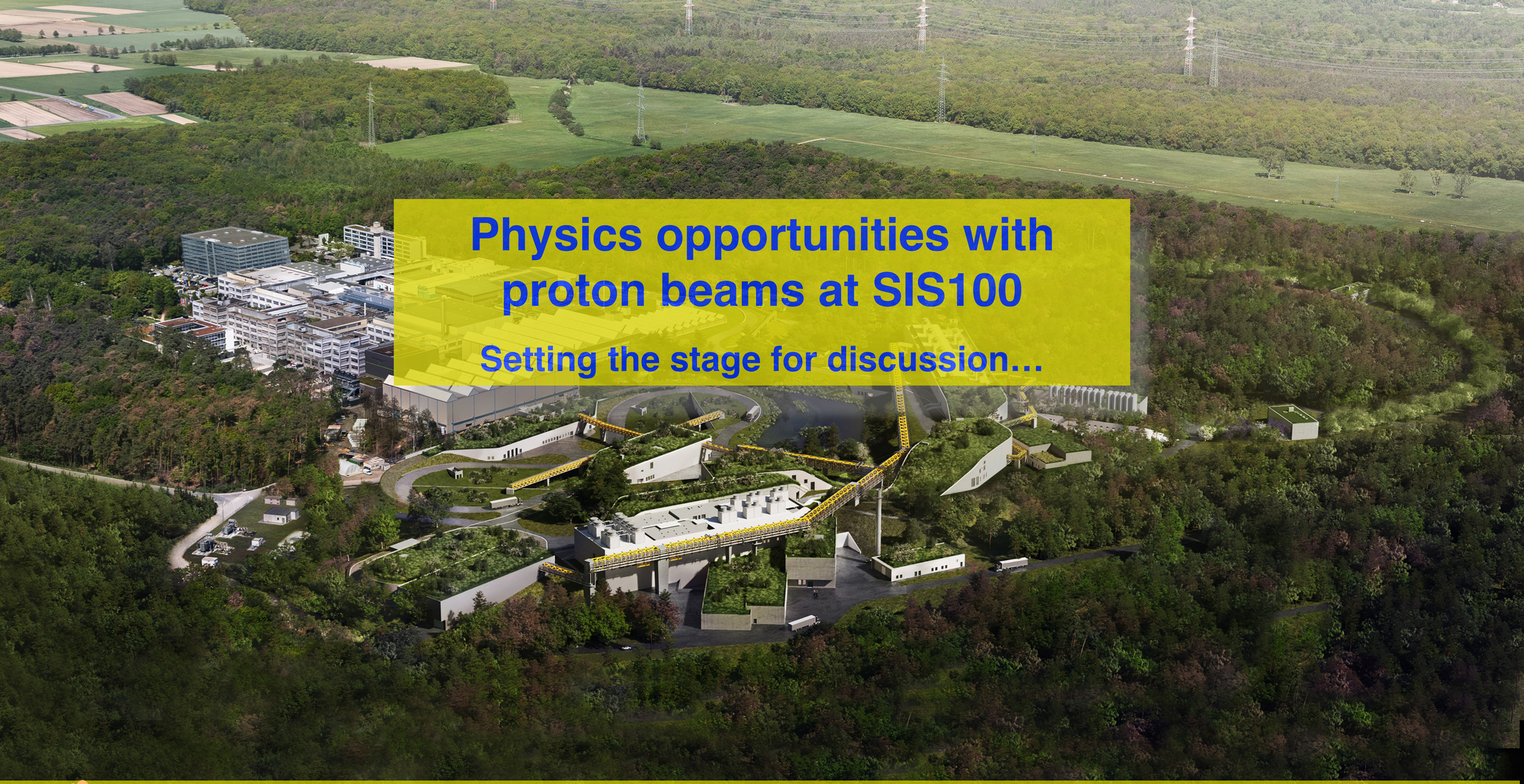


Physics opportunities with proton beams at SIS100

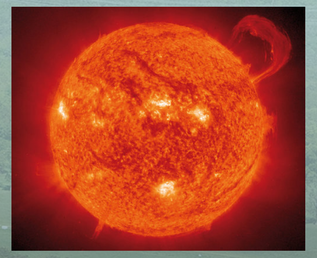
Setting the stage for discussion…

Johan Messchendorp (GSI/FAIR)

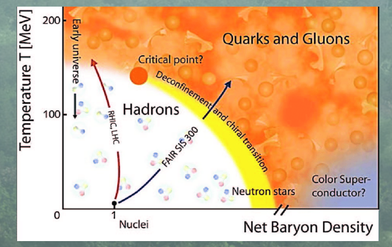
Satellite workshop MESON2023, June 21, 2023

Facility for Antiproton and Ion Research -
"The Universe in the Laboratory"

APPA

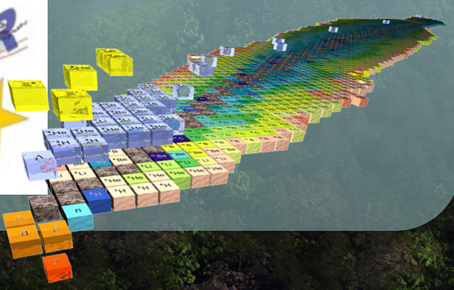


CBM



panda

NUSTAR



$$\mathcal{L}_{QCD} = \sum_{q=u,d,s,c,b} \bar{q} \left(i\gamma_\mu D^\mu - m_q \right) q - \frac{1}{4} G^{\mu\nu} G_{\mu\nu}$$

Properties of strongly interacting matter?

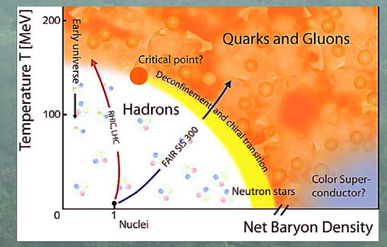
Formation of hadronic matter?

Underlying symmetries

Degrees of freedom: from quarks/gluons to baryons/mesons?

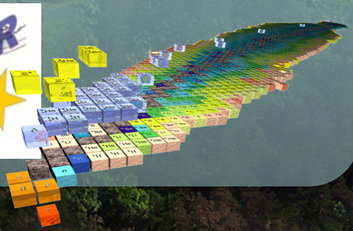
Origin of mass?

