Charm and Multi-Strange Hyperons with the CBM Experiment

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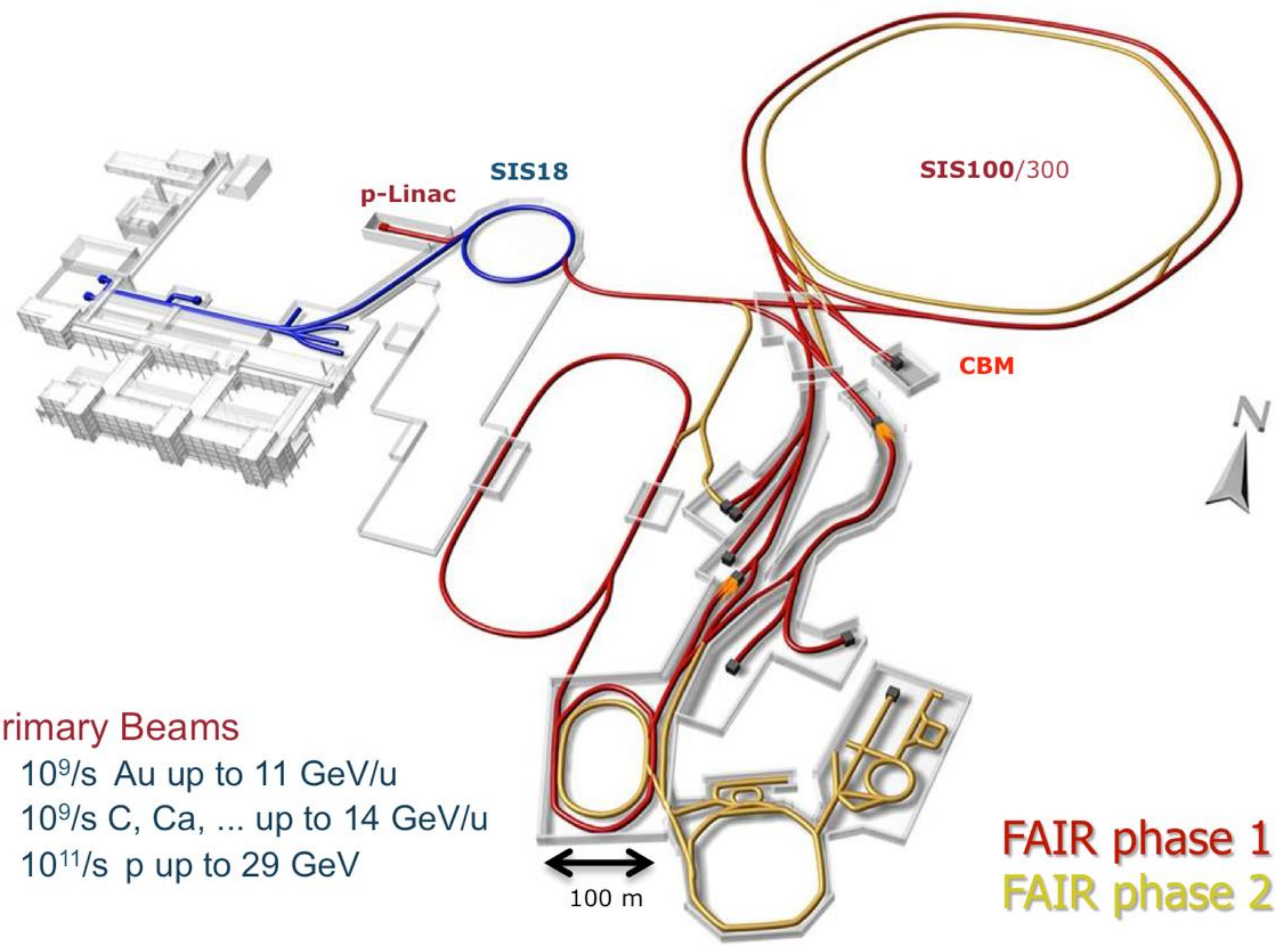
on behalf of the CBM Collaboration

