Future Directions

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Recap and Strategy

In the previous two talks, Christoph Blume and Che-ming Ko have laid out the experimental and theoretical status and listed ***Open Questions***

The ***Open Questions*** fall is four broad categories:

1. The energy dependence of strangeness production
2. The system size dependence of strangeness production
3. Strange hadron cross-sections and potentials
4. Hyperon interactions and Hyper-nuclei

I will overview how the upcoming experimental programs will address the questions

We should note, that there are other important *Open Questions* that we felt were addressed in other sessions in the Conference:

- Global Hyperon vorticity (*Thursday 14:00-15:30*)
- Hadron resonances (*Friday 09:00-10:30 and 16:05-17:55*)

Outline

- New Facilities or Upgrades to Existing Facilities

  Also see session Sat 11:00 -12:55

- New Detectors or Upgrades to Existing Detectors

  Also see sessions Fri 11:00 -12:05 and 16:05 -17:25

- Future Opportunities to address Open Questions about:

  1. Energy Dependence

     Also see session Thu 09:00 – 12:30

  2. System size dependence

     Also see sessions Thu 9:00 -12:30 and Sat 09:00 -10:30

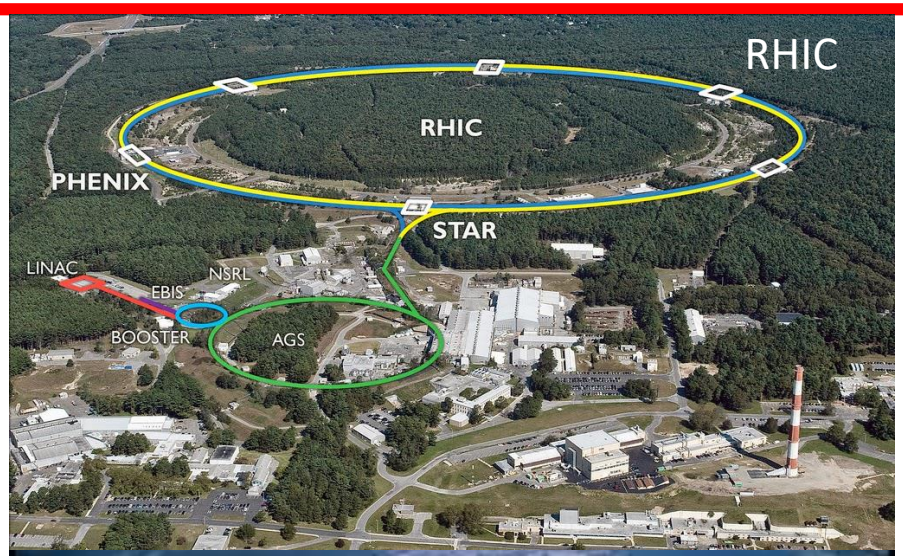
  3. Hardonic cross-sections and potentials

  4. Hyperon interactions and Hypernuclei

Facilities

Laboratory	Accelerator	Energy Range	Operational	Notes
GSI	SIS18	2.0 - 2.6 GeV	Now	Running 2.6 GeV Ag+Ag
GSI	SIS100	2.7 – 4.9 GeV	2022	Under Construction
GSI	SIS300	4.9 – 8.2 GeV	2025	Planned Upgrade
CERN	SPS	5.1 – 17.3 GeV	Now	
CERN	**LHC**	**2.76 – 5.0 TeV**	**Now**	Long Shutdown 2 coming up
CERN	LHC-AFTER	115 GeV	TBD	Under Consideration
BNL	**RHIC**	**7.7 – 200 GeV**	**Now**	Installing Electron Cooling
BNL	RHIC-FXT	3.0 – 7.7 GeV	2018	Approved Program
Dubna	**NICA**	**2.7 – 11 GeV**	**2020**	Under Construction
Dubna	Nuclotron	2.0 – 3.5 GeV	2018	Installing HI source
J-PARC	J-PARC-HI	2.0 – 6.2 GeV	2025	Install HI source and booster

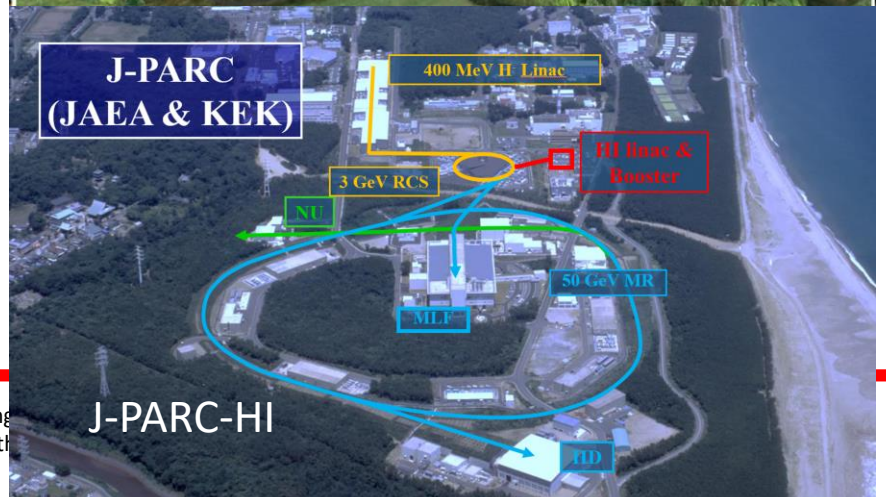
Facilities


RHIC
RHIC
PHENIX
STAR
LINAC
EBIS
NSRL
BOOSTER
AGS


LHC
SPS


MPD
SPD
NICA


SIS100/300


J-PARC
(JAEA & KEK)
400 MeV H- Linac
HI linac &
Booster
3 GeV RCS
NU
50 GeV MR
MLF
HD
J-PARC-HI