CBM

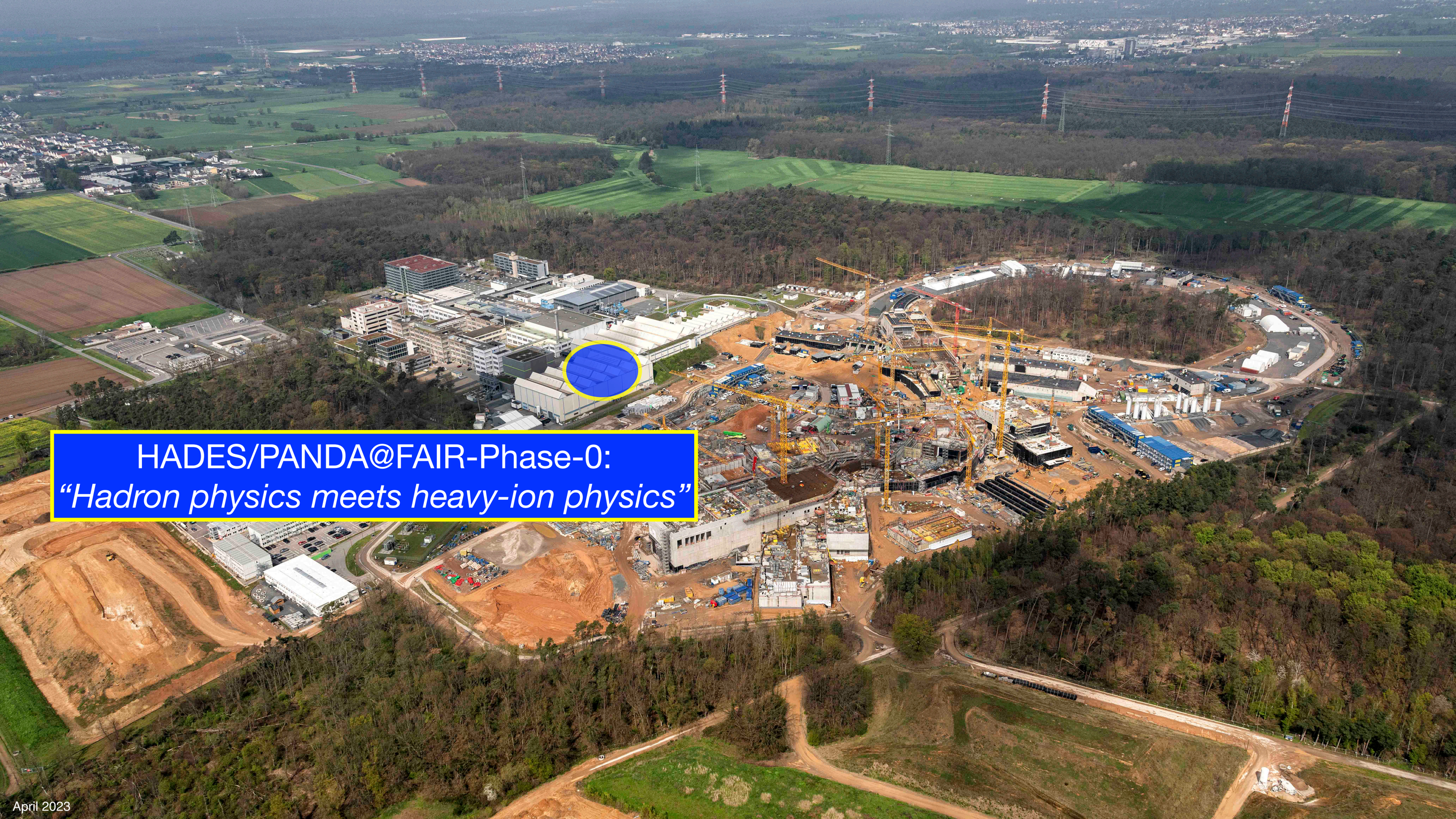


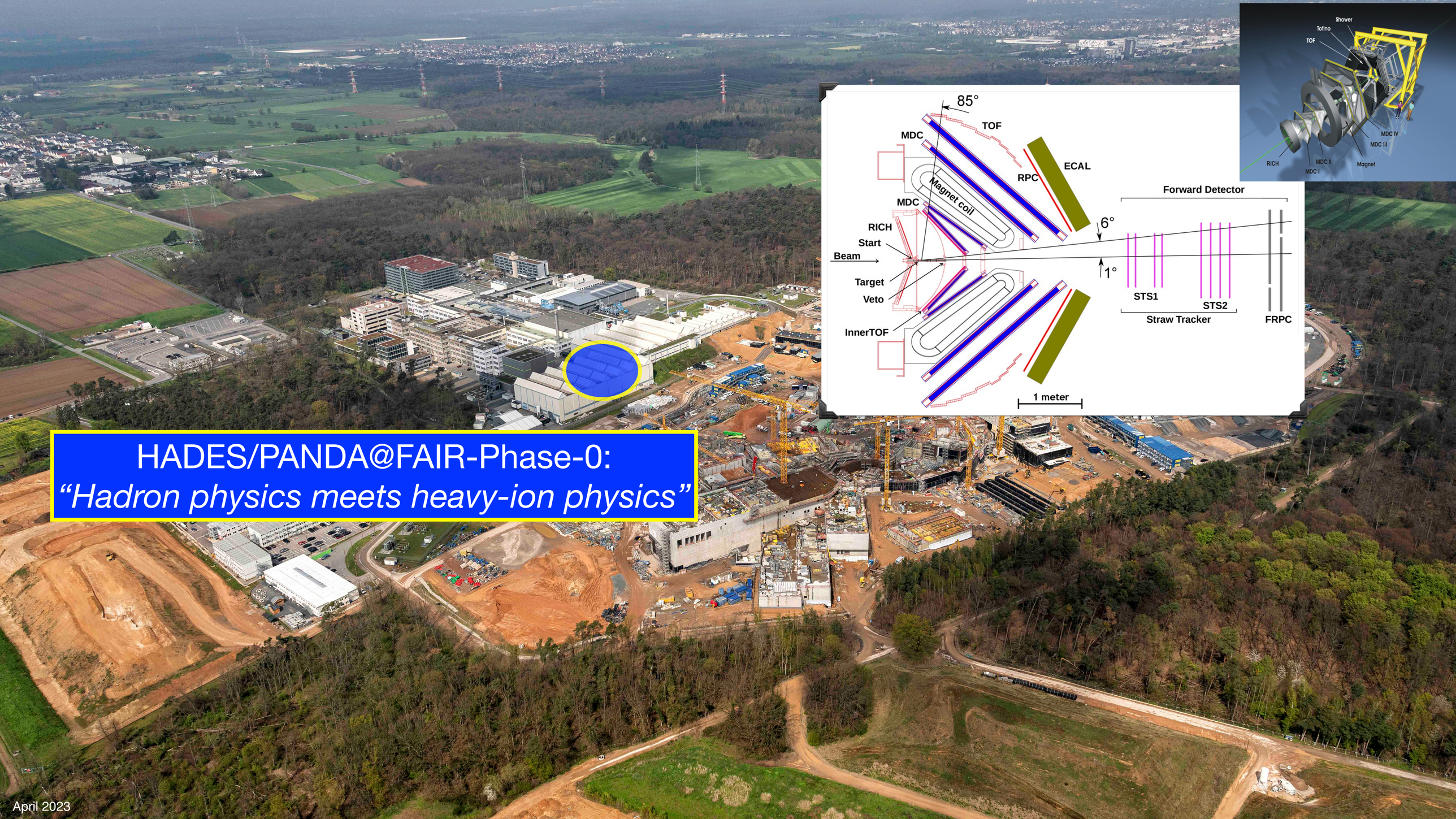
panda

NUSTAR



April 2023


HADES/PANDA@FAIR-Phase-0:
“Hadron physics meets heavy-ion physics”
April 2023



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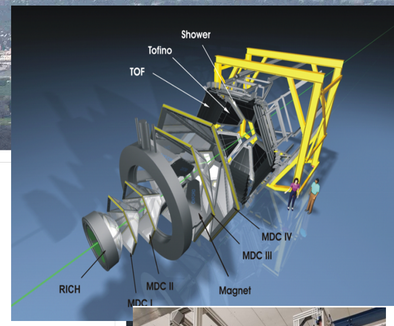