Workshop “NA61 beyond 2020”, Geneva, 27 Juli 2017

FAIR Accelerator Complex



Primary 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

FAIR Accelerator Complex and CBM

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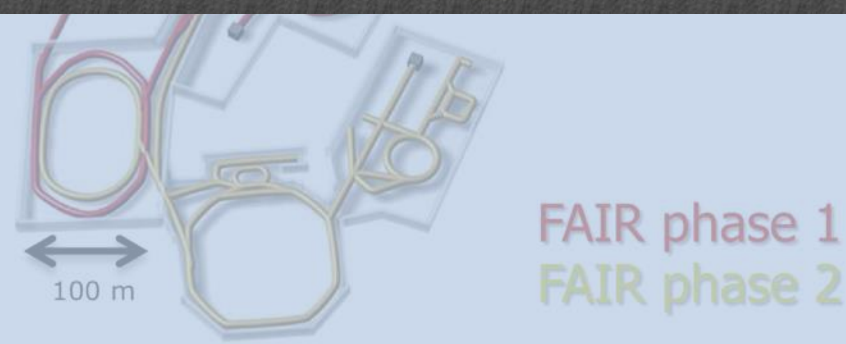
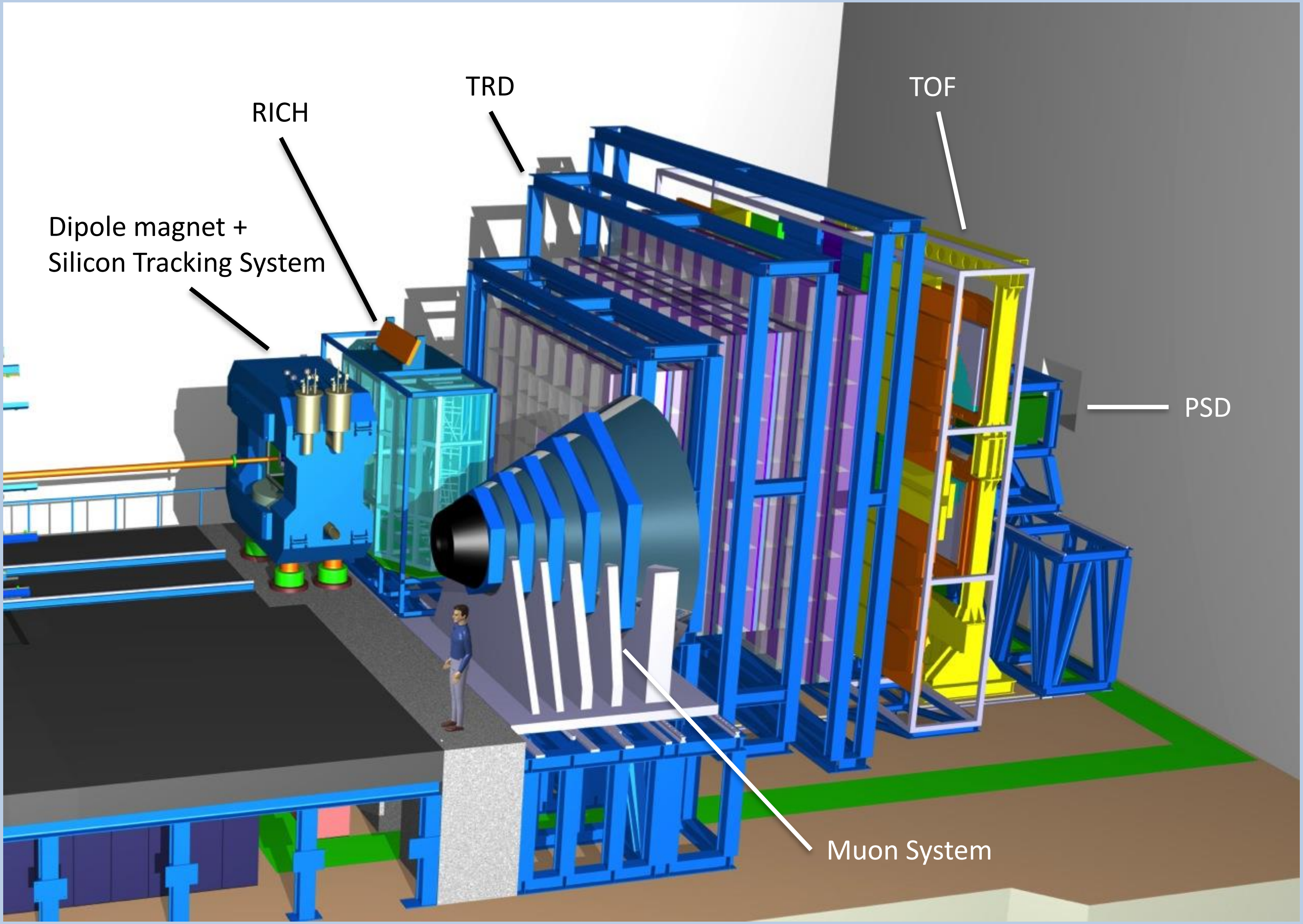
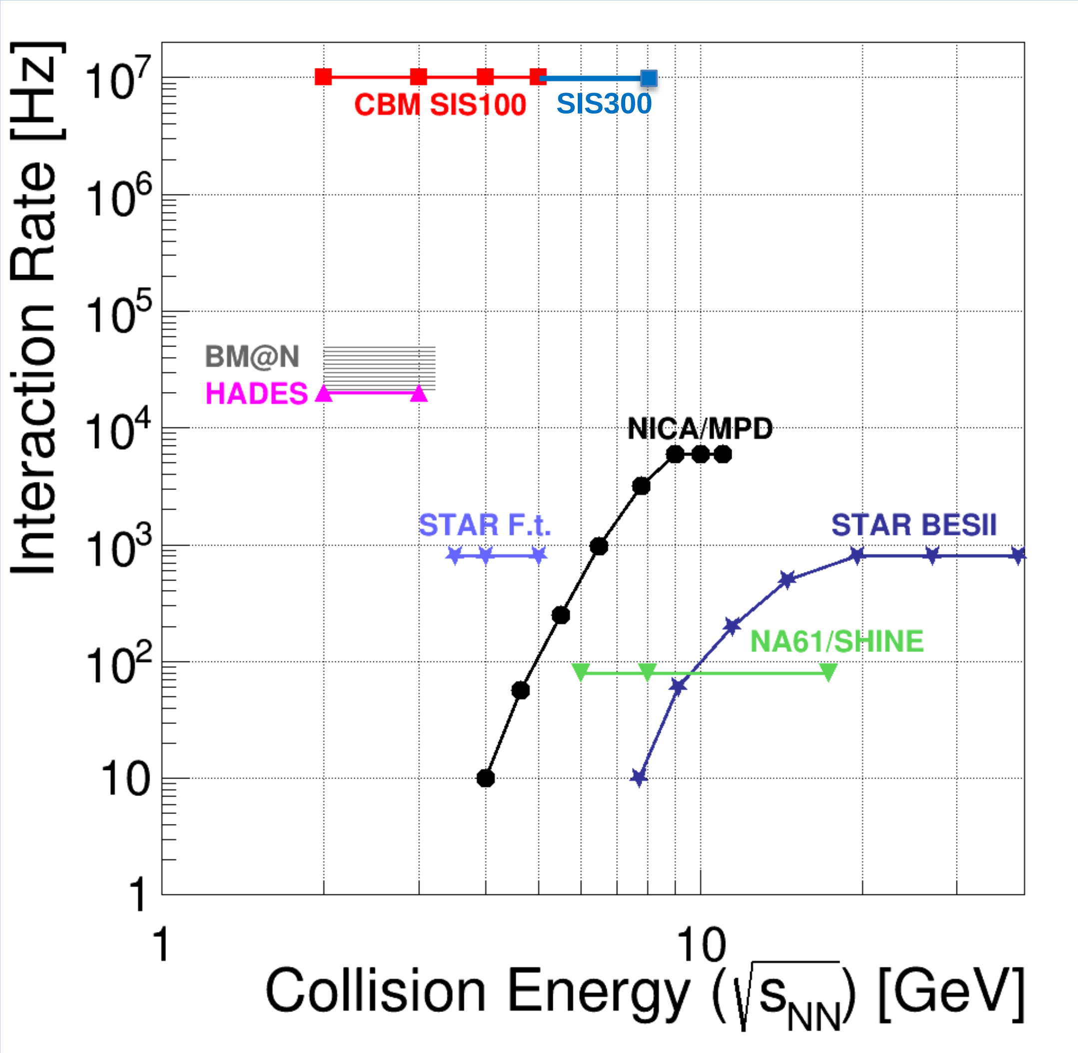


