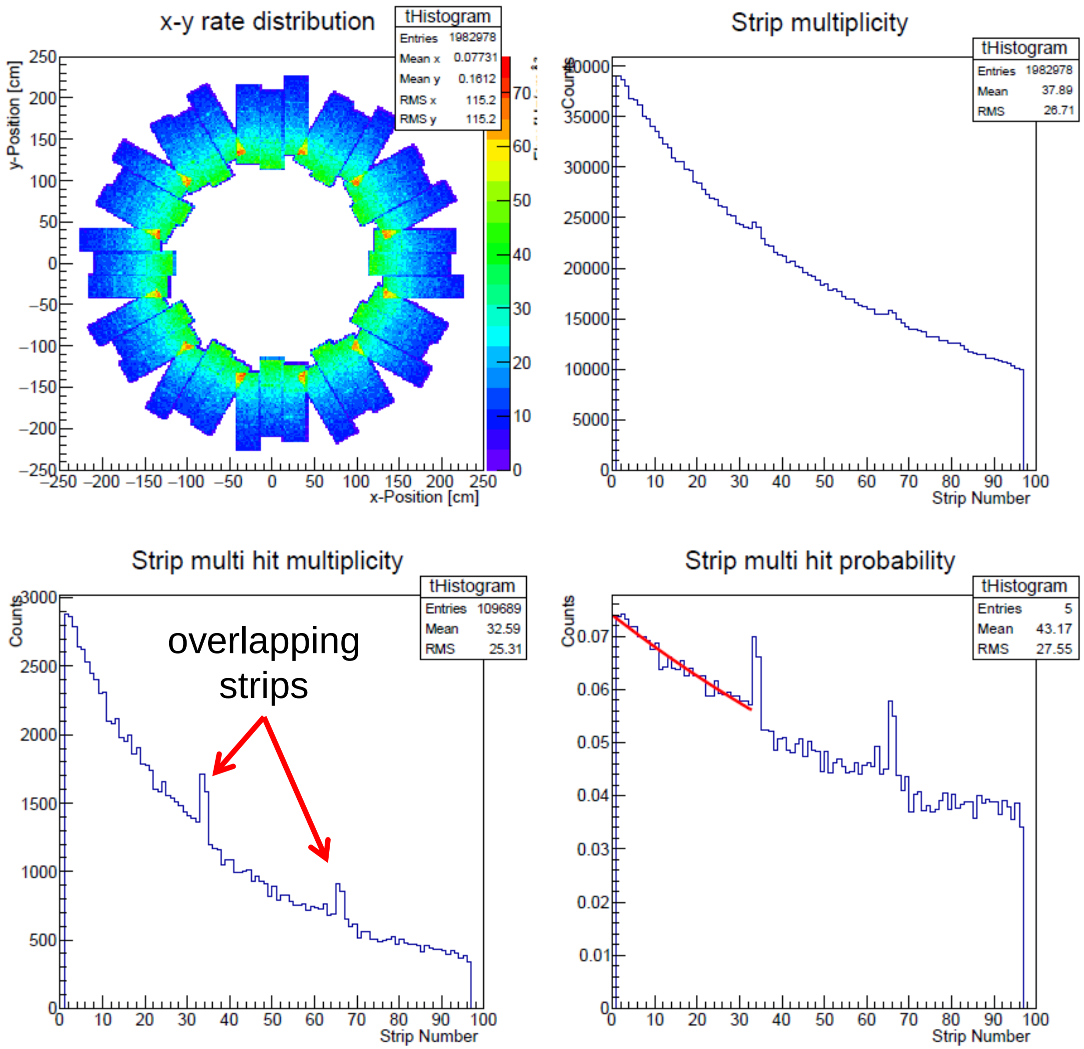


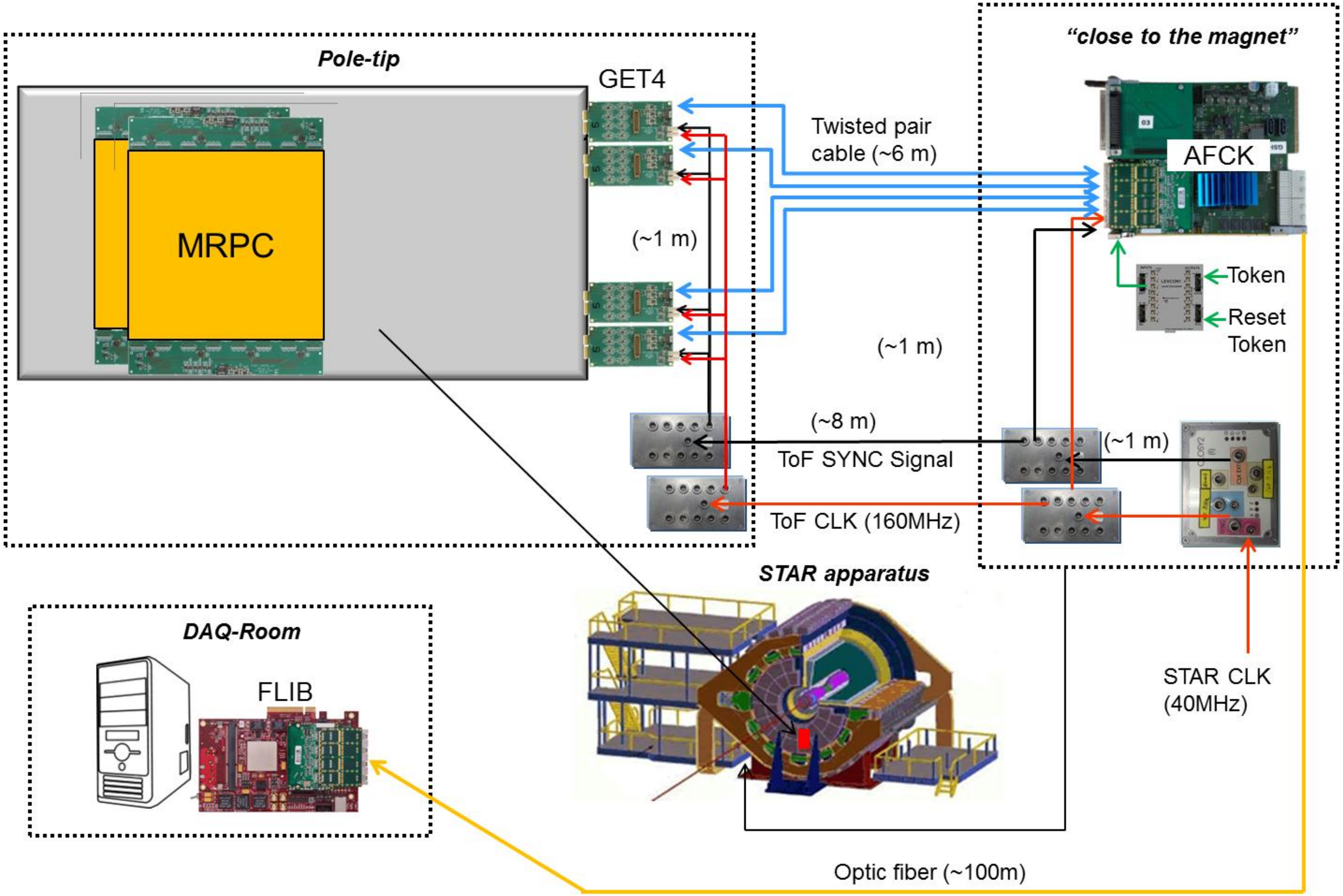
Rate and multi-hit



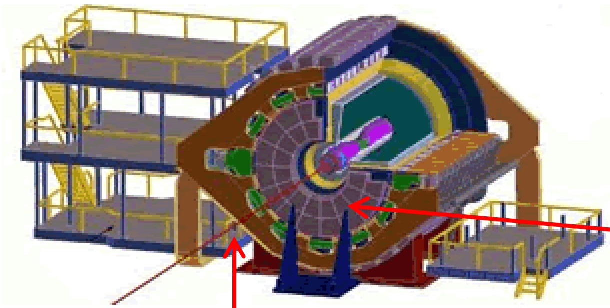
All particles

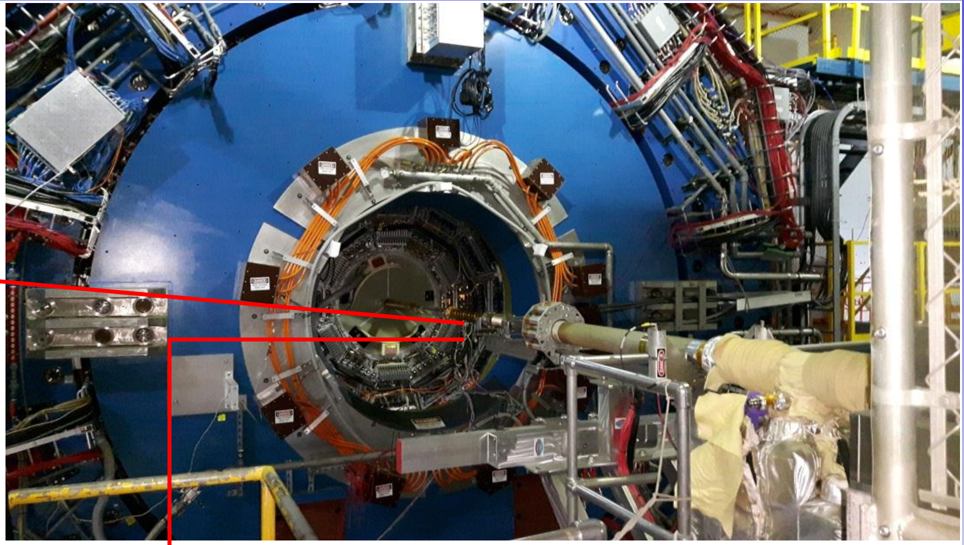
- Beam energy **25 AGeV**
- **Interaction rate 10kHz (2kHz recording rate)**
- **Fixed target position 4.8 m**
- **Particle flux < 45Hz/cm^2**
- **Multi-hit probability < 7.4 %**