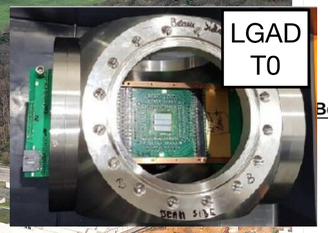

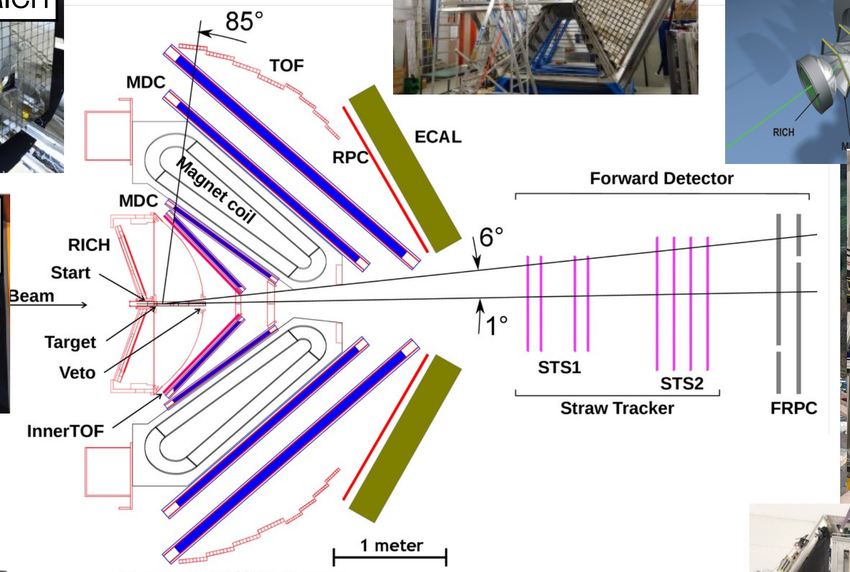

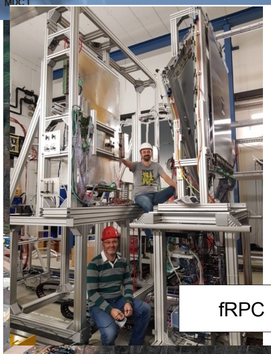

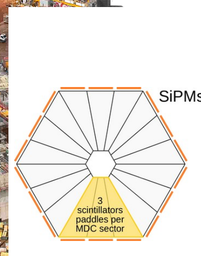

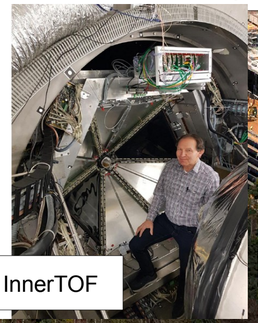

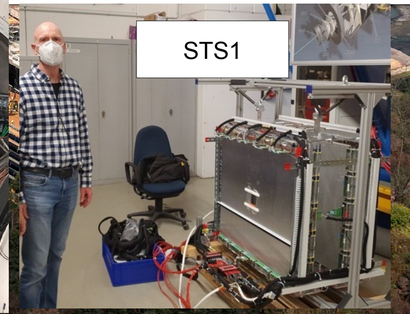

April 2023

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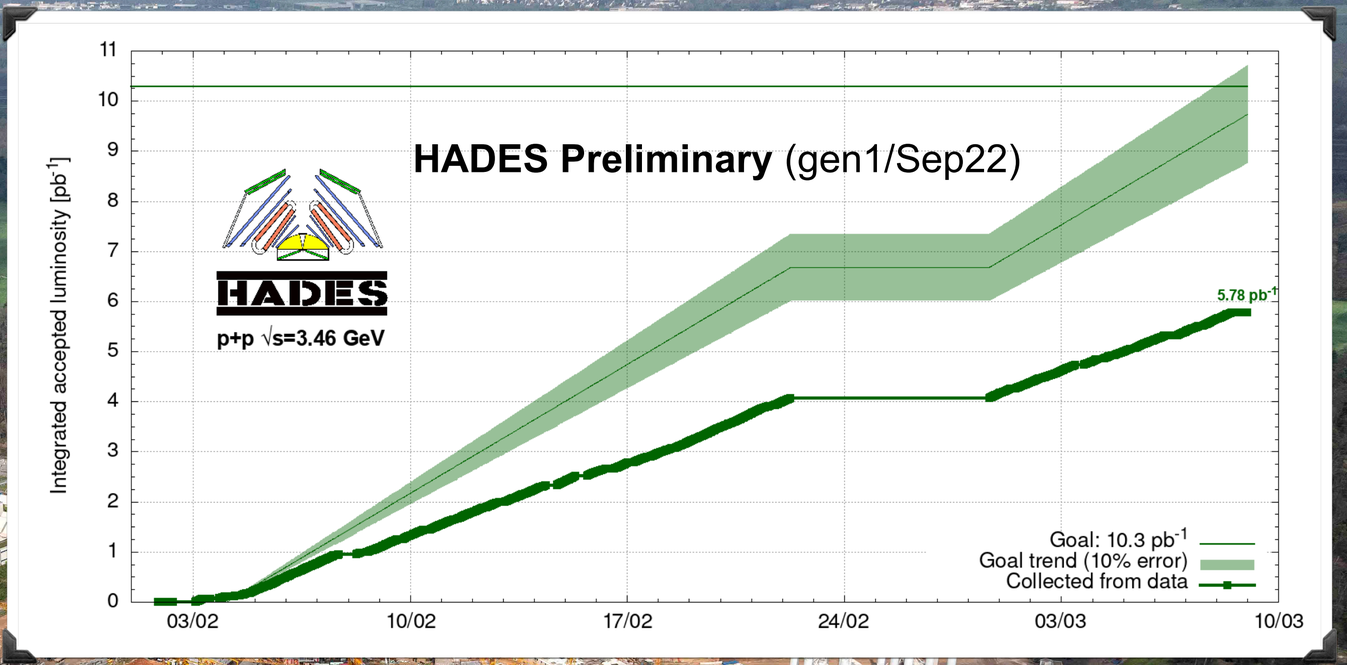
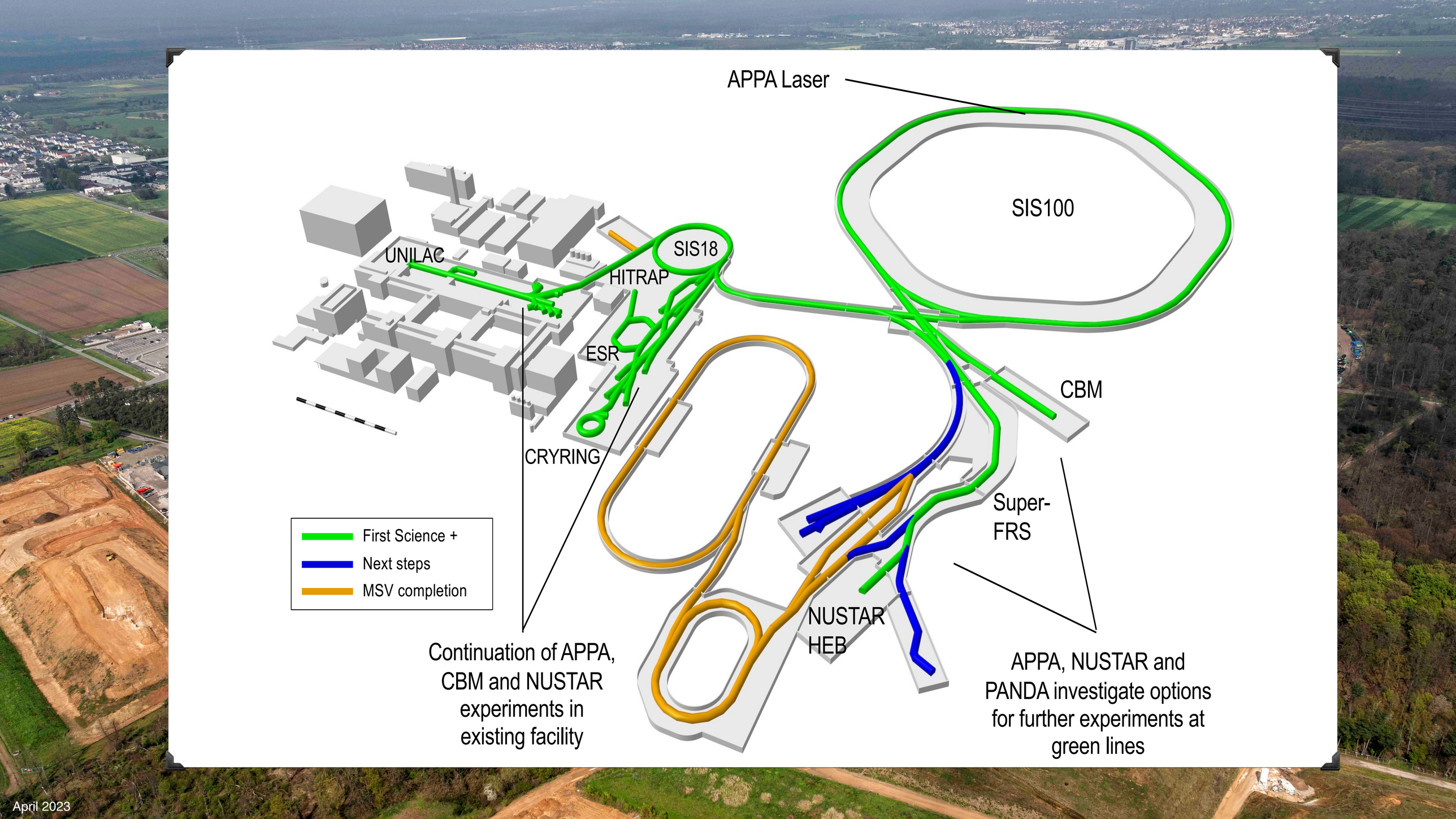
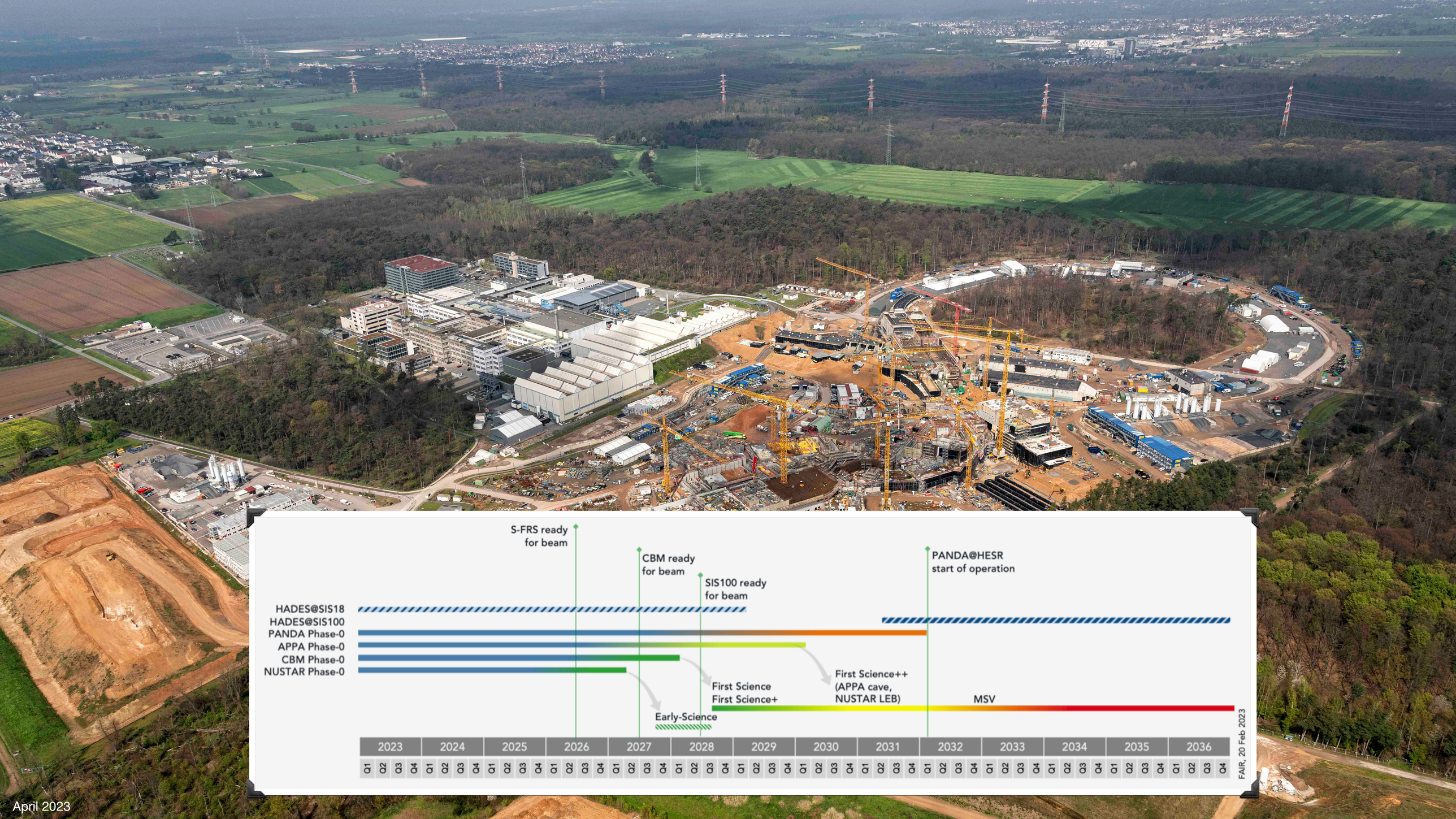


Table 2: Projected number of events reconstructed during 84 shifts.

Electromagnetic hyperon decays ($\Lambda\gamma^*$ and $\Lambda\gamma$)			
$\Sigma(1385)^0 \to \Lambda e^+e^-$	$\Lambda(1520) \to \Lambda e^+e^-$	$\Sigma(1385) \to \Lambda\gamma$	$\Lambda(1520) \to \Lambda\gamma$
302	352	1484	1559
Hyperon hadronic decays			
$\Lambda(1405) \to \Sigma^0\pi^0 \to \Lambda\ 3\gamma$	$\Lambda(1405) \to \Sigma^{\pm}\pi^{\mp}$	$\Lambda(1520) \to \Lambda\pi^-\pi^+$	
3.6×10^4	7.2×10^4	5.2×10^5	
Production of double and hidden strangeness			
$\Xi^- \to \Lambda\pi^-$	$\Lambda\Lambda$	$\phi \to K^+K^-$	
$(4.7 - 47.6) \times 10^4$	$(0.62 - 6.17) \times 10^4$	3.1×10^6	
Inclusive measurement of hadrons and dielectrons			
$M_{ee} < 0.15\,\mathrm{GeV}/c^2$	$M_{ee} > 0.15\,\mathrm{GeV}/c^2$	$\omega \to e^+e^-$	$\phi \to e^+e^-$	$M_{ee} > 1.1\,\mathrm{GeV}/c^2$
5.72×10^6	7.41×10^5	5.8×10^4	1.86×10^3	69


APPA Laser
SIS100
SIS18
UNILAC
HITRAP
ESR
CBM
CRYRING
Super-
FRS
NUSTAR
HEB
First Science +
Next steps
MSV completion
Continuation of APPA,
CBM and NUSTAR
experiments in
existing facility
APPA, NUSTAR and
PANDA investigate options
for further experiments at
green lines

April 2023


S-FRS ready for beam
CBM ready for beam
SIS100 ready for beam
PANDA@HESR start of operation
HADES@SIS18
HADES@SIS100
PANDA Phase-0
APPA Phase-0
CBM Phase-0
NUSTAR Phase-0
First Science
First Science+
First Science++ (APPA cave, NUSTAR LEB)
MSV
Early-Science
2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036
Q1 Q2 Q3 Q4
FAIR, 20 Feb 2023

April 2023

Purpose

…the context

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…the context

- Initiative from FAIR-physics motivated group: Tetyana Galatyuk, Norbert Herrmann, Claudia Hoehne, JM, Frank Nerling, Jim Ritman, Piotr Salabura, Karin Schoenning, Joachim Stroth

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- Identify a physics program with proton beams, win-win:
  - *Heavy-ion physics communities:* enrich program with “elementary” component, strengthen political impact at FAIR
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- Reach out for new collaborators from both experiment and theory!

Purpose

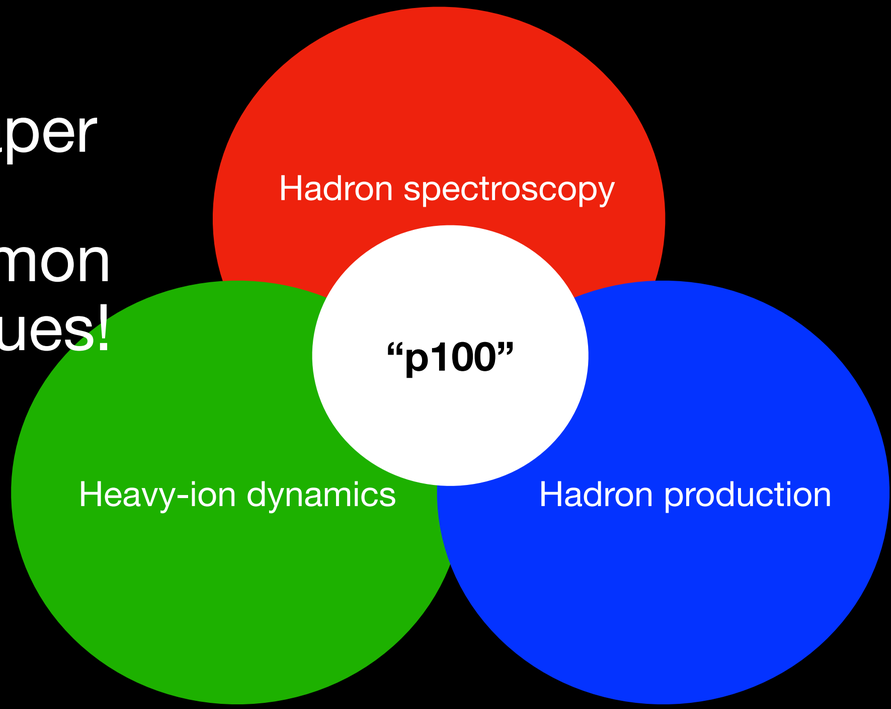
…the process

- Various brainstorming activities have been ongoing this year
- Feasibility studies using “fast simulations” in progress
- Discussions among physicists from various FAIR collaborations
- Presentations at FAIR advisory boards ECE/ECSG and JSC
- Planning a follow-up workshop “Proton induced physics at FAIR”