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR

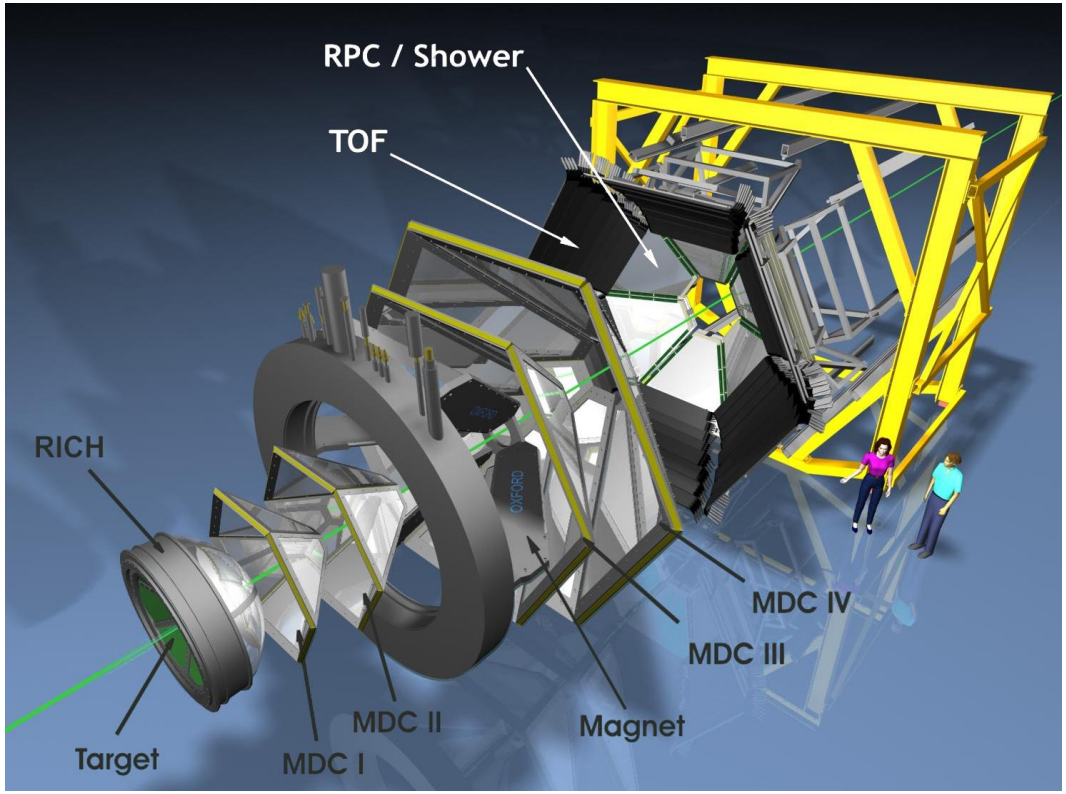
CERN-SPS: NA61

CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

J-PARC-HI: JHITS



Will take 2.6 GeV Ag+Ag as part of FAIR-0

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR

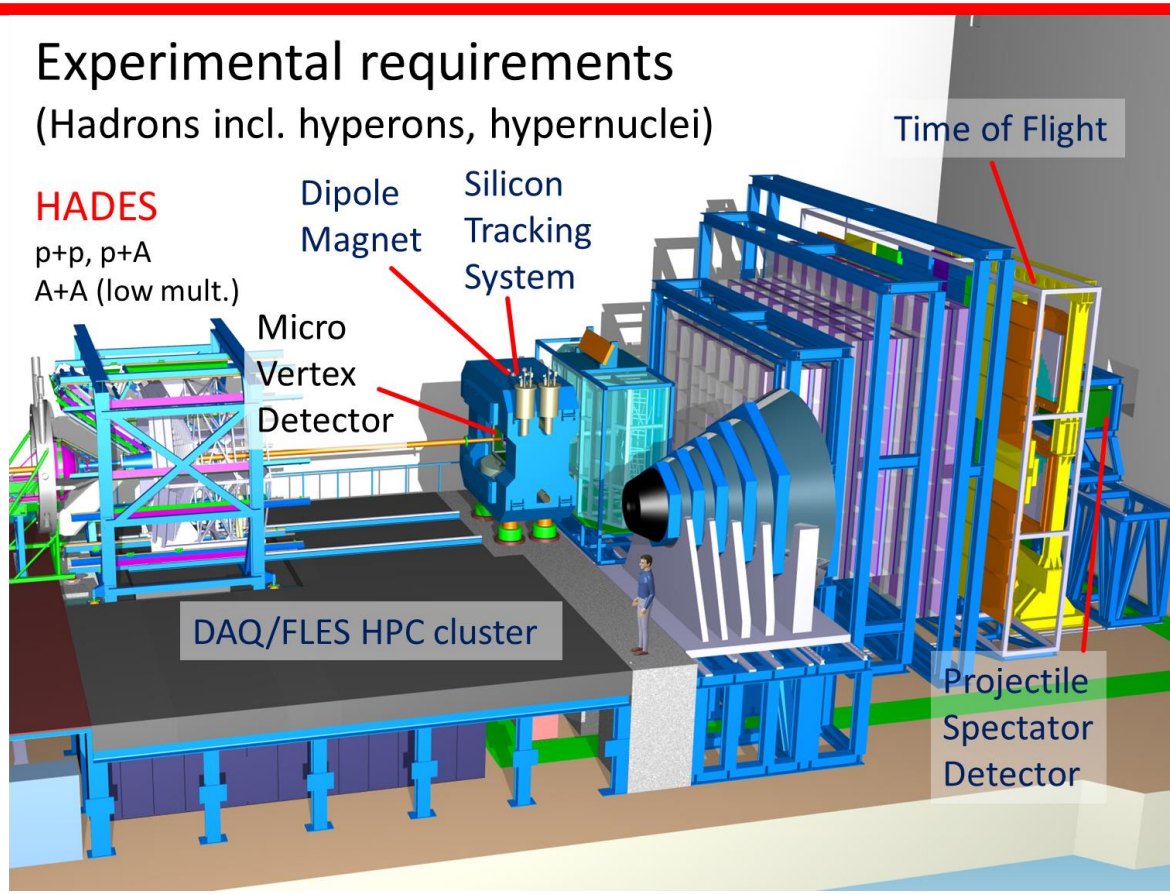
CERN-SPS: NA61

CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

J-PARC-HI: JHITS



FAIR Phase-0:

- HADES
- STAR-eTOF
- BM@N-Silicon

FAIR Phase-1: CBM
First data runs 2022

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

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CERN-SPS: NA61

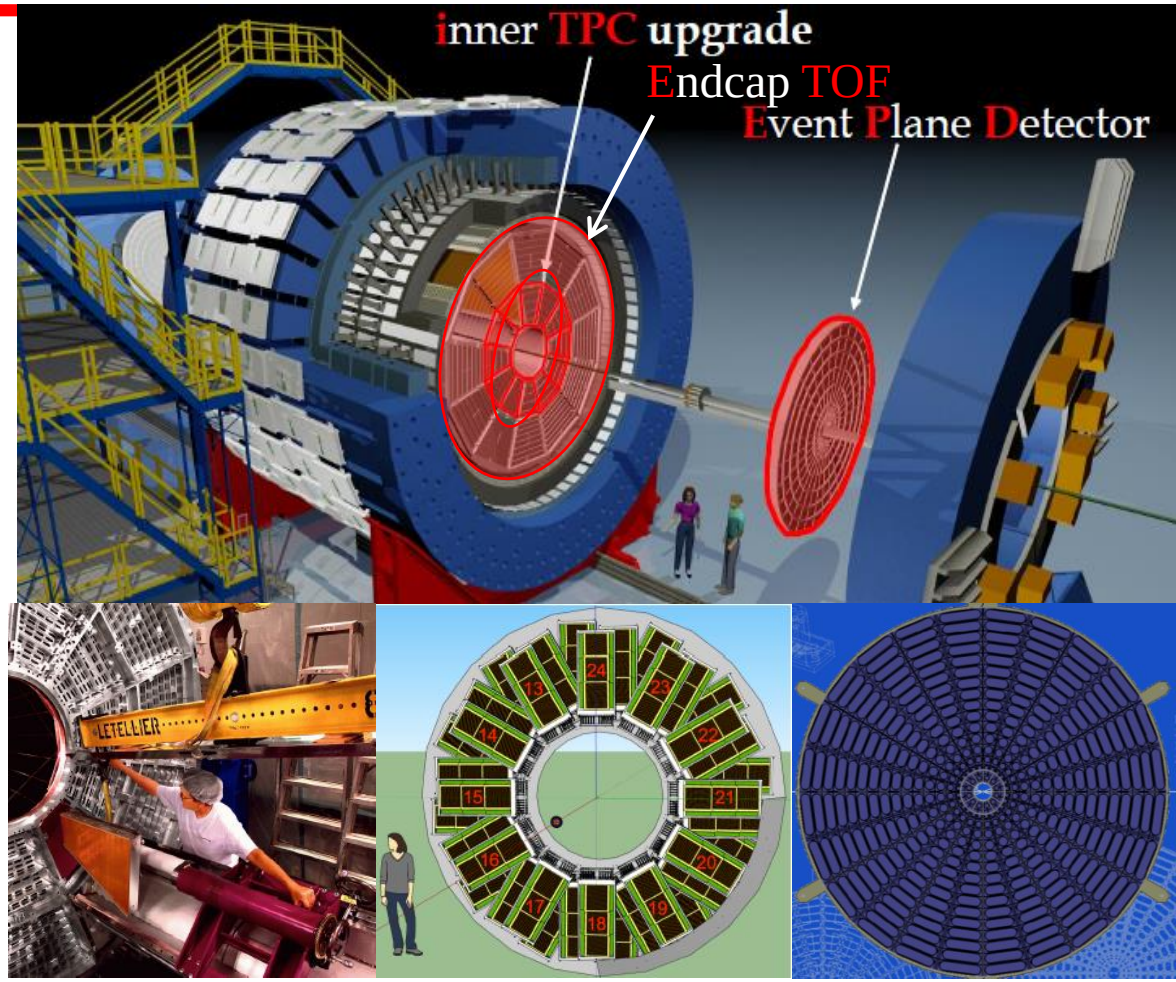
CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

J-PARC-HI: JHITS

PHENIX has ended operations
sPHENIX optimized for jets



Upgrade to TPC, new end-cap TOF, new forward trigger
➔ BESII ➔ 2019 and 2020 ➔ 7.7 to 19.6 GeV