CBM: Experiment Systems



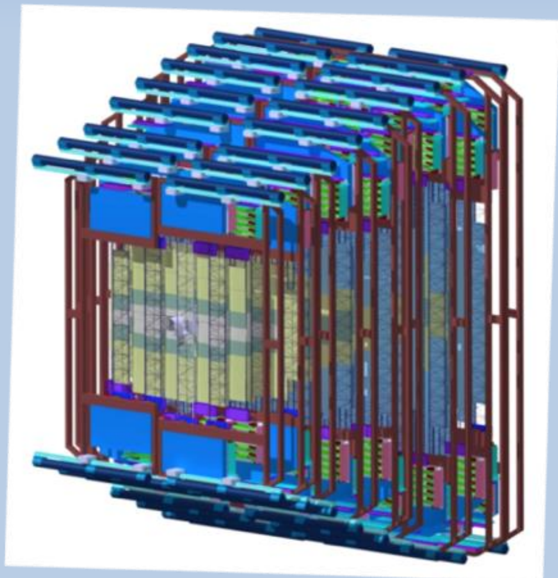
CBM Punchline: Rates



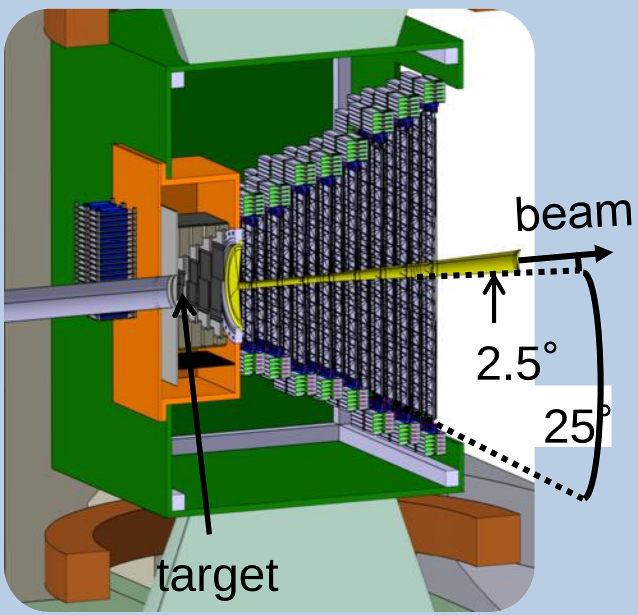
SIS-100 and SIS-300

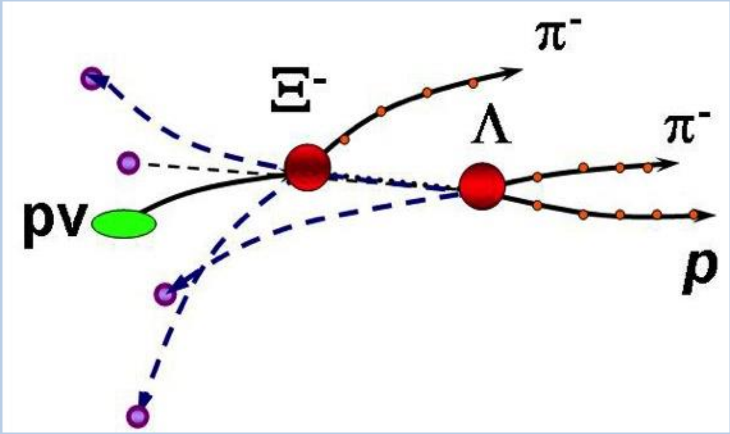
- SIS-100 and CBM are part of the FAIR Modularised Start Version (MSV)
- SIS-300 is not yet funded; timeline unsure
- we concentrate now on CBM@SIS-100
  - Au: 2A – 11A GeV
  - Ni: 2A – 15A GeV
  - p: up to 30 GeV
- staying open for SIS-300 as later upgrade

The Workhorse: Silicon Tracking System



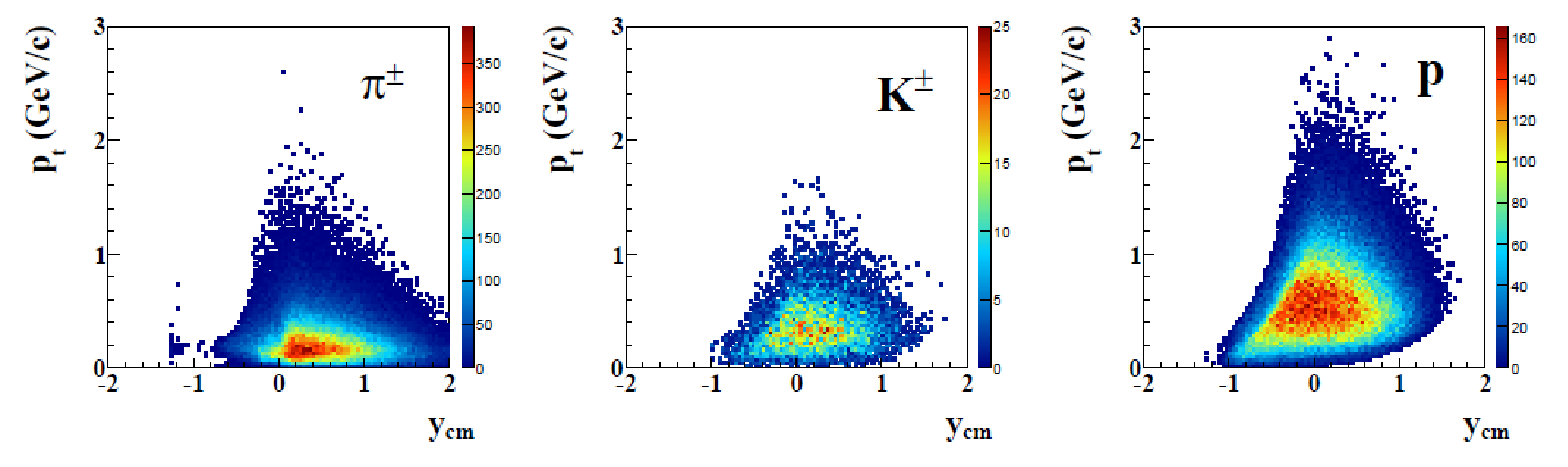
- *8 tracking stations in dipole magnet: between 0.3 m and 1 m from target*
- *Aperture: 2.5° < Θ < 25° (38°)*
- *Double-sided micro-strip sensors arranged in modules on low-mass, carbon-fiber supported ladders.*
- *1,220 sensors (4 m^2), 1.8 M channels*
- *Readout electronics at periphery*
- *Thermal enclosure, sensors at -5 °C*
- *CO_2 cooling (42 kW power dissipation)*