Purpose

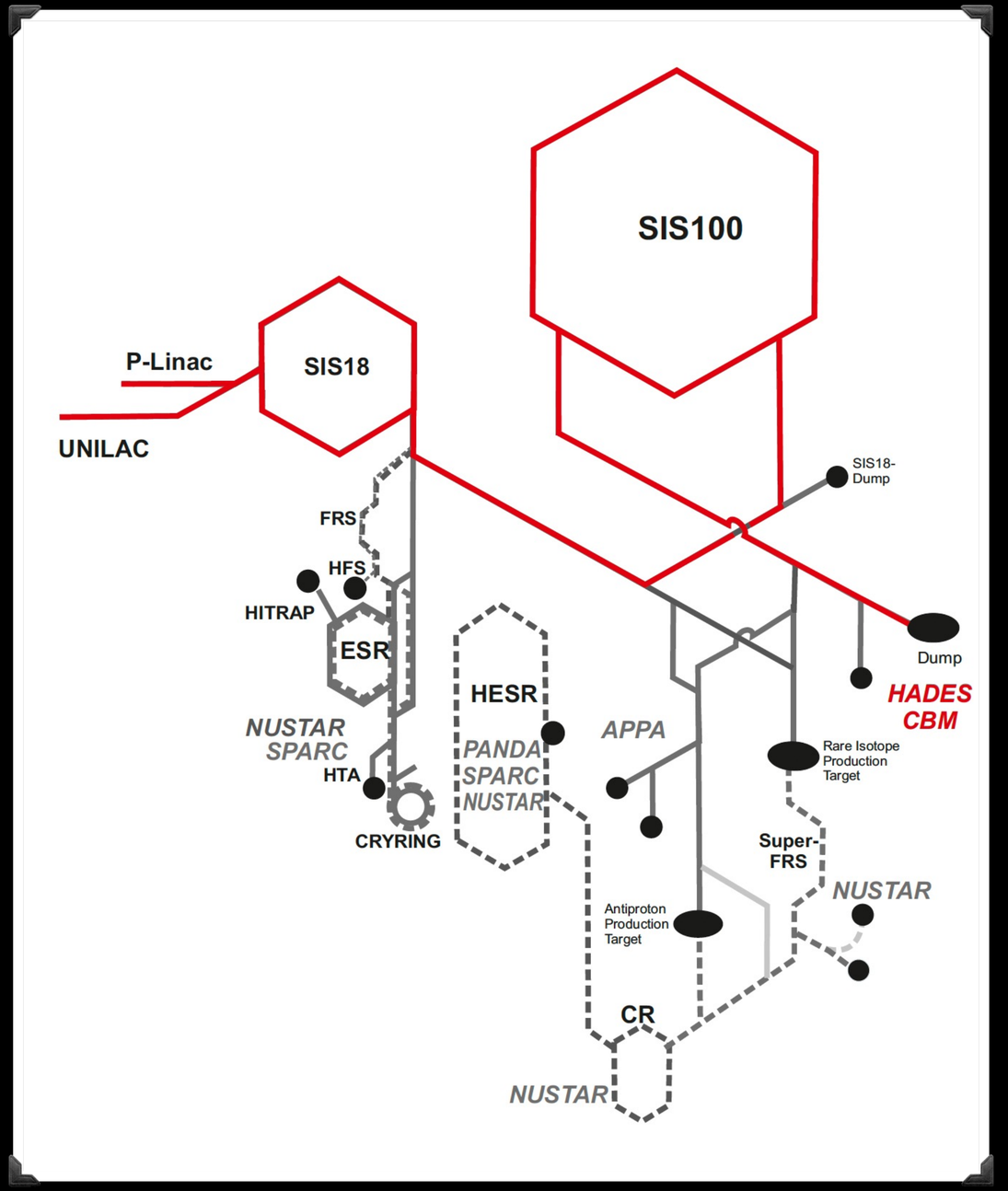
…this satellite workshop (my wish)

- Identify key elements as a basis for a proton-driven physics program
- Identify the requirements, experiment and theory, for a successful endeavour
- Plan follow-up activities towards a position-/white-paper
- Form a (federated) collaboration connecting the common interest among FAIR communities and theory colleagues!



From SIS18 to SIS100

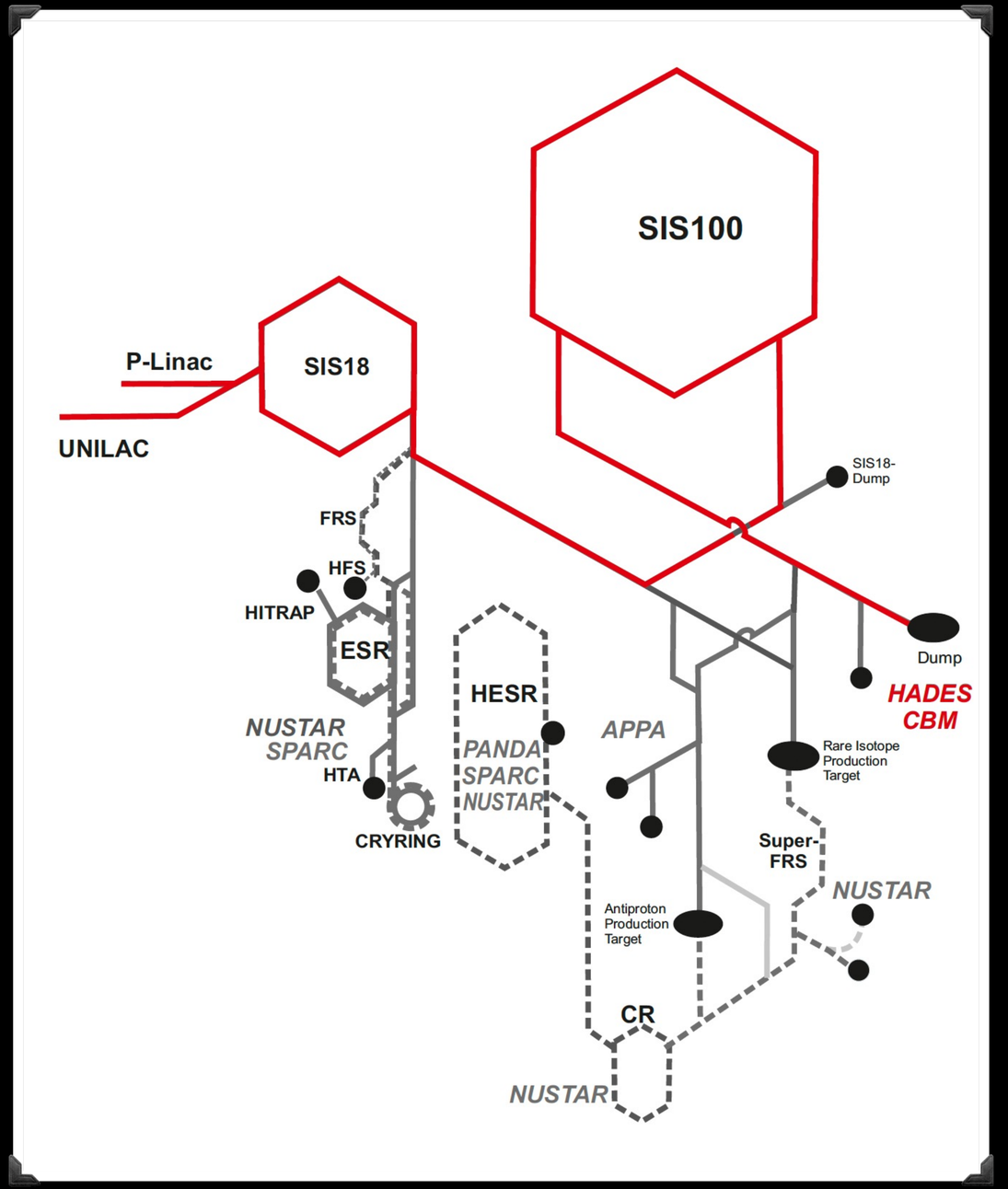
…what could that add in proton physics?



From SIS18 to SIS100

…what could that add in proton physics?

- **Energy upgrade:**
  - From max 4.7 GeV (SIS18) to 29 GeV (SIS100) proton energy
  - Opening new realm: double+triple strangeness and even charm baryons and mesons!
  - Significant increase in production yield of hyperons



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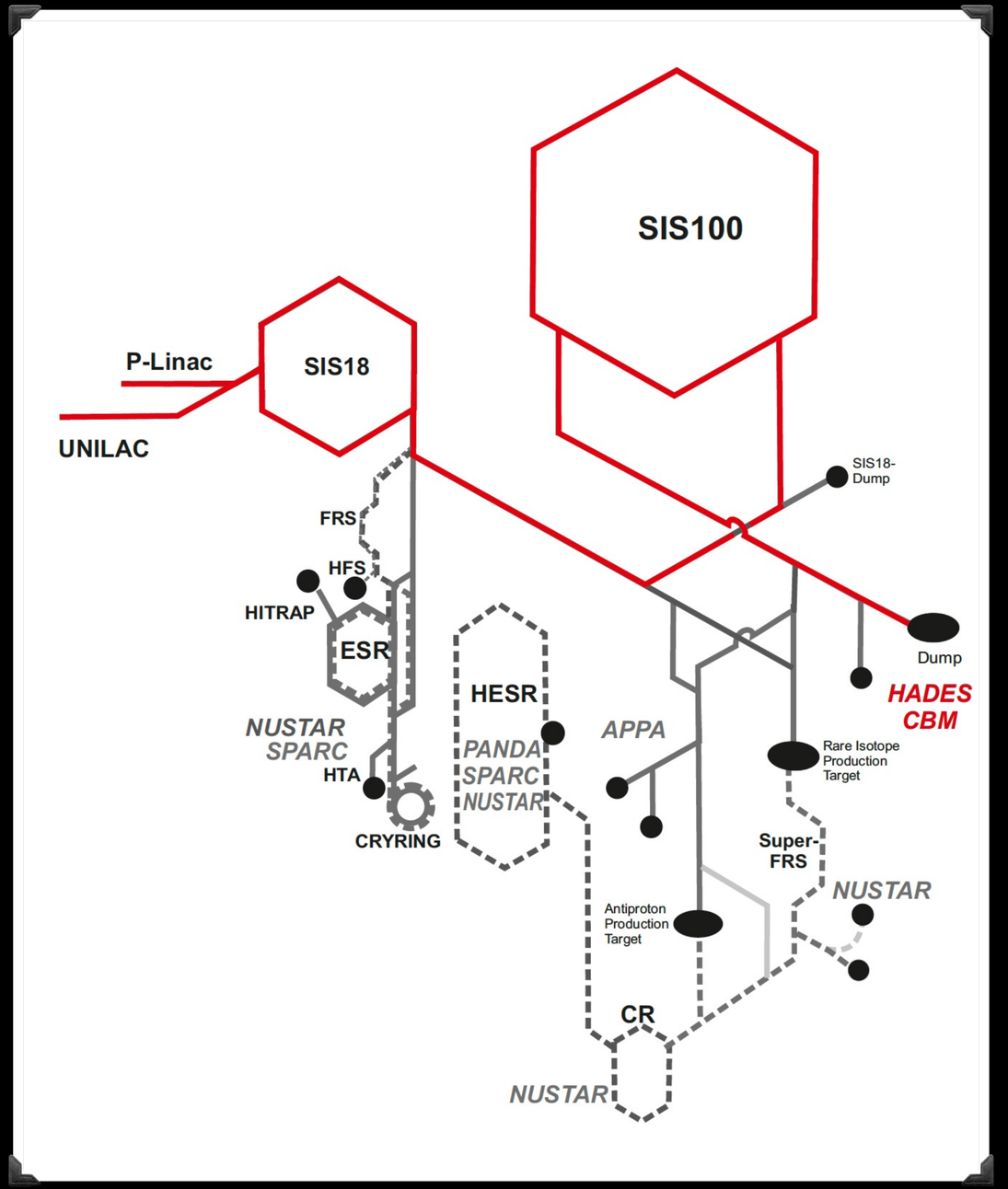
  - From max #protons/cycle of 10^{12} (SIS18) to 2×10^{13} (SIS100)
  - Even during “commissioning” (10^{10} protons/cycle) and 5 cm LH2 target: ~8 pb^{-1} day^{-1}