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR-FXT

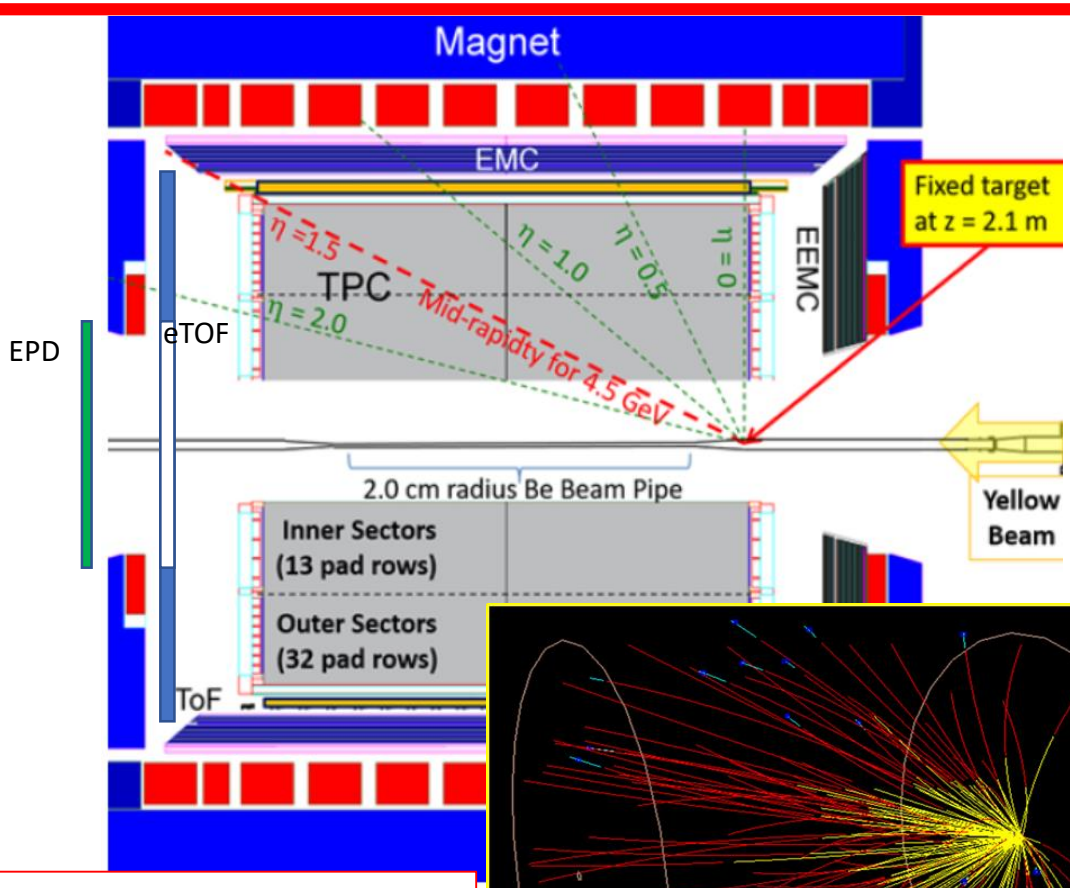
CERN-SPS: NA61

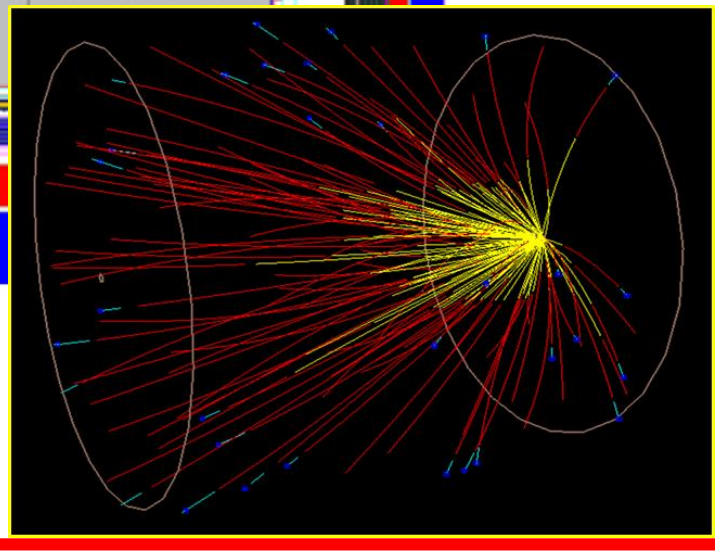
CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

J-PARC-HI: JHITS





STAR FXT – Approved last month
2018 ➔ 3.0 GeV Au+Au
2019 ➔ 3.9, 4.5, 5.2, 6.2, 7.7
2020 ➔ 3.2 and 3.5

Experiments

GSI-SIS18: HADES

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BNL-RHIC: STAR

CERN-SPS: NA61

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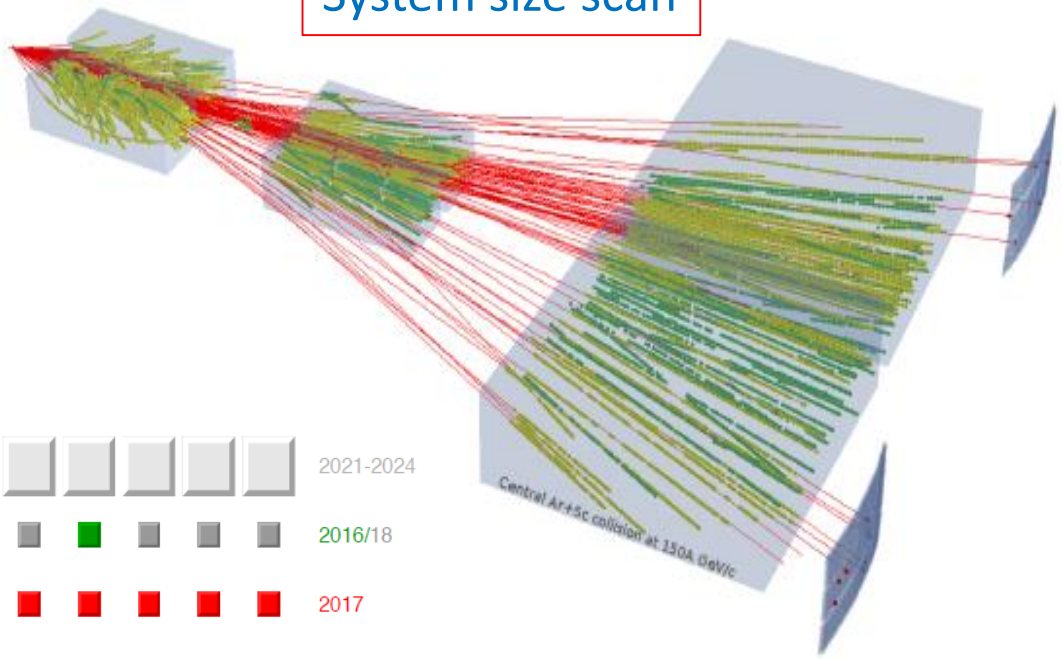
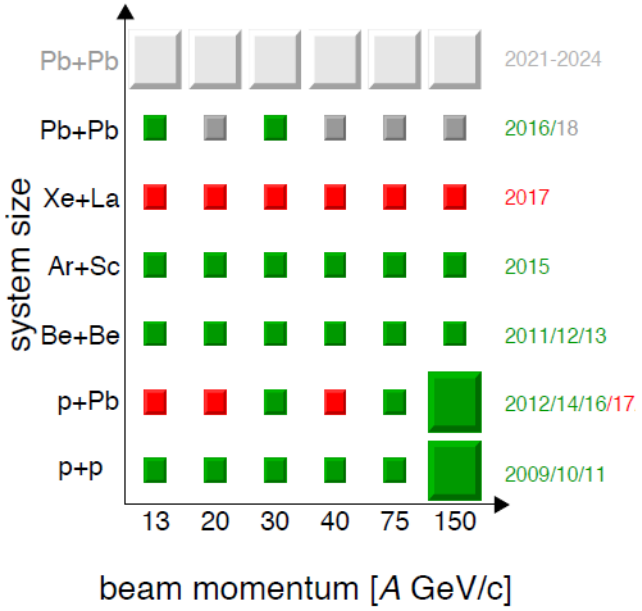
Dubna-NICA: MPD

J-PARC-HI: JHITS

System size scan





Will upgrade DAQ system to 1 kHz and redo the Pb+Pb scan with much higher statistics (2021-2014)