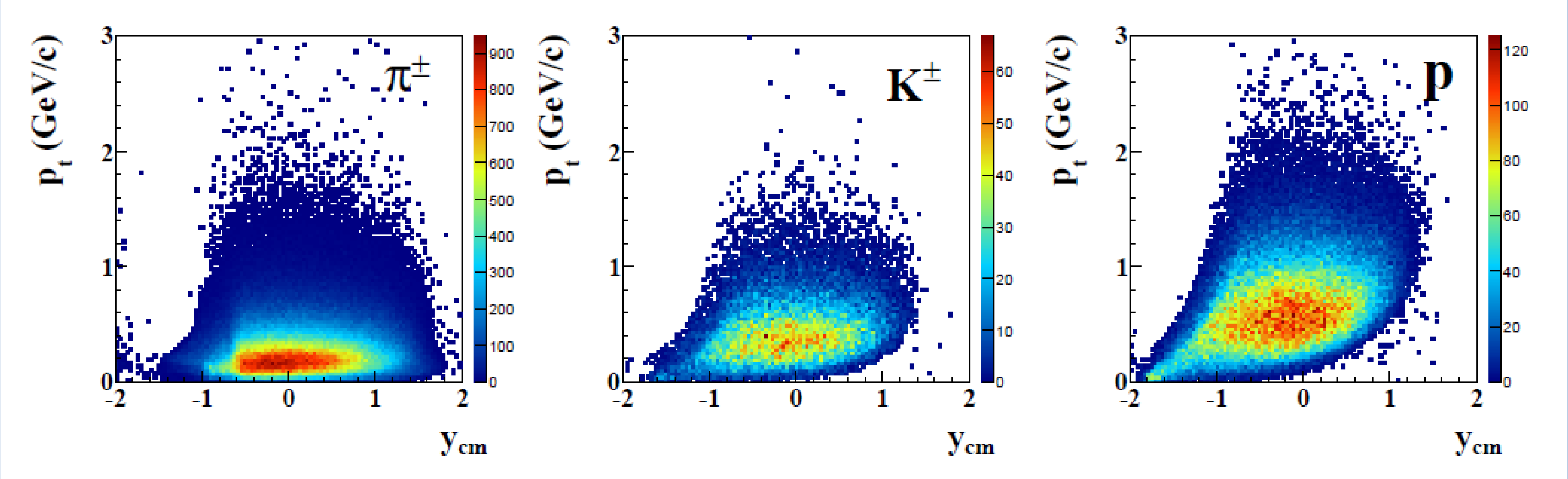


STS Acceptance...