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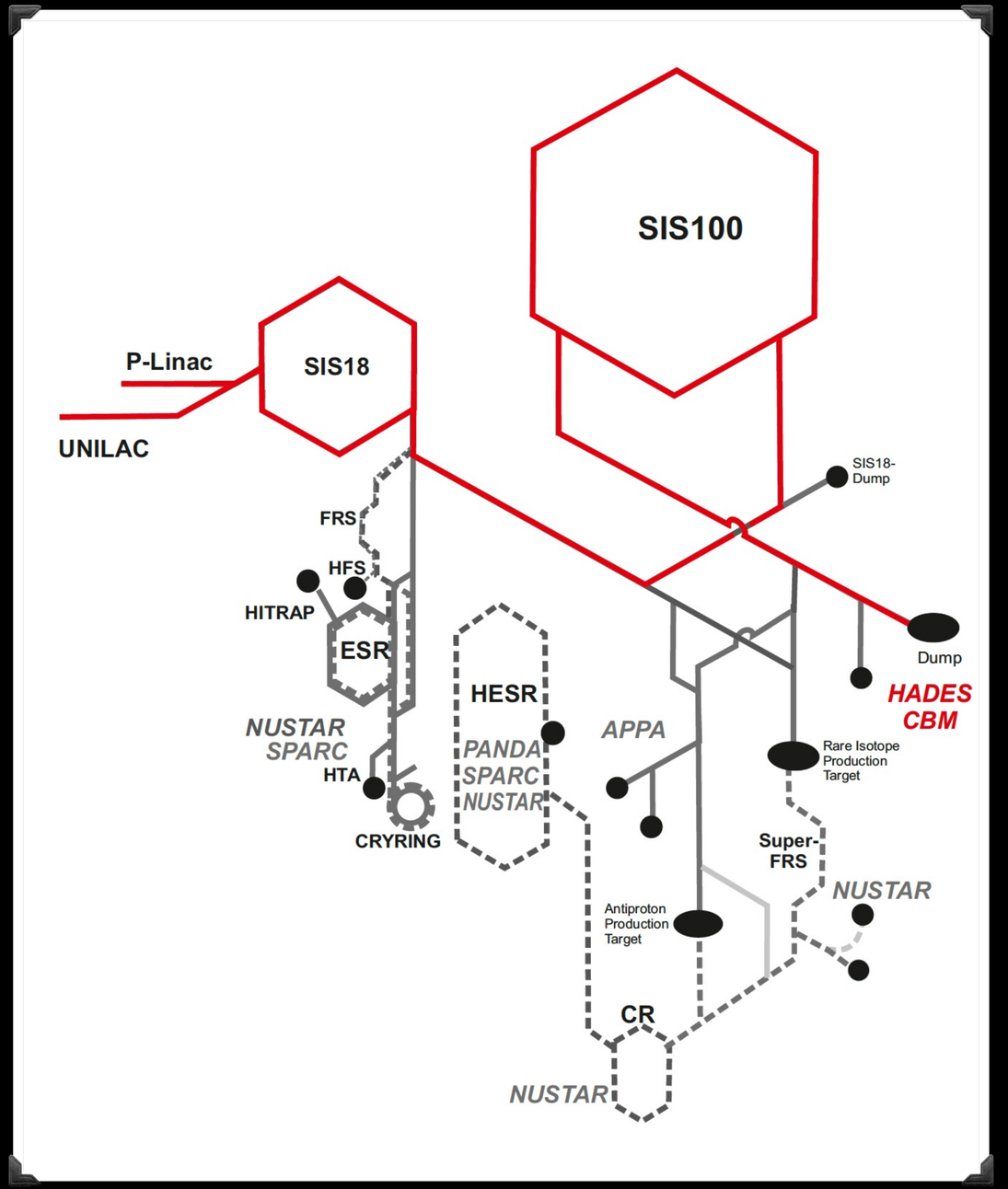
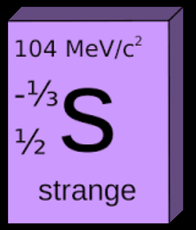
- **Detector enrichment:**
  - Towards high-rate capabilities and free-streaming DAQ’s etc.



Hadron Physics aspects with p100

… incomplete shopping list!



Strangeness physics

- Hyperon (Y) spectroscopy in |S|=1,2,3 systems, f.e. Ξ^*, Ω^*, spin-parity determination
- N* spectroscopy and coupling to strangeness, f.e. $N^* \rightarrow \Xi KK$
- YN, YY interactions in exclusive pp reactions and via Femtoscopy
- Hyperon structure, e.g. $Y^* \rightarrow Y\ell^+\ell^-$, precision eTFF studies
- Low-energy constants in chiral SU(3) via axial-vector transition form factors, e.g. $\Xi^* \rightarrow \Xi\pi\gamma$

Hadron Physics aspects with p100
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104 MeV/c²
-⅓
½ S
strange

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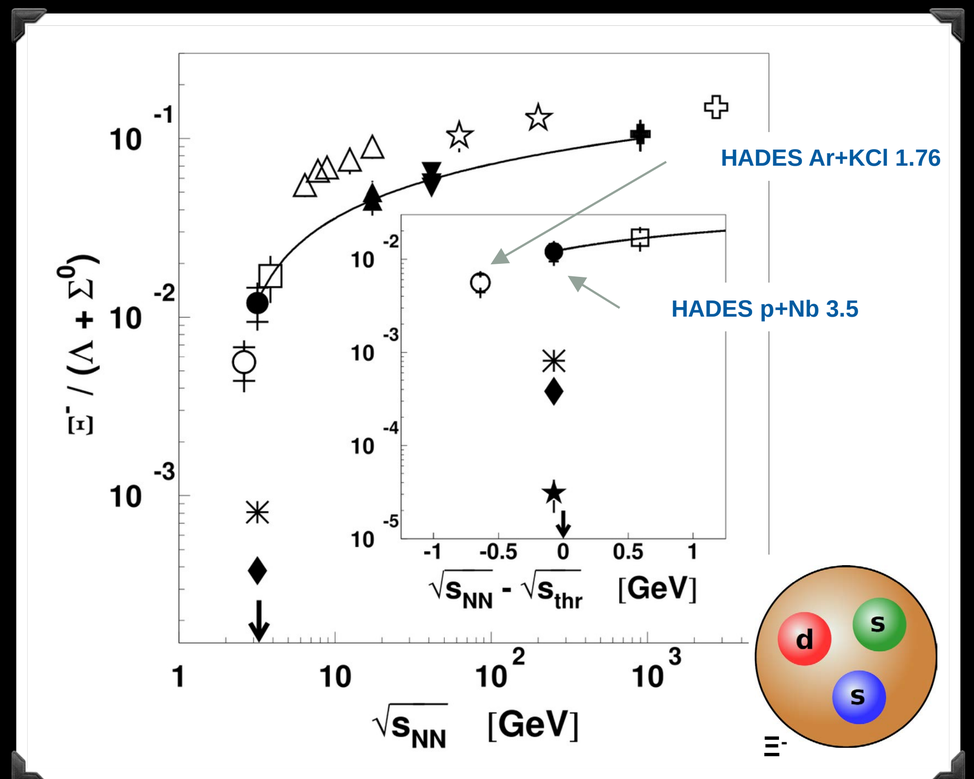

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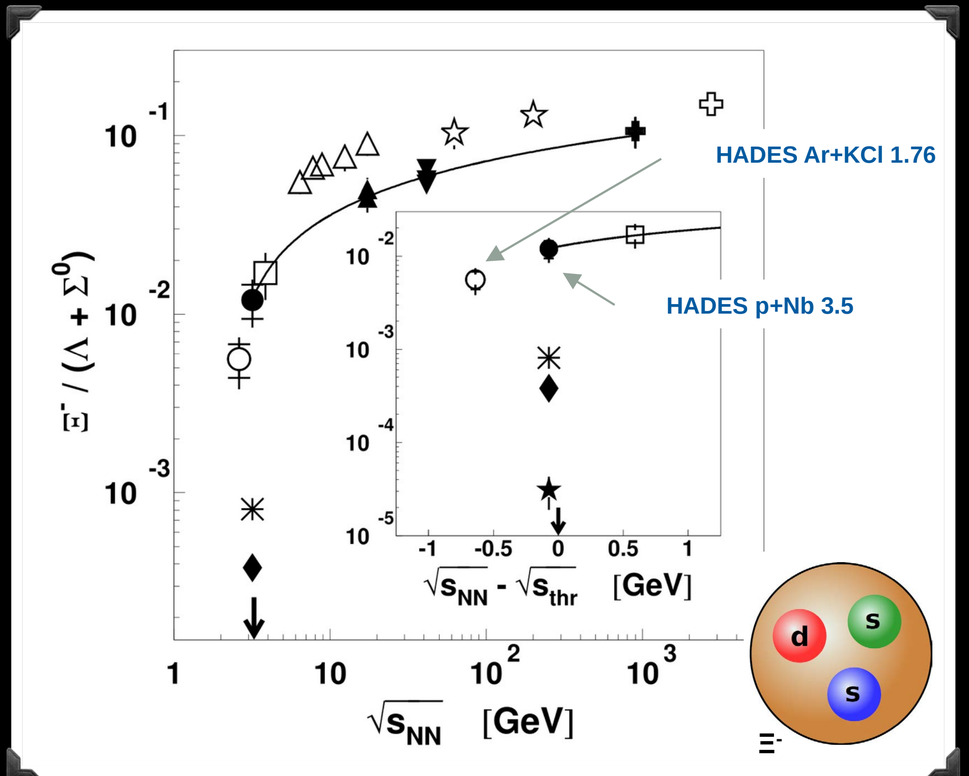