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR

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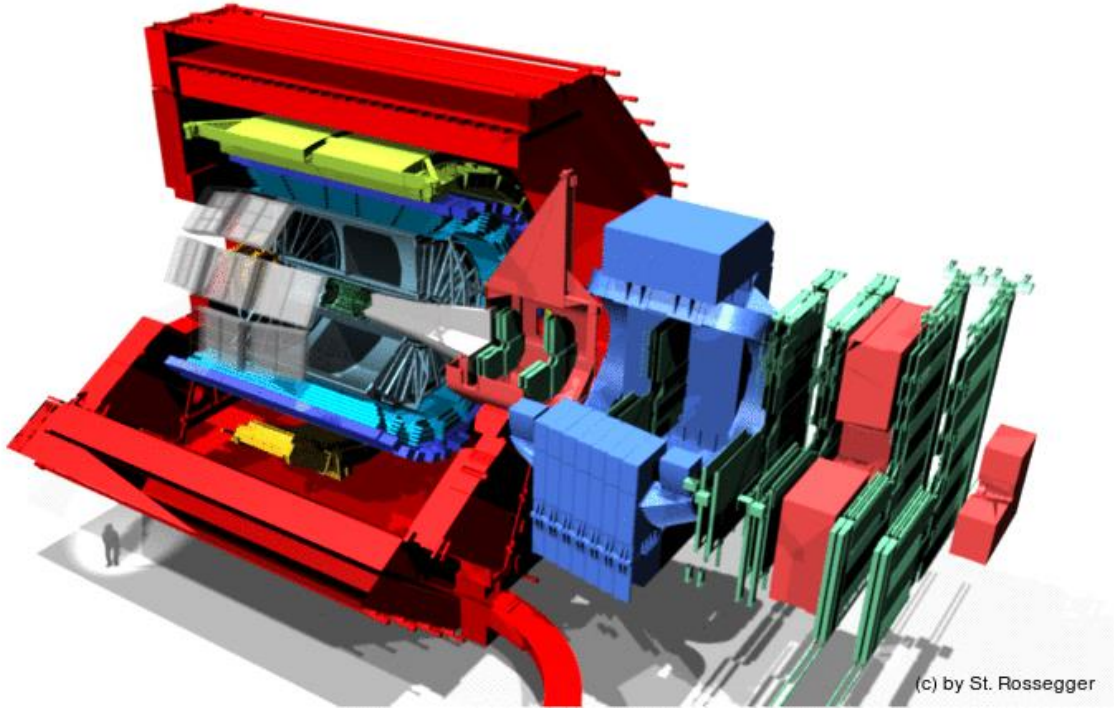
J-PARC-HI: JHITS



Long Shutdown 2 Upgrades:
TPC, Vertex, ITS

Also CMS, ATLAS, LHCb

Experiments

GSI-SIS18: HADES

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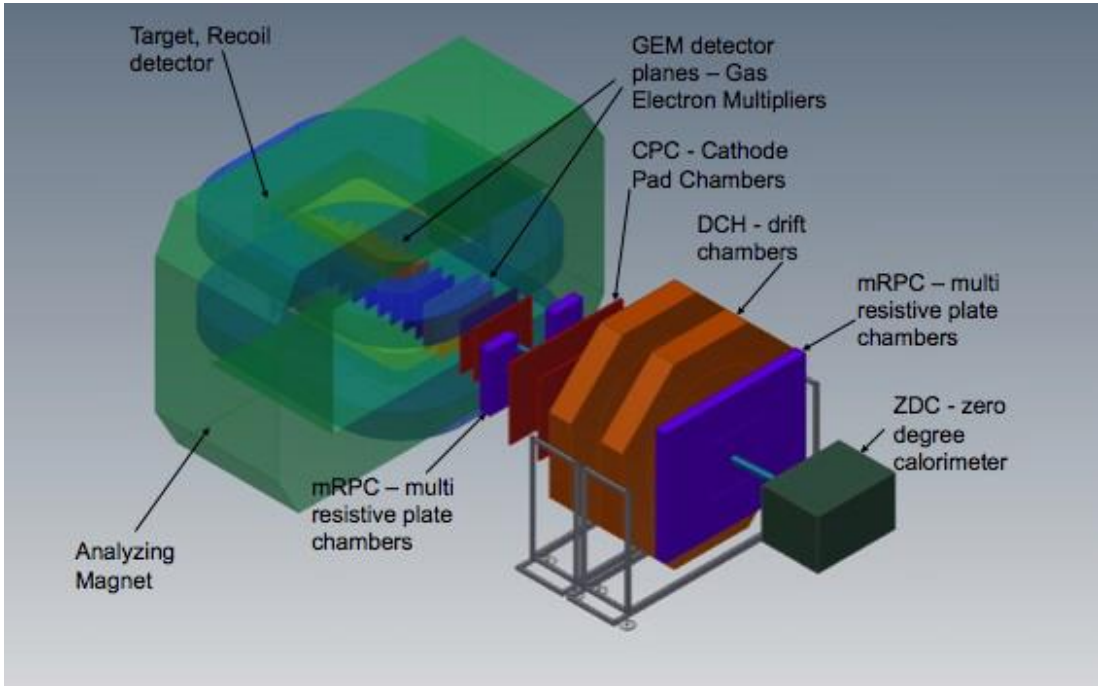


BM@N:

- Fixed-target
- $\sqrt{s_{NN}}$ 2.0 - 3.5 GeV from Nuclotron
- Interaction rates up to 50 kHz
- Measurement of hadrons
- Light ion beams 2017; heavy ion beams 2019

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR

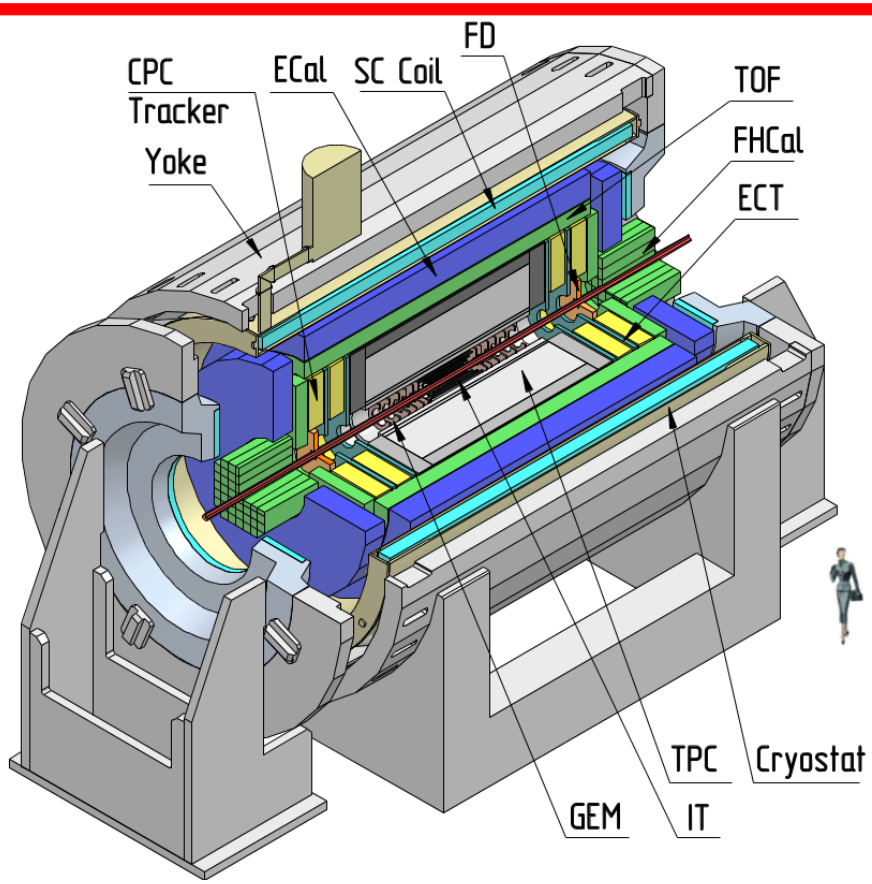
CERN-SPS: NA61

CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

J-PARC-HI: JHITS



MPD:

- Collider experiment
- $\sqrt{s_{NN}}$ = 4 – 11 GeV
- Event rate up to 7 kHz
- Hadron and lepton measurements – Vertexer, Tracking, TOF, ECal
- Time line (staged): 2019 - 2013