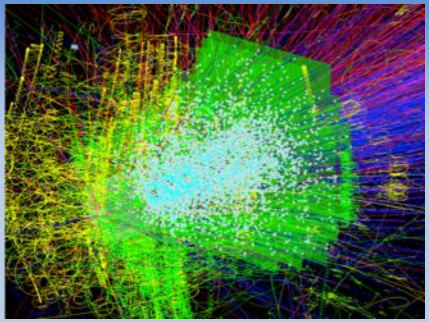
Au+Au 6 AGeV y_{beam} = 1.28



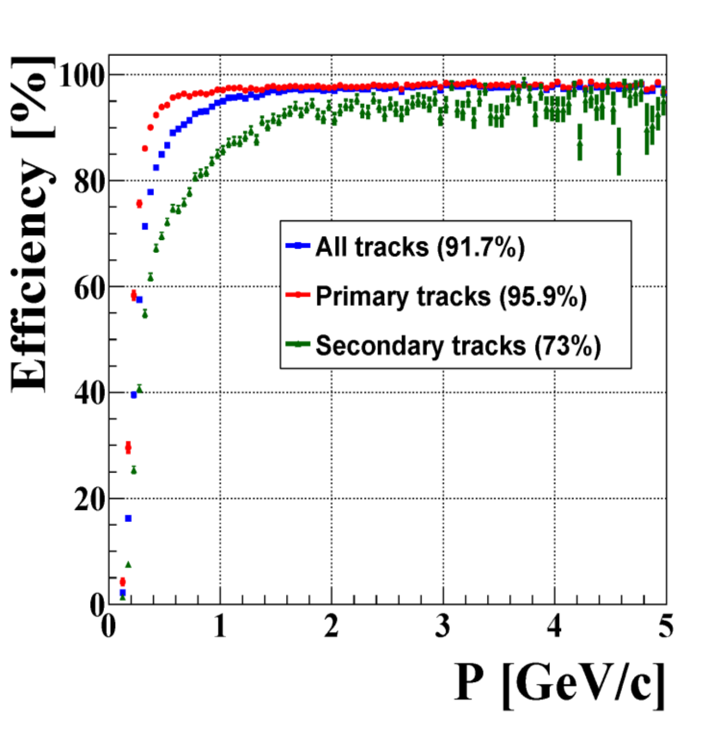
Au+Au 25A GeV y_{beam} = 1.98



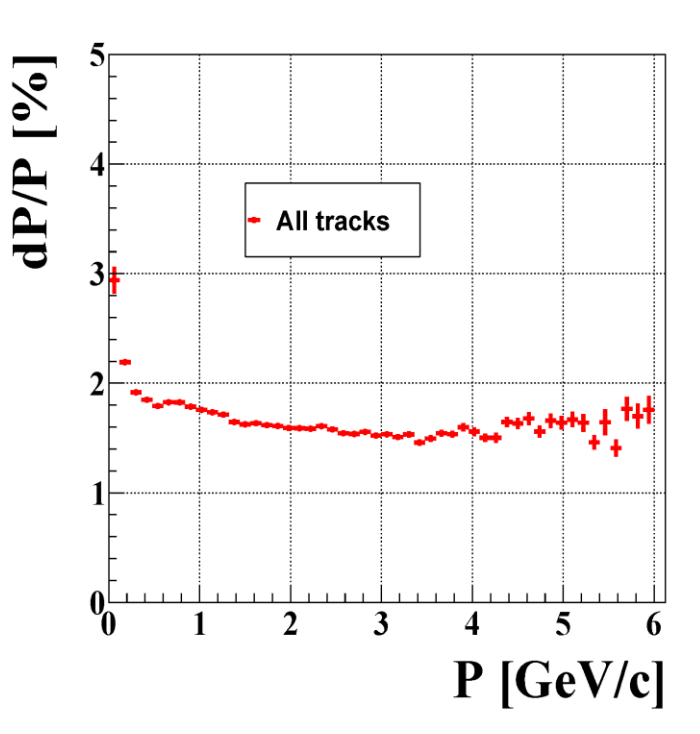
... and Performance



Track finding efficiency
central Au+Au 10A GeV

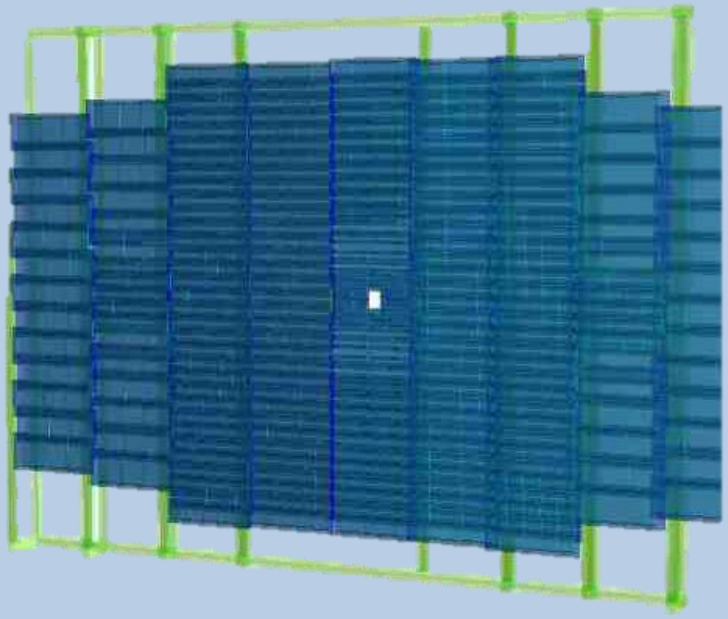


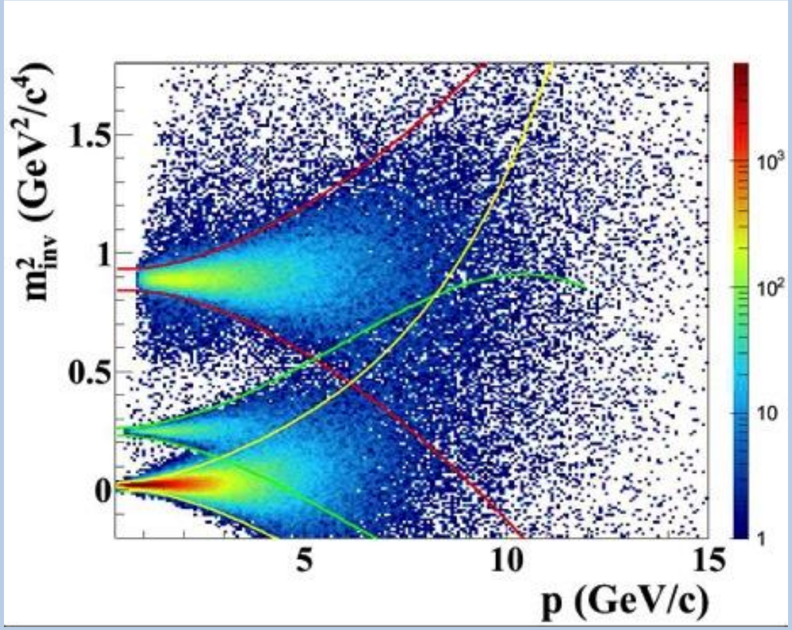
Momentum resolution



Track reconstruction with Cellular Automaton and Kalman Filter

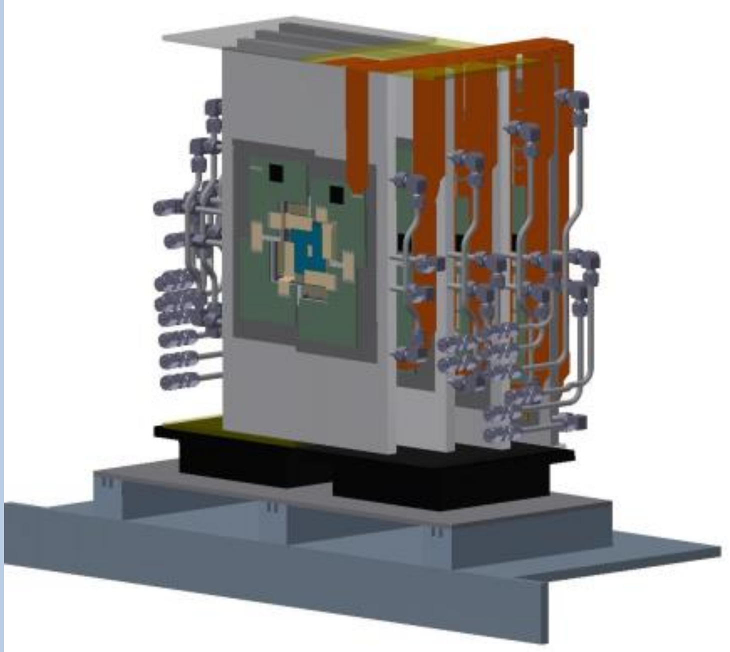
Hadron ID: Time-of-Flight Detector

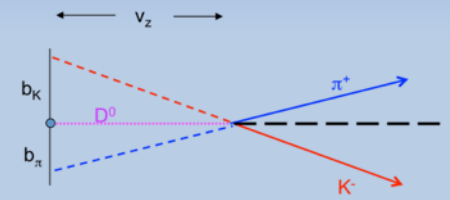




- *array of Resistive Plate Chambers (120 m^2)*
- *resolution ≈ 60 ps*
- *high rate capability (- 25 kHz/cm^2)*
- *located at z = 6 m (10 m) from the target*