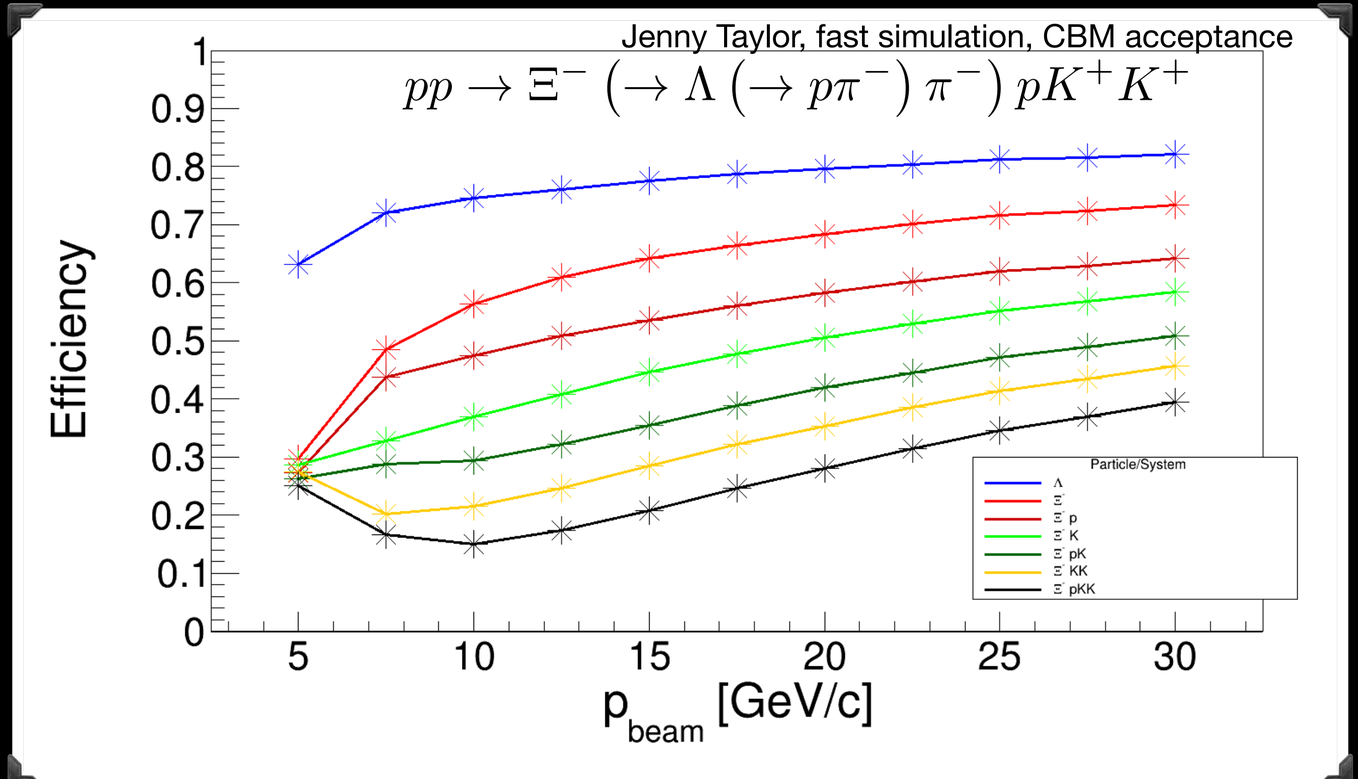

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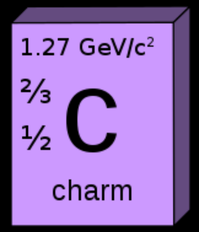

Charm physics

- Charm-N interactions: SU(4) dynamics!
- Intrinsic charm component of the nucleon
- Mass structure of the proton

Hadron Physics aspects with p100
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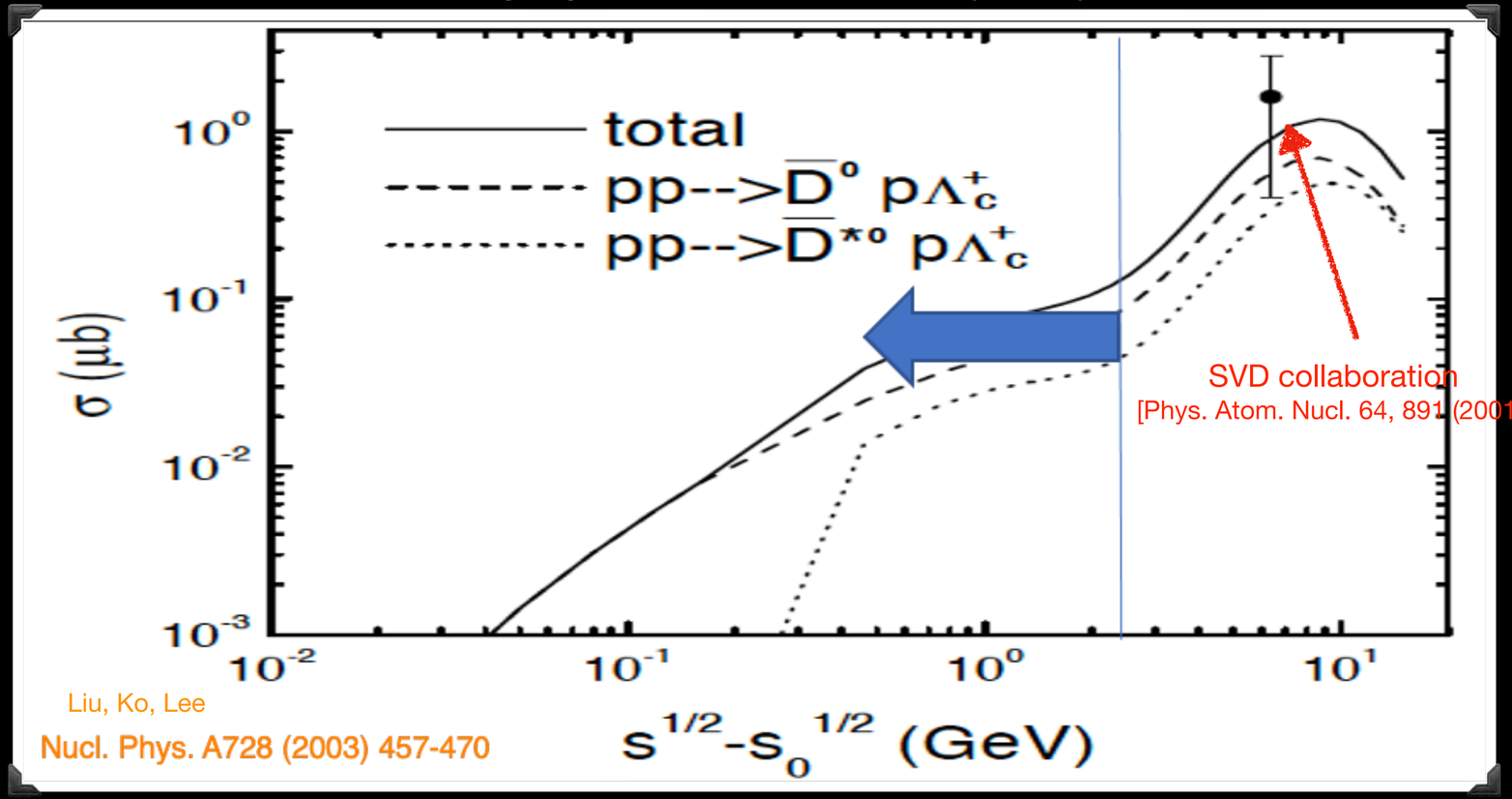
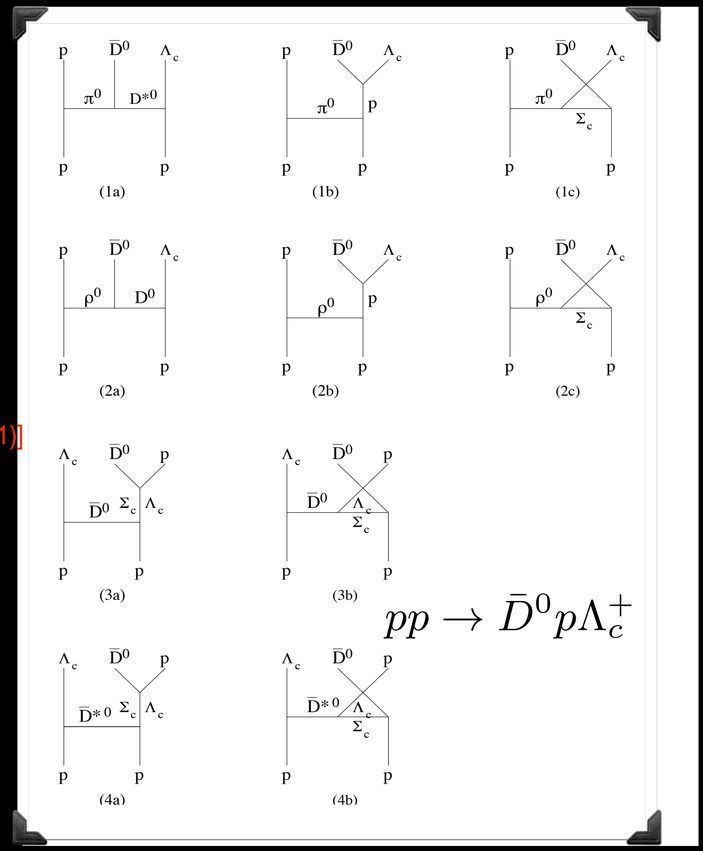
Hadronic model with interaction Lagrangian based on SU(4) flavour symmetry



SVD collaboration
[Phys. Atom. Nucl. 64, 891 (2001)]

Liu, Ko, Lee
Nucl. Phys. A728 (2003) 457-470



$pp \to \bar{D}^0 p \Lambda_c^+$

Hadron Physics aspects with p100

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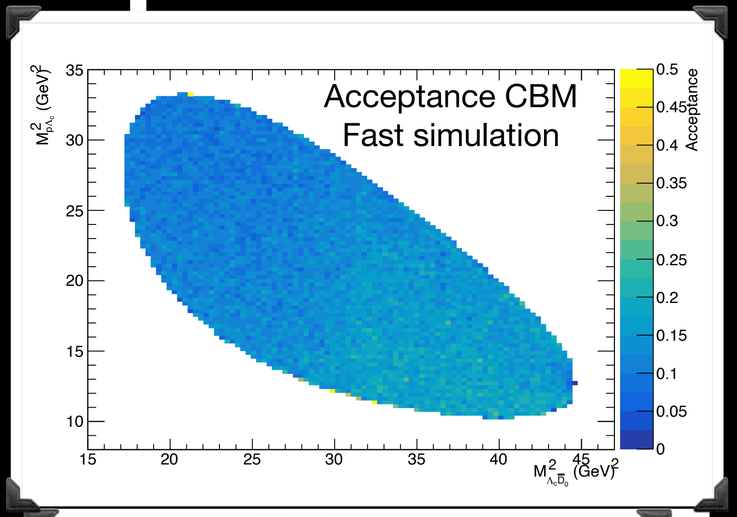