Experiments

GSI-SIS18: HADES

GSI-SIS100/SIS300: CBM/HADES

BNL-RHIC: STAR

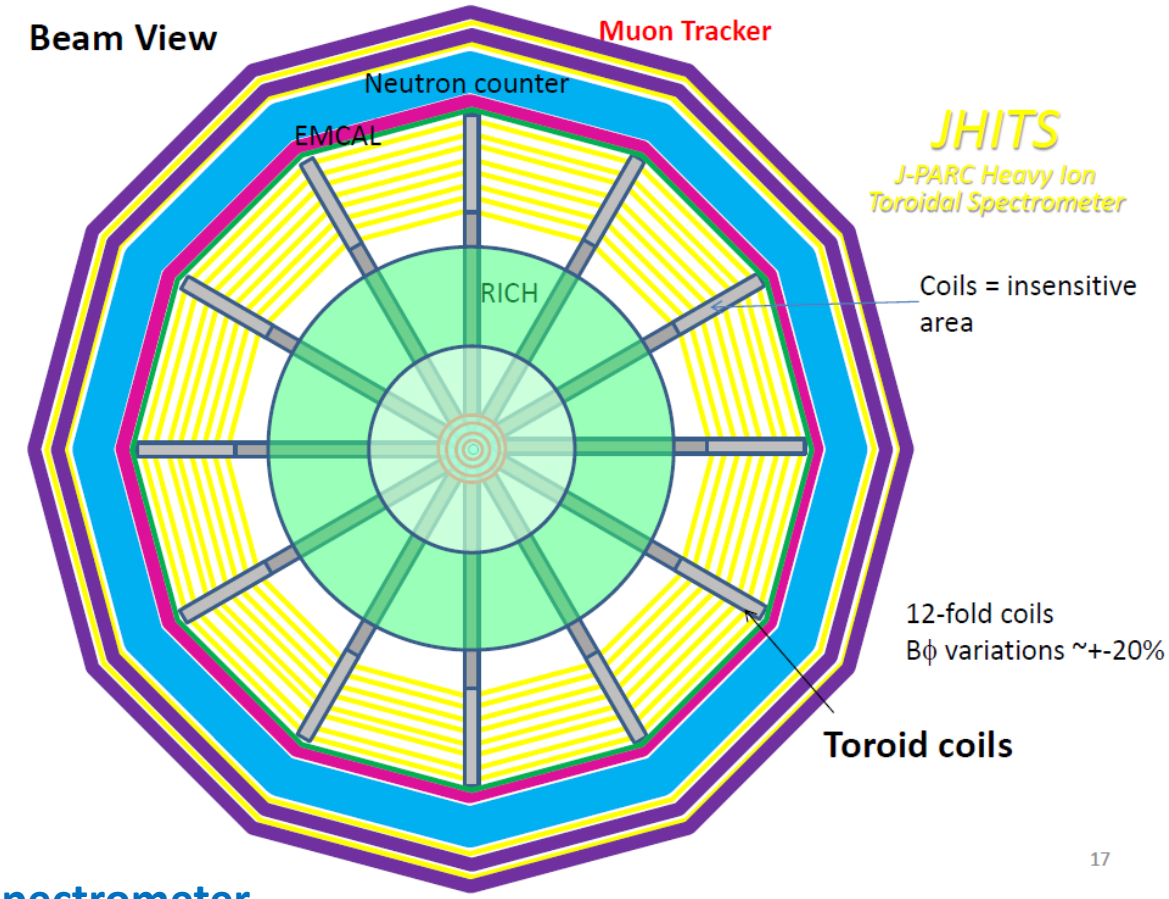
CERN-SPS: NA61

CERN-LHC: ALICE

Dubna-Nuclotron: BM@N

Dubna-NICA: MPD

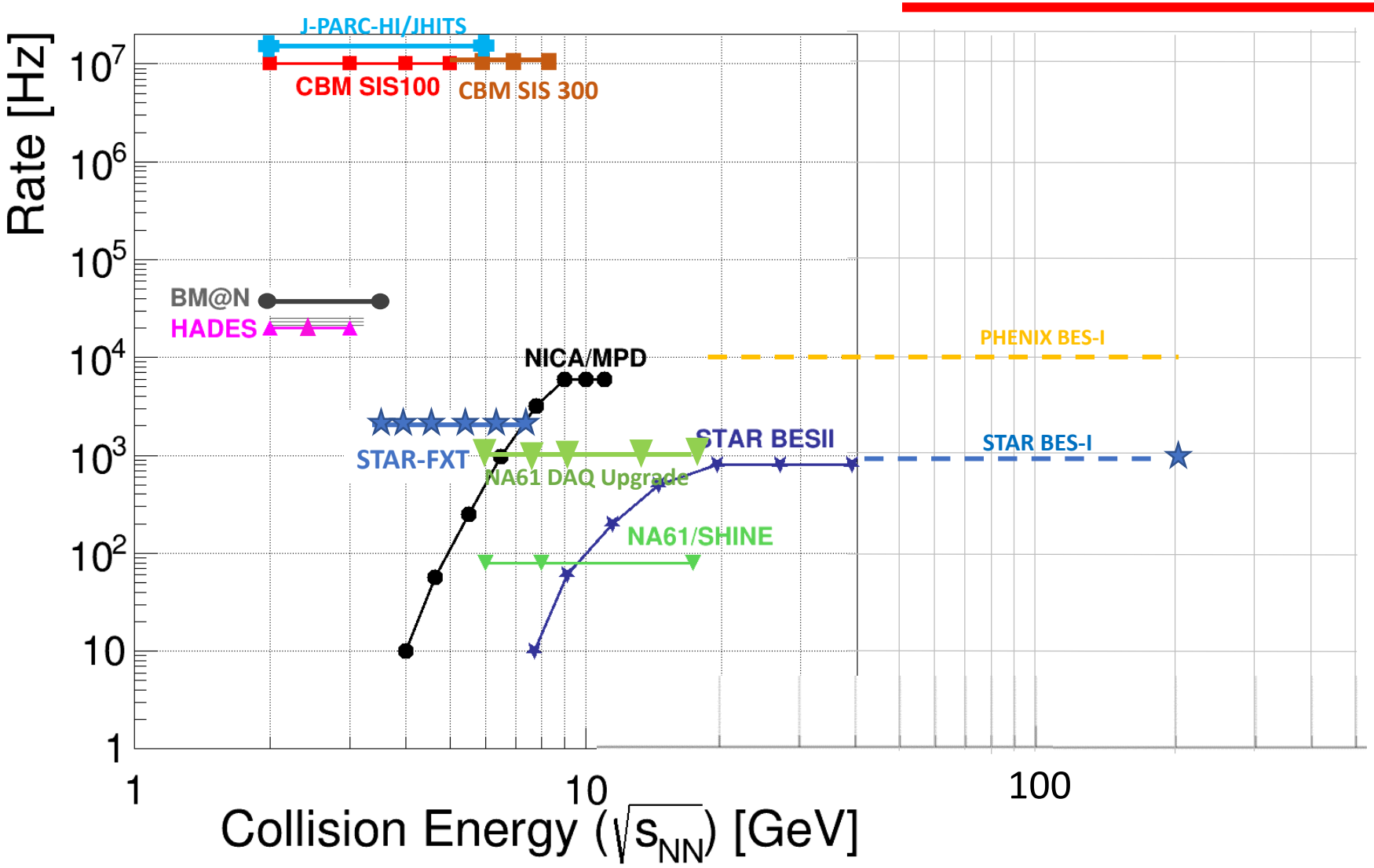
J-PARC-HI: JHITS



Toroidal Spectrometer

- Interaction rates up to 10 MHz
- Measurement of hadrons, electrons, muons and neutral probes
- Timeline roughly 2025

Experiments



Energy Dependence of Strangeness in A+A Collisions

List of ***Open Questions***:

1. What is the energy dependence of strangeness enhancement? Could there be an onset somewhere? ➔ Need p+p data, these are limited. STAR-BESII, STAR(200 GeV), ALICE, NA61

2. Interpretation of the structures in the energy dependence (e.g. is the horn in K/pi ratio due to deconfinement transition or chiral symmetry restoration?)
   ➔ Need better measures around this horn (and similar horns). NA61 high statistics, STAR-BESII, STAR-FXT, MPD

3. While the yields of cascades and anti-lambda rise in the RHIC BES range, Lambdas and cascade- do not.
   ➔ Need better lower energy measures, STAR-FXT and MPD will measure lambda and cascade, CBM and JHITS are needed for anti-lambda

4. Need to compare rapidity densities (distributions) at low (SPS and below) and high (RHIC and LHC) energies?
   ➔ STAR-BES II will measure rapidity density. STAR-FXT and MPD will get measurements in the AGS range. LHCb could help for the higher energies

Strangeness Production in Small Systems (p+p and p+A)

List of ***Open Questions***:

1. Does $dN_{ch}/d\eta$ provide an universal scaling for system size dependencies (pp → pA → AA)?
   ➔ Need this analysis done one the existing data of STAR (200 GeV), and of NA61. Need p+p and p+A data.

2. Does the multiplicity dependence match the transition from canonical to grand-canonical ensemble at all energies ?
   ➔ Need theoretical comparisons to quality data from STAR, NA61, MPD

3. Is the core corona correction necessary for particle yields?
   ➔ Need to compare to the p+p, p+A, and centrality dependent A+A data from STAR-BES, NA61, MPD, and CBM

4. AntiOmega/Omega ratio in p+p (from string decays)
   ➔ Need NA61 results. CBM and JHITS for lower energies if they will have a hydrogen target.