Precision Vertexing: Micro-Vertex Detector

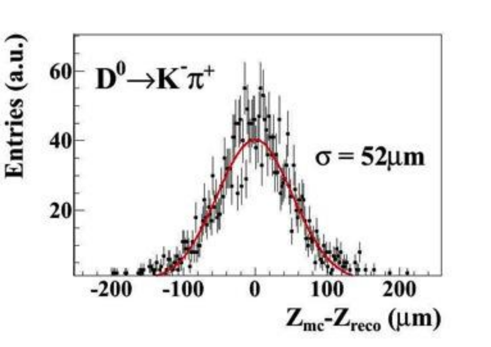




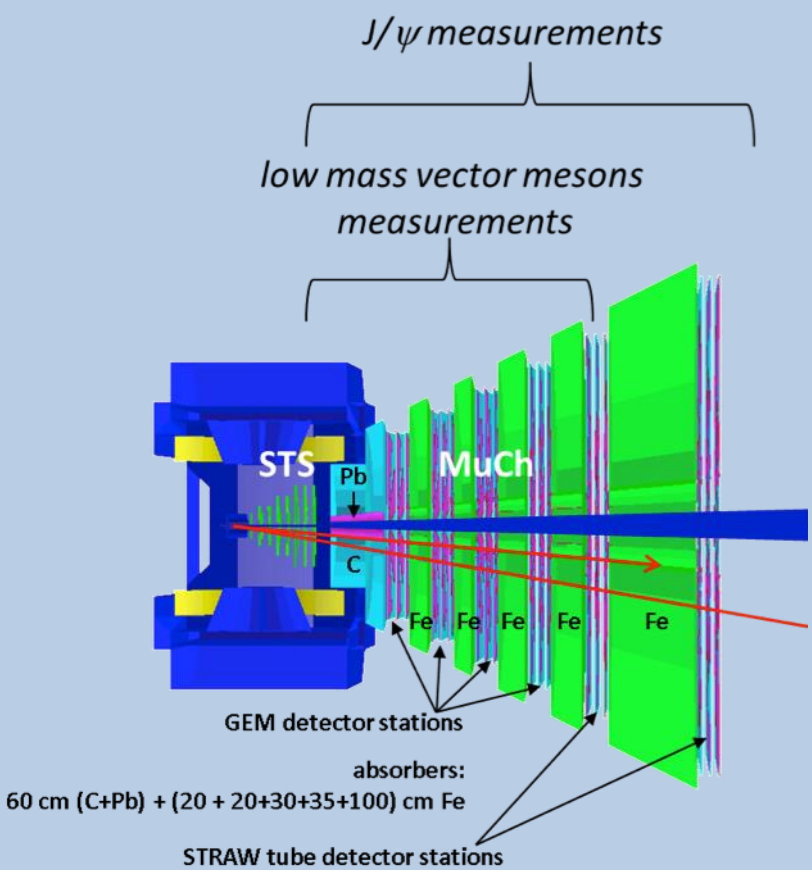
- *4 layers of Monolithic Active Pixel Sensors*
- *located at z = 5 cm - 20 cm*
- *pixel size 20 x 20 μm^2*
- *resolution 4 μm*
- *low-mass: < 0.5 % X_0 per layer*
- *operated in vacuum*
- *rad. hardness 10^{13} n_{eq}/cm^2 / 3 MRad*
- *sec. vertex resolution ≈ 50 μm along beam axis*

MIMOSA-26

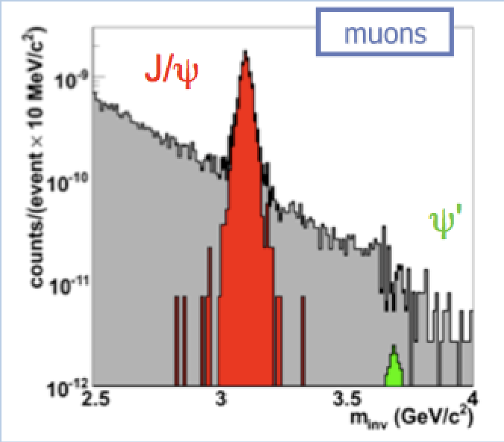
Prototype station



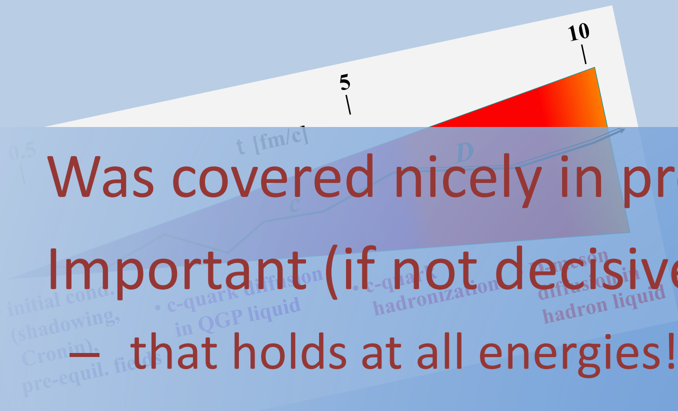
Muon Detector

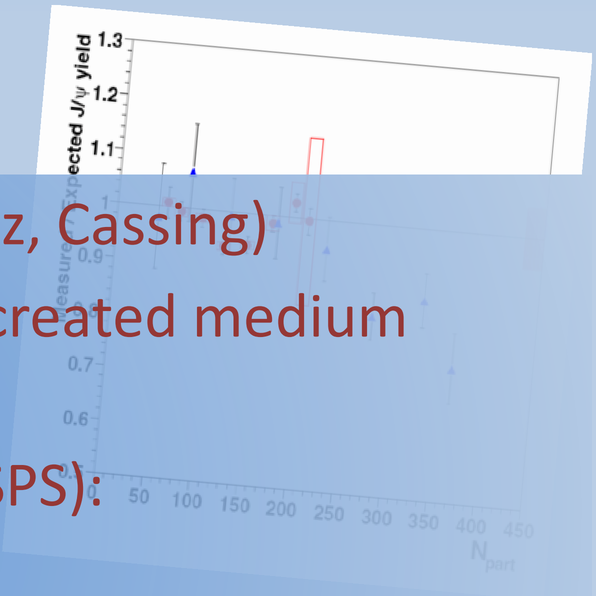


- *active absorber system with tracking detectors (GEM/straw) sandwiched between absorber slices*
- *allows track following through the system*