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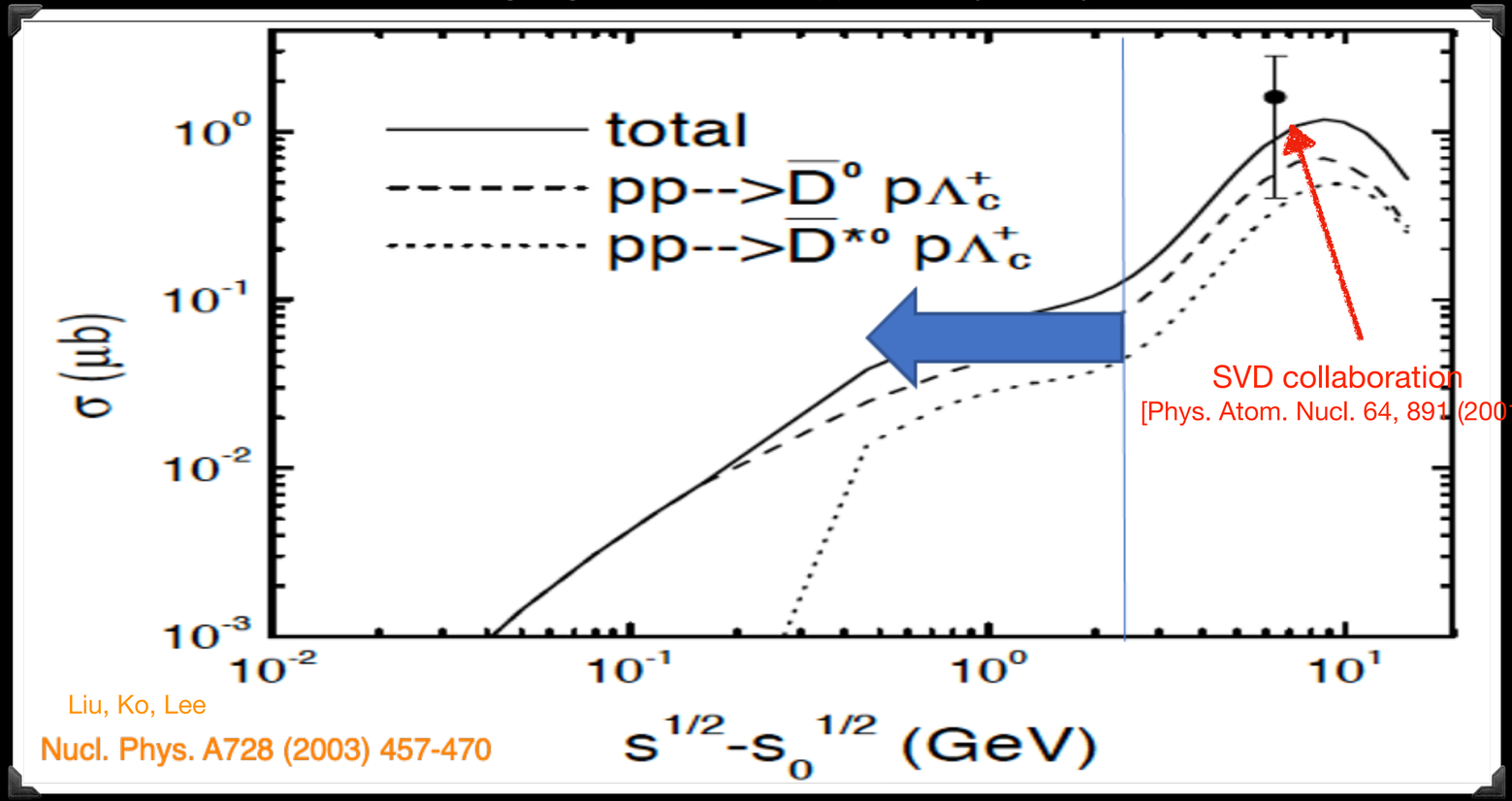

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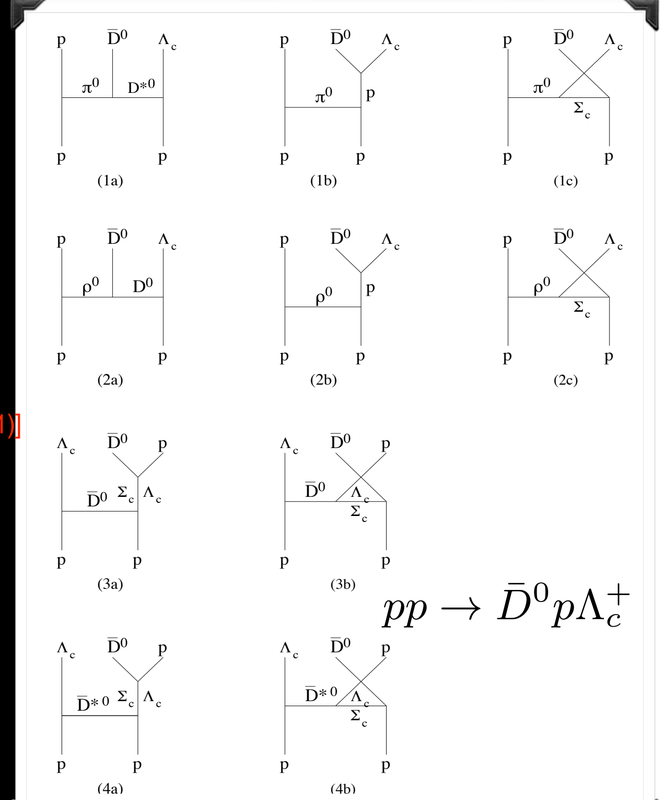

Hadron Physics aspects with p100

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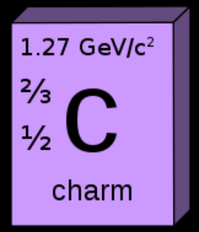

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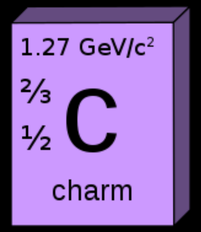

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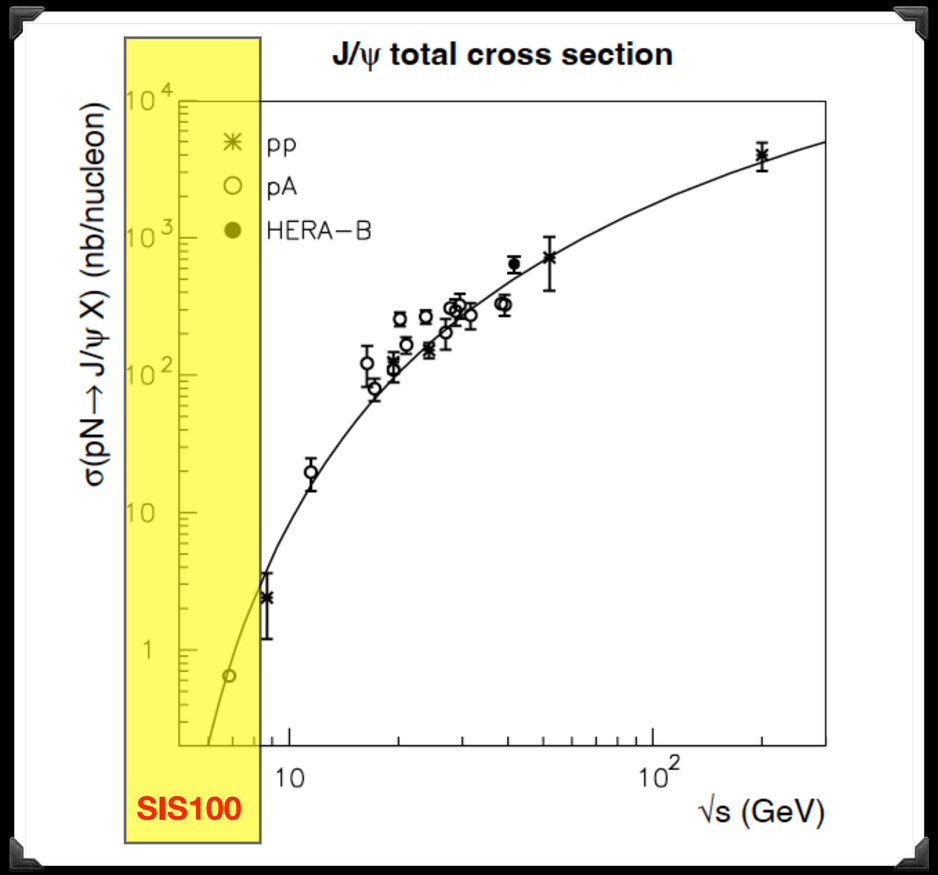

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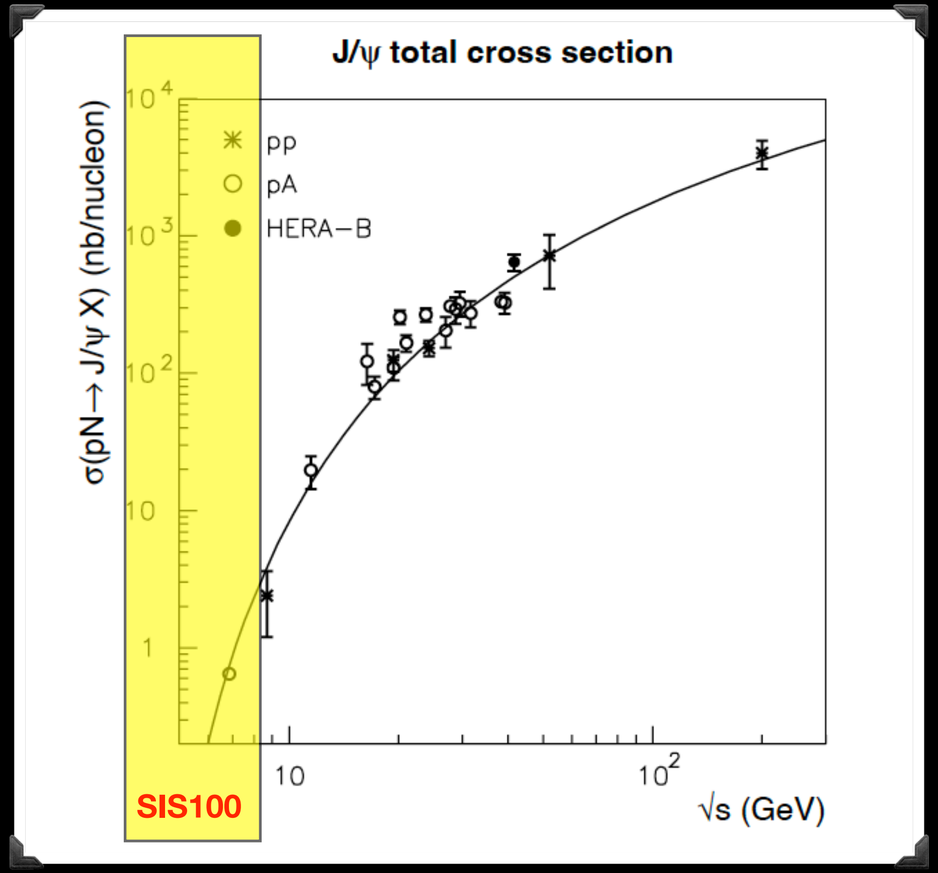
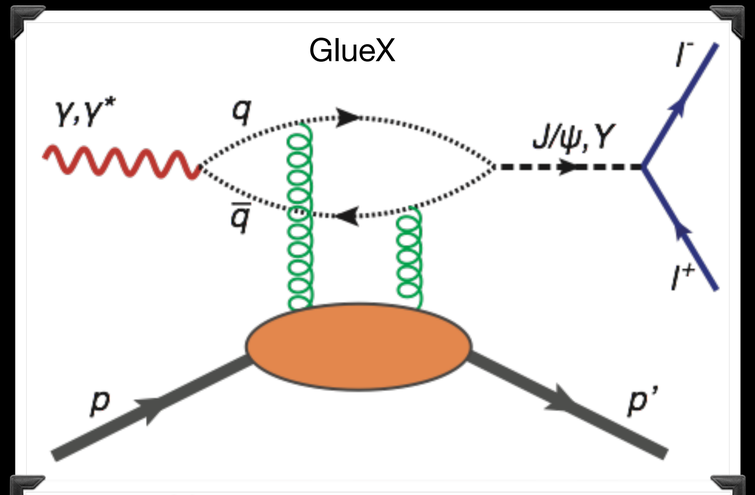
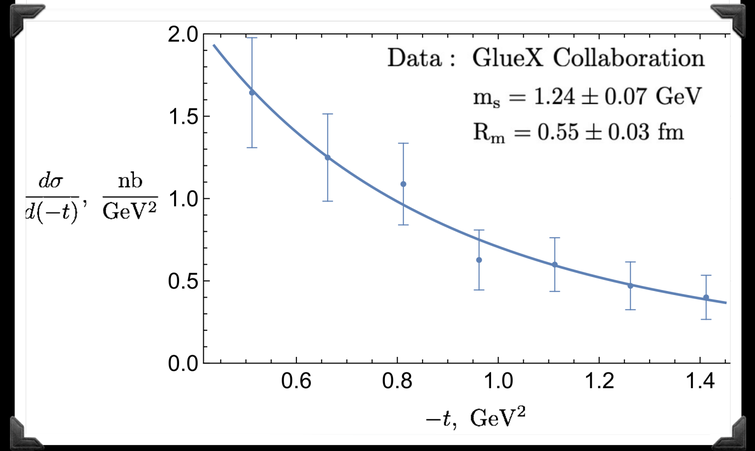