Strange Hadron Cross-Sections and Potentials

List of ***Open Questions***:

1. Do we understand kaon propagation in medium?
   ➔ need to studies of elliptic and directed flow of strange particles to lower energies ➔ STAR-FXT, MPD, CBM

2. Is there any evidence for a sequential freeze-out due to different cross section?
   ➔ Need measures of the kaon slopes at low energy. HADES, BM@N

3. Does the medium also at low energies behave macroscopically, fully described by statistical model?
   ➔ Would be good to have data from different system sizes. HADES, BM@N

4. Is the phi meson yield enhanced in the dielectron channel?
   ➔ HADES 2.6 GeV Ag+Ag run will have less background for a cleaner study.

Hyperon Interactions and Hyper-nuclei

List of ***Open Questions***:

1. What do we really know up-to-now about hyperon-hyperon interactions? What do we learn about dibaryon from HBT?
   ➔ STAR has measured $\Lambda\Lambda$ correlations at 200 GeV. Will continue these to BES-II energies. Will need the higher statistics of CBM to go to lower energies

2. What is the contribution to an understanding of large-mass neutron stars? Is there stable strange matter in neutron stars?
   ➔ This will need the development from the theory collaborations such as BEST

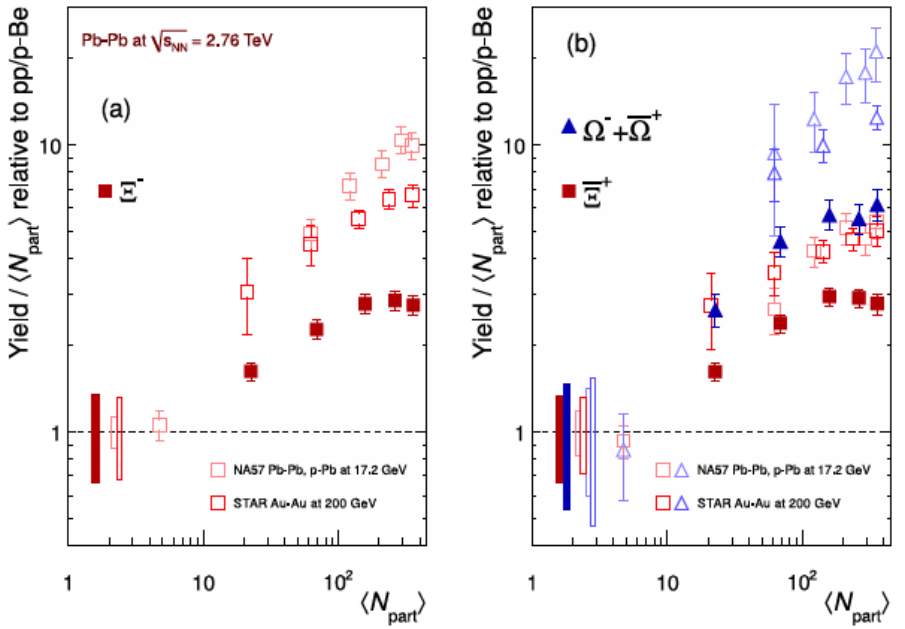
3. Why are the yields of very weakly bound objects (e.g. $^{3}_{\Lambda}$H) so well described by the statistical model ("snowball in hell")?
   ➔ Need measurements of more hypernuclei. Optimal energy is in the range of STAR-FXT, CBM, and JHITS. STAR-FXT will be able to measure hypertritons, CBM will measure the multiple strange hypernuclei

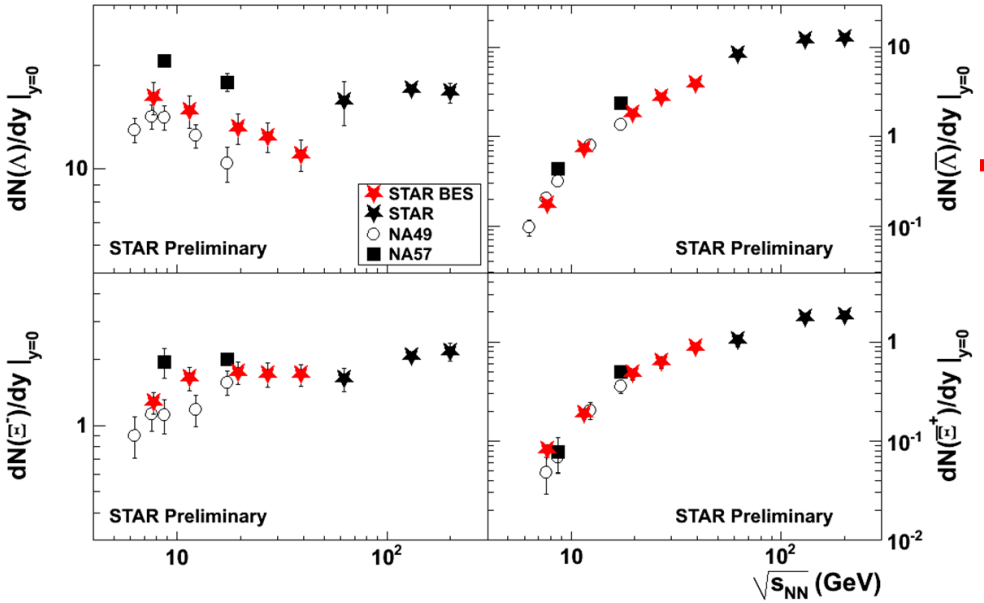
4. Are the properties of hyperons modified inside nuclei?
   ➔ Need to improve measurements of the lifetime of hypernuclei. STAR-FXT, CBM