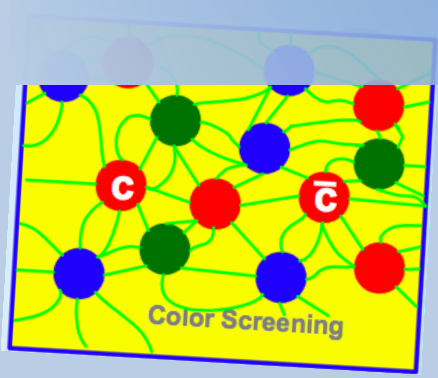


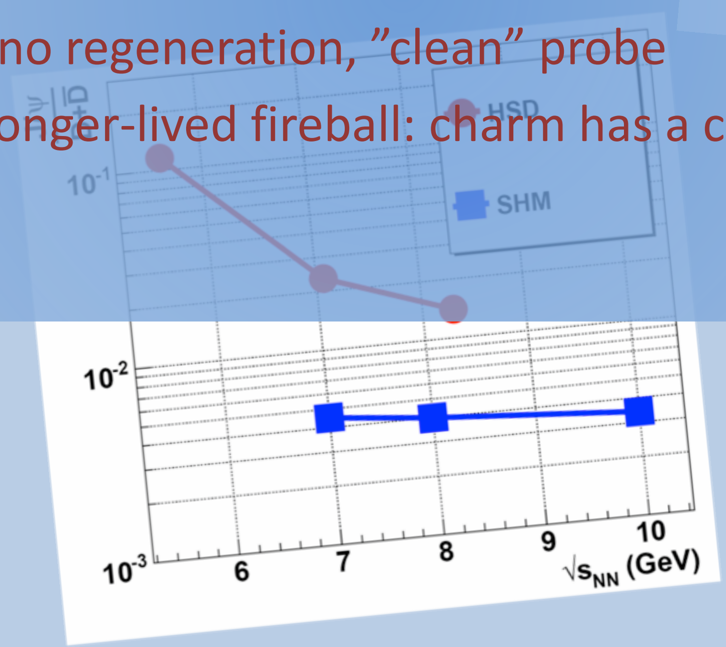
Charm in Heavy-Ion Collisions





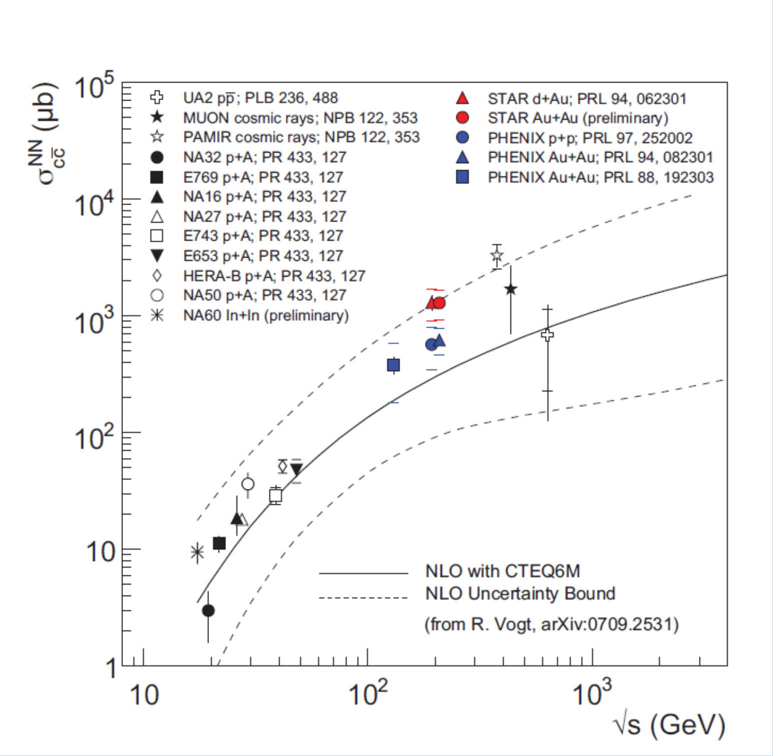
- Was covered nicely in previous talks (Satz, Cassing)
- Important (if not decisive) probe of the created medium
  - that holds at all energies!
- Particular at lower energies (below top SPS):
  - N_{ccbar} << 1 -> no regeneration, "clean" probe
  - Softer J/psi, longer-lived fireball: charm has a chance to see the medium





Charm Cross Section

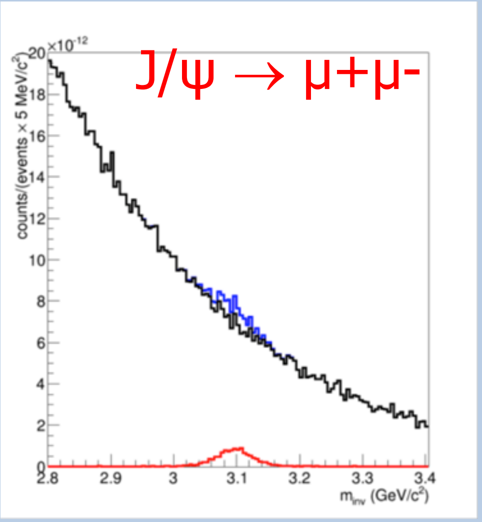
- For the interpretation of charmonium data, the total c-cbar production cross section is required: need to measure also open charm.
  - cave: near threshold, $N_{J/\psi} << N_D$ not necessarily true
- Charm cross section close to threshold is experimentally unknown below √s = 20 GeV even in elementary reactions (let alone A+A)!
- pQCD calculations also come with large uncertainties.



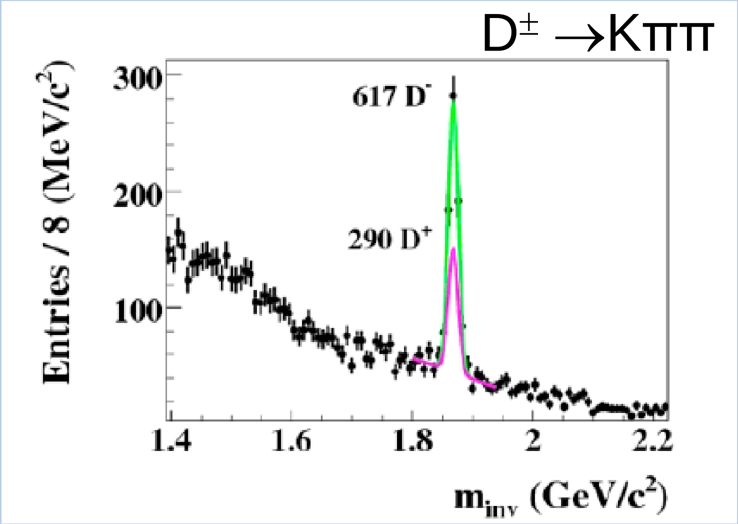
Charm at SIS-100

- The CBM charm programme is tailored for SIS-300 energies
- At SIS-100:
  - charmonium at top energy: Au+Au, 11A GeV (sub-threshold, extremely challenging)
  - Z/A = 0.5 (e.g., Ni+Ni) @ 15A GeV (slightly above threshold)
  - open and hidden charm in p+A up to 30 GeV (c-cbar cross section, cold matter effects)