Setup in Jan 2017

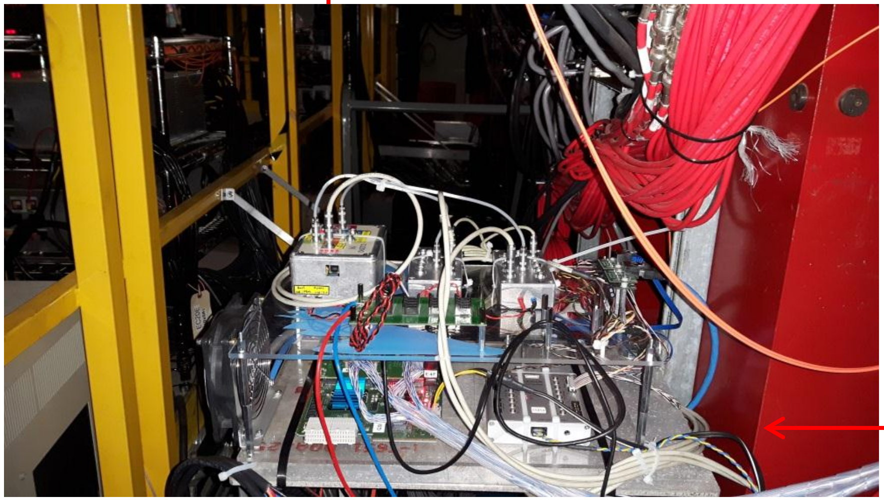


Setup in Jan 2017





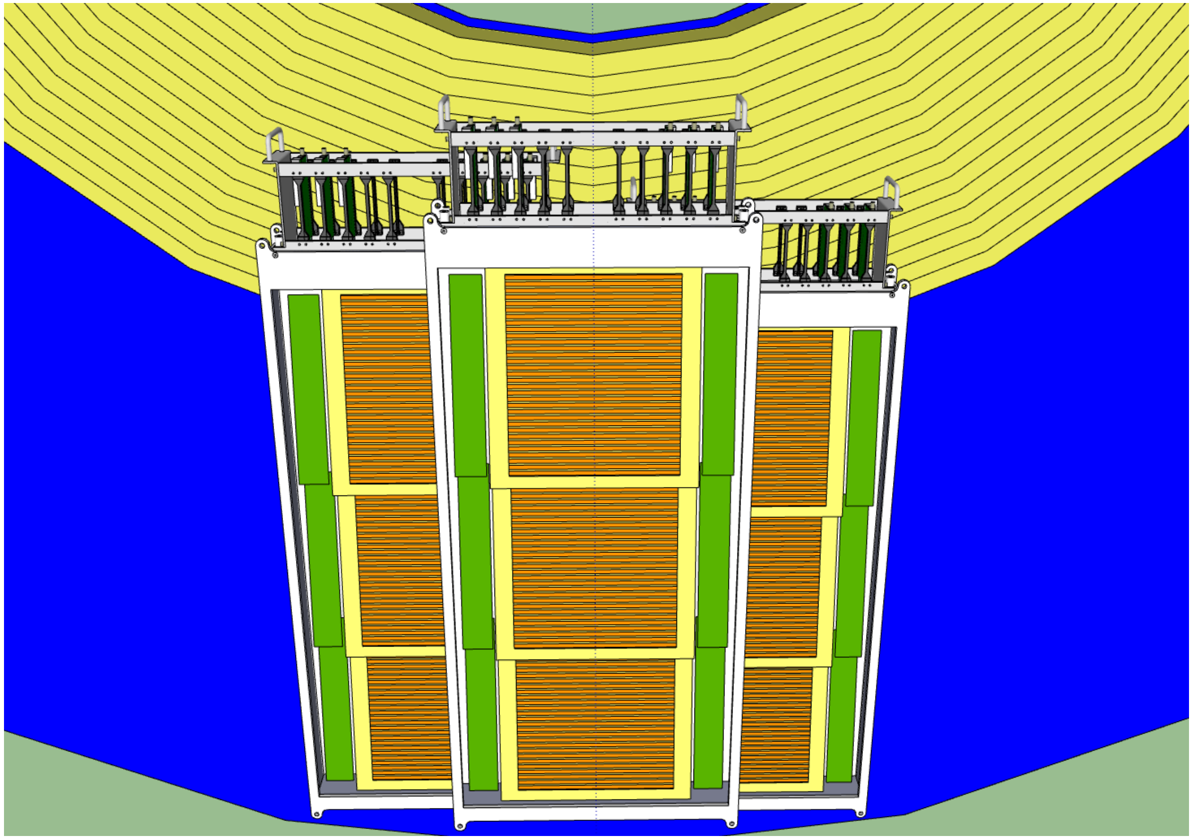
place for CLK and AFCK



6m cable
CLK / SYNC + DATA/
LV power

Setup in Jan 2018

One full sector



- 6 MRPCs with float glass (USTC)
- 3 MRPCs with low resistive glass (Tsinghua Univ.)
- Review readiness report March 2017