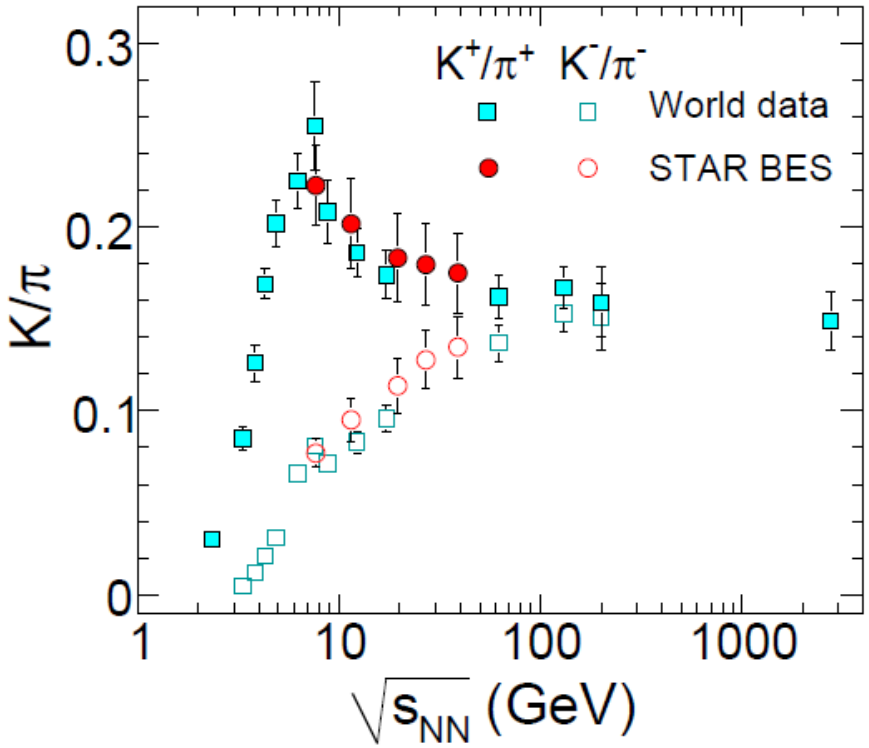
Conclusions

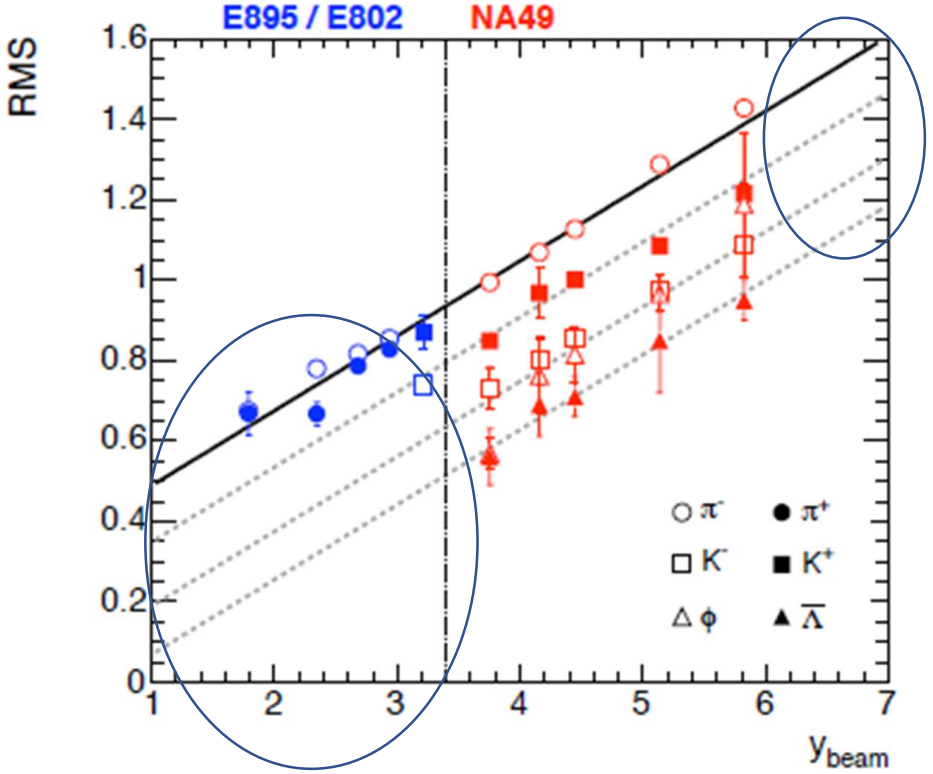
- Upgrades to accelerator facilities and to many detectors are planned
- Strangeness studies were limited in the AGS energy range ➔ New facilities will study this region. In the high energy region, collider detectors generally have limited rapidity coverage.
- For the studies of some systems p+p results are limited to colliders or facilties with a hydrogen target.
- New fixed target program at the nuclotron can help confirm and explore the remarkable subthreshold production results.
- Hyper nuclei help us understand the hyperon-hyperon interaction, which may effect exotic astrophysical objects. New facilities should be in the optimal energy range for the study of multi-strange hypernuclei.

Backup

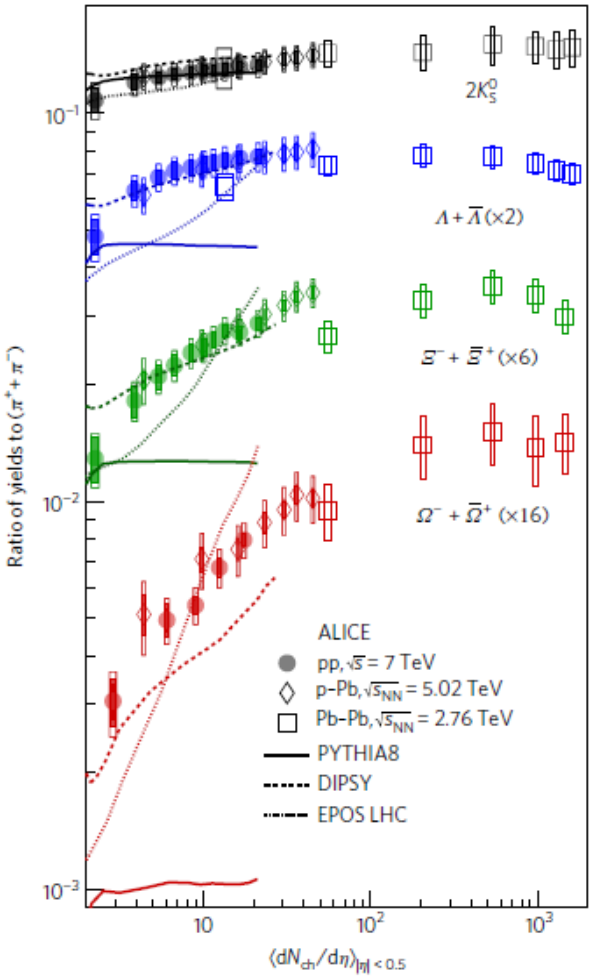

Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV
(a)
Ξ^-
Yield / $\langle N_{part} \rangle$ relative to pp/p-Be
NA57 Pb-Pb, p-Pb at 17.2 GeV
STAR Au-Au at 200 GeV
$\langle N_{part} \rangle$
(b)
$\Omega^- + \overline{\Omega}^+$
$\overline{\Xi}^+$

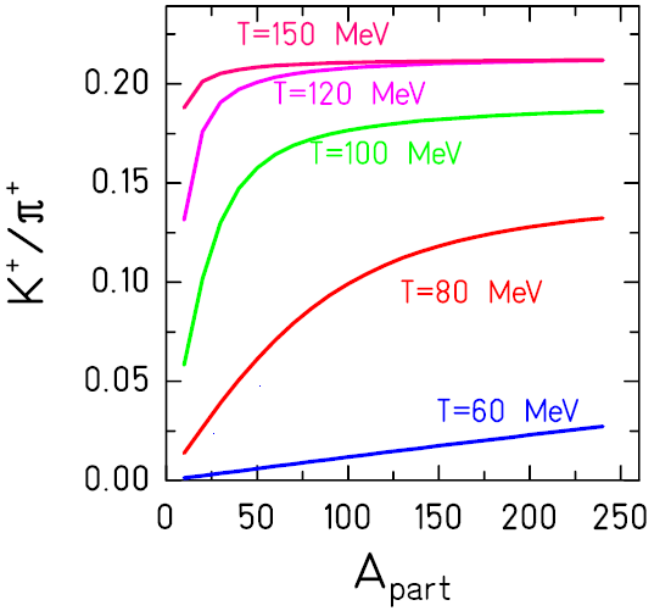

$dN(\Lambda)/dy|_{y=0}$
$dN(\overline{\Lambda})/dy|_{y=0}$
$dN(\Xi^-)/dy|_{y=0}$
$dN(\overline{\Xi}^+)/dy|_{y=0}$
STAR BES
STAR
NA49
NA57
STAR Preliminary
$\sqrt{s_{NN}}$ (GeV)

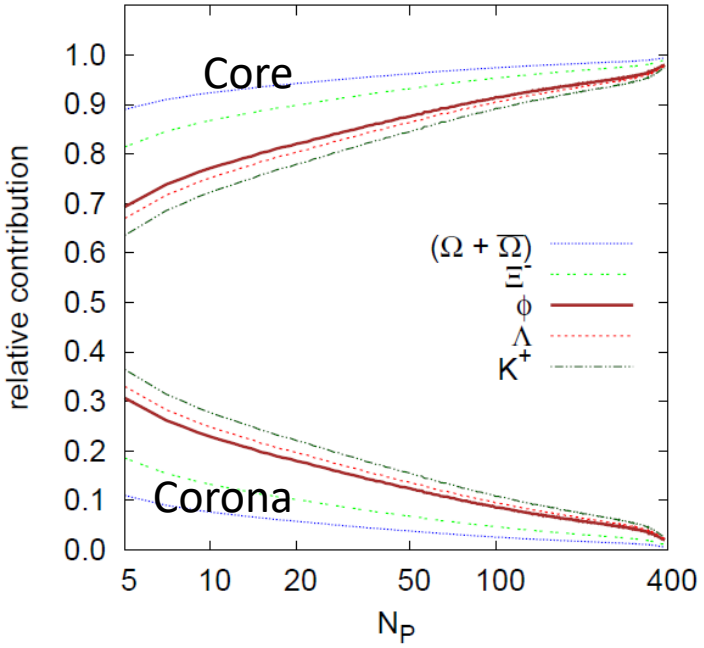

K^+/π^+ K^-/π^-
World data
STAR BES
K/π
$\sqrt{s_{NN}}$ (GeV)