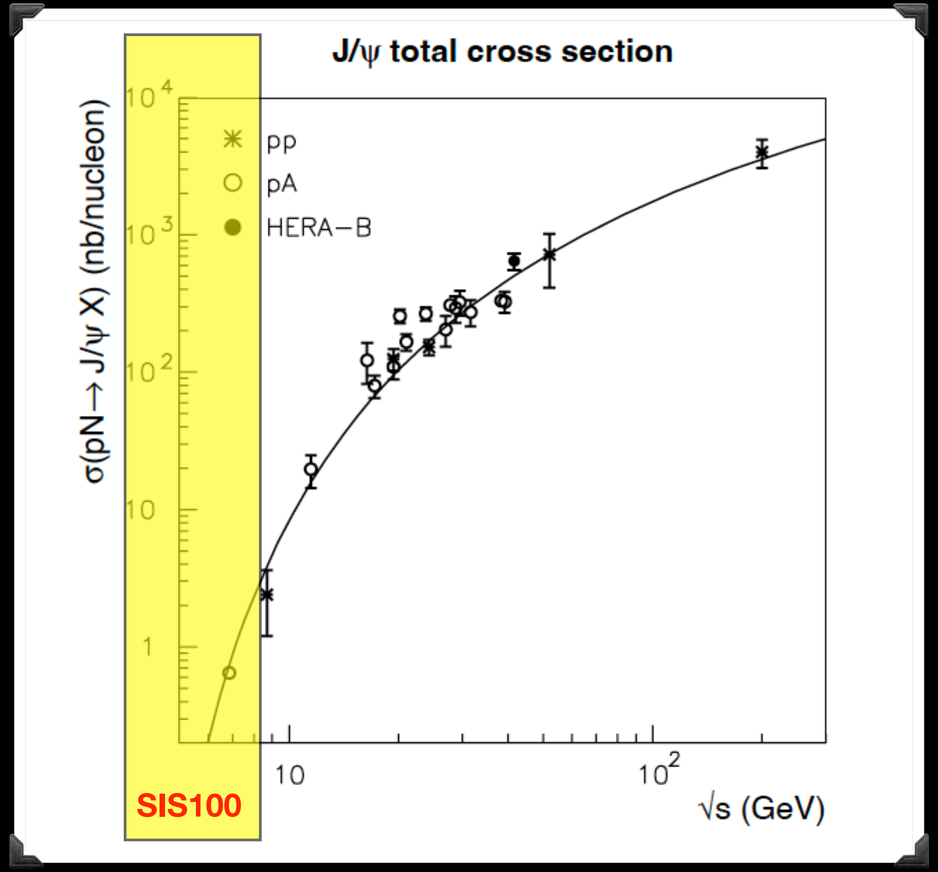
Hadron Physics aspects with p100

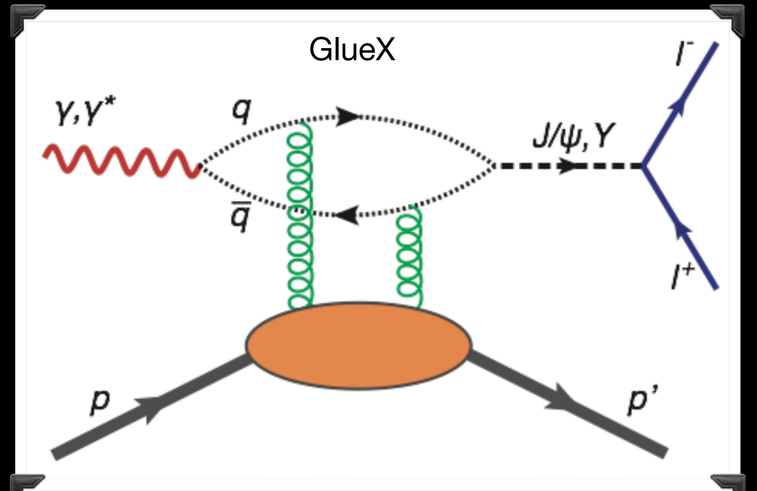
… incomplete shopping list!

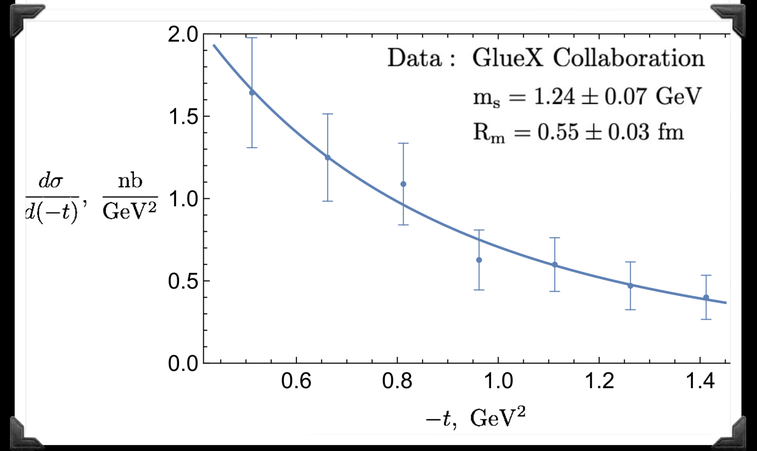
1.27 GeV/c²
⅔
½ C
charm

Charm physics

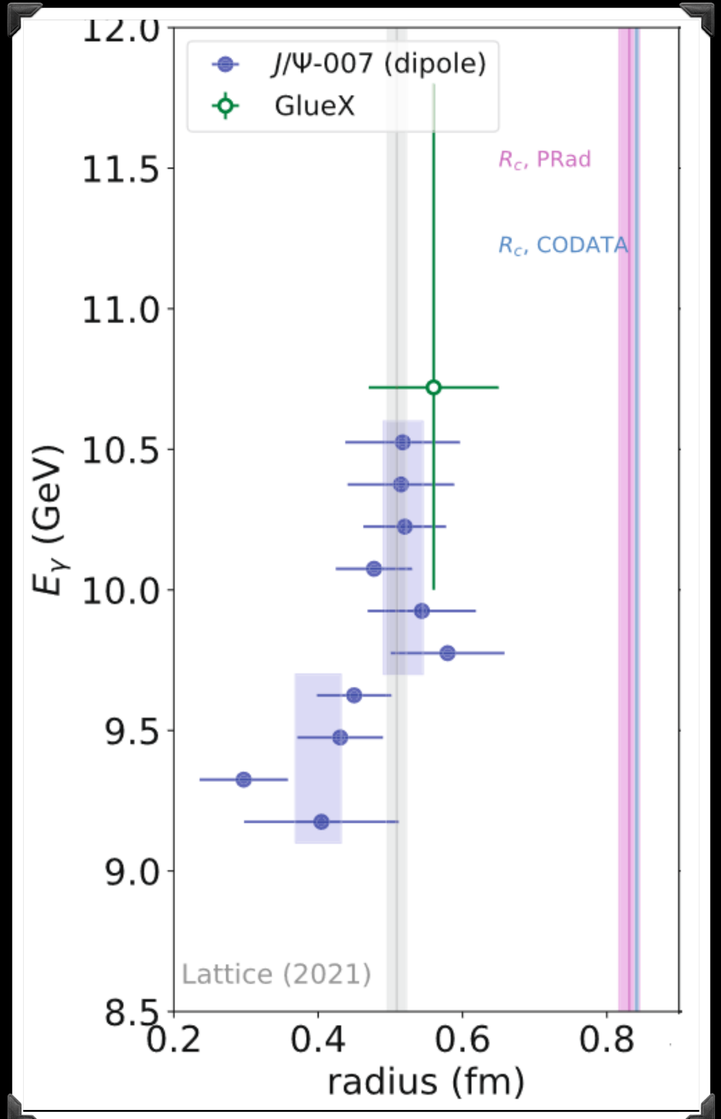
- Charm-N interactions: SU(4) dynamics!
- Intrinsic charm component of the nucleon
- Mass structure of the proton







Duran et al., Nature 615, 813 (2023),
"Determining the gluon gravitational form factor of the proton"



Physics opportunities with proton beams at SIS100

… the workshop program

9:00 AM → 9:25 AM **Welcome and introduction** — 25m

Speaker: Johan Messchendorp (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

ppWorkshop_introd…

9:25 AM → 9:50 AM **The emergence of nucleon mass** — 25m

Speaker: Craig Roberts

9:50 AM → 10:15 AM **Loose thoughts on possible proton-proton collisions program with SIS100** — 25m

Speaker: Antoni Szczurek

10:15 AM → 10:30 AM **Break** — 15m

10:30 AM → 10:50 AM **Open charm production at low energies** — 20m

Speaker: Rafal Maciula

10:50 AM → 11:10 AM **Searching for f_1(1285) in proton-proton collisions** — 20m

Speakers: Piotr Lebiedowicz (Henryk Niewodniczanski Institute of Nuclear Physics (IFJ)(IFJ)) , Piotr Lebiedowicz

11:10 AM → 12:00 PM **Discussion**

12:00 PM → 1:30 PM **Lunch** — 1h 30m

Physics opportunities with proton beams at SIS100

… the workshop program

1:30 PM	→ 1:55 PM	**Electroweak probes and the structure of hyperons**	25m
1:55 PM	→ 2:20 PM	**Baryon spectroscopy** **Speaker**: Volker Crede (Florida State University)	25m
2:20 PM	→ 2:45 PM	**Baryons, chiral dynamics, and coupled channels** **Speaker**: Matthias F.M. Lutz (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))	25m
2:45 PM	→ 3:00 PM	**Break**	15m
3:00 PM	→ 3:25 PM	**femtoscopy with hyperons and charmed mesons** **Speaker**: Laura Fabbietti (TUM)	25m
3:25 PM	→ 4:00 PM	**p+p reactions as input to our understanding of heavy-ion dynamics** **Speakers**: Nu Xu (Central China Normal University(CCNU)) , Prof. Piotr Salabura (Jagiellonian University) , Tetyana Galatyuk (TU Darmstadt / GSI)	35m
4:00 PM	→ 4:30 PM	**Discussion**	
4:30 PM	→ 4:45 PM	**Break**	15m

Physics opportunities with proton beams at SIS100

… the workshop program

4:45 PM	→ 5:10 PM	**Strange hadron spectroscopy at KL facility** **Speaker**: Mikhail Bashkanov (Uni York)	25m
5:10 PM	→ 5:35 PM	**Strangeness physics at JPARC** **Speaker**: Hiroyuki Noumi (Research Center for Nuclear Physics, Osaka University)	25m
5:35 PM	→ 6:35 PM	**Discussion**	
6:35 PM	→ 6:50 PM	**Closing** **Speaker**: Johan Messchendorp (GSI Helmholtzzentrum für Schwerionenforschung GmbH)	15m
7:00 PM	→ 10:00 PM	**Dinner**	3h

Physics opportunities with proton beams at SIS100

… the workshop program

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7:00 PM	→ 10:00 PM	**Dinner**	3h