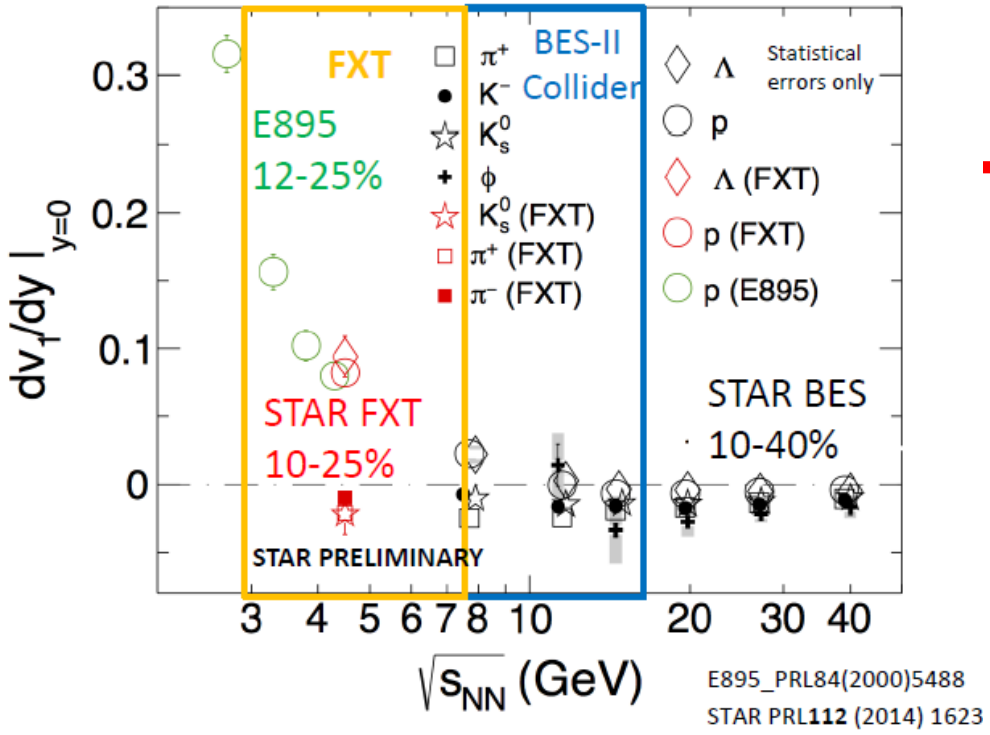

E895 / E802
NA49
RMS
π^-
π^+
K^-
K^+
ϕ
$\overline{\Lambda}$
y_{beam}

Universal Scaling









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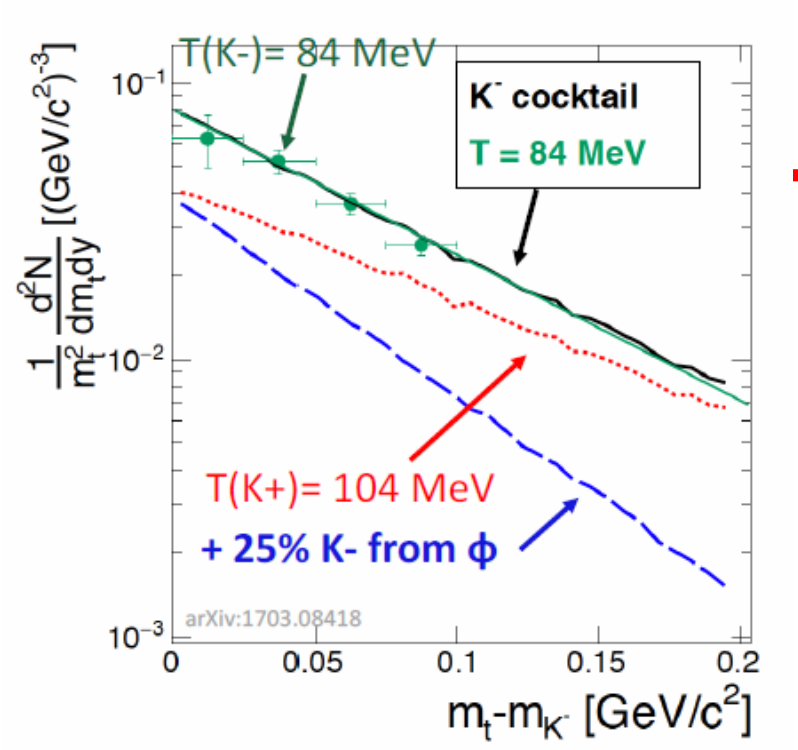
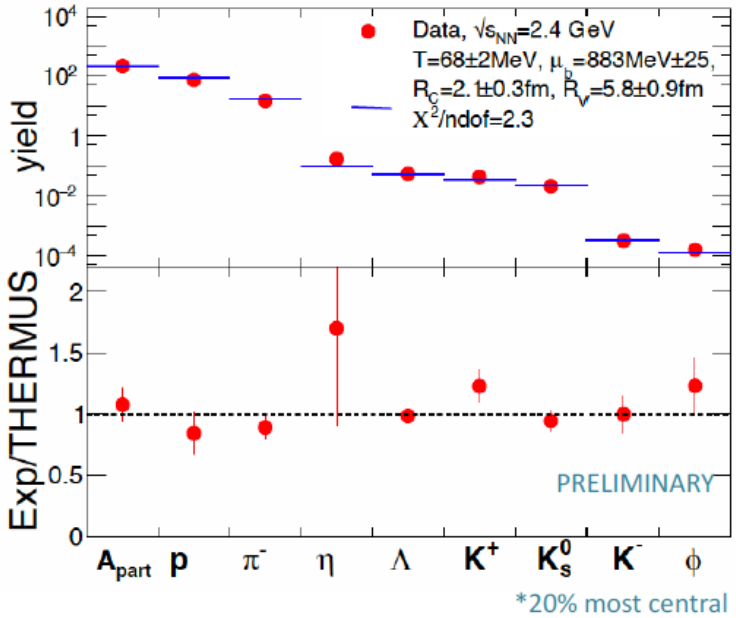
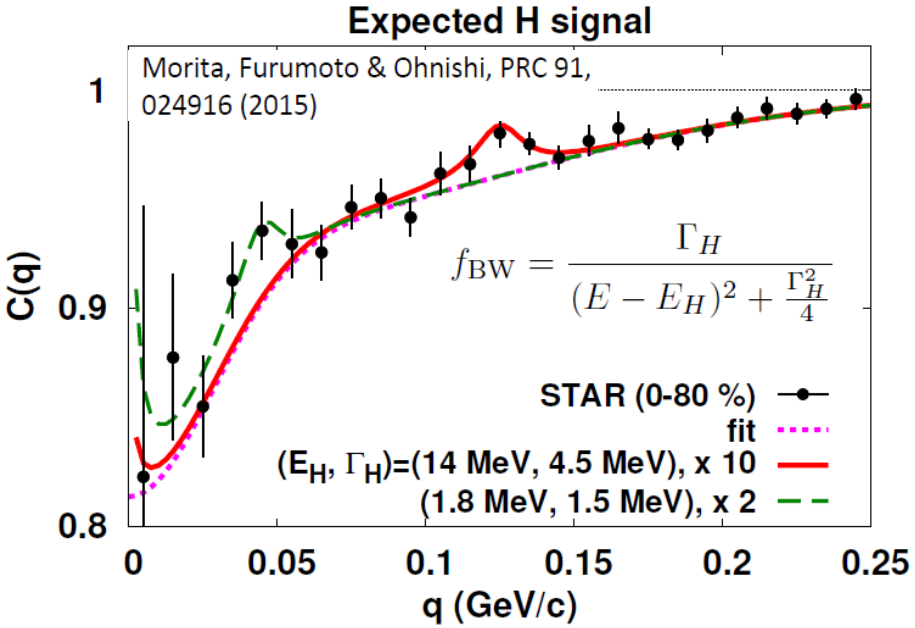
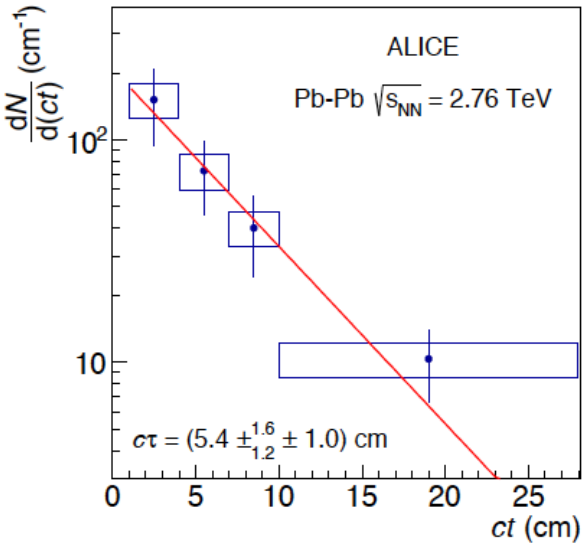




*20% most central





ALICE
PLB **754** (2016) 360