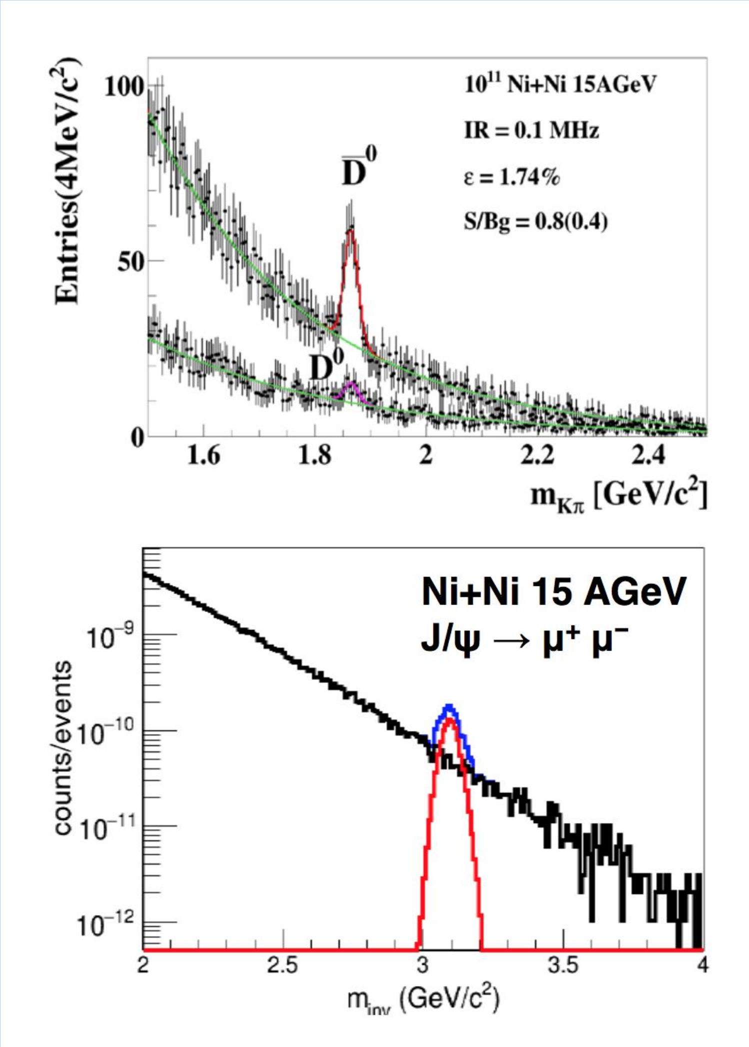
central Au + Au, 10A GeV



p + C, 30 GeV



Charm at SIS-100: Ni + Ni @ 15A GeV



D mesons:
Interaction rate 0.1 MHz
260 $\bar{D}^0$ and 45 D^0 in 2 weeks

Acceptance down to zero p_t

Charmonium (muon channel):
Interaction 1 MHz
3300 J/Ψ in 2 weeks

Strangeness

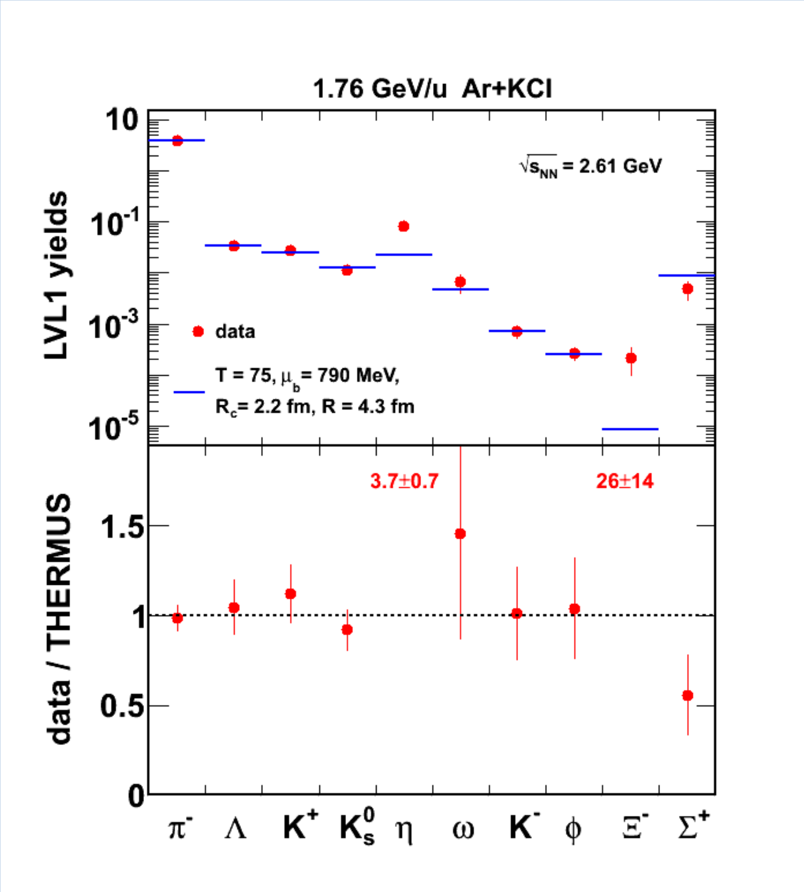
- One of the ”classical” observables: strangeness enhancement / canonical suppression
- Strangeness yields from are well described by the statistical model: strong argument for phase transition (no hadronic mechanism to equilibrate e.g. Omega)
- Following this: measuring strange baryon abundances at lower energies.
  - Down to which collision energies does the hadron gas model hold?
- Model fits describe data at lower SPS and at AGS
  - But with a limited amount of particle species
  - Data on multi-strange baryons are scarce

Breakdown of strangeness thermalisation?

HADES result for Xi^- at SIS-18 (1.76A GeV): Xi^- yield is off by an order of magnitude from the statistical model.

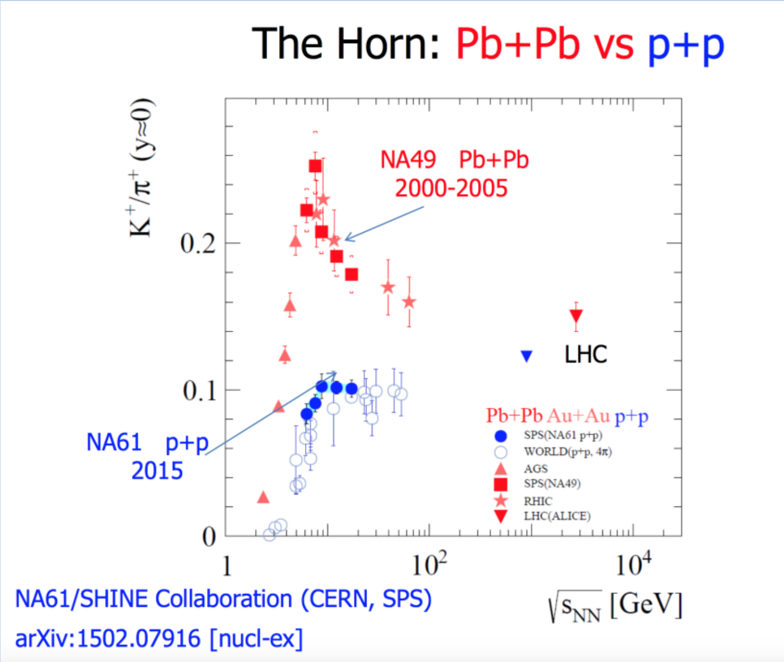
N.b.: This is deep sub-threshold. Production through multi-step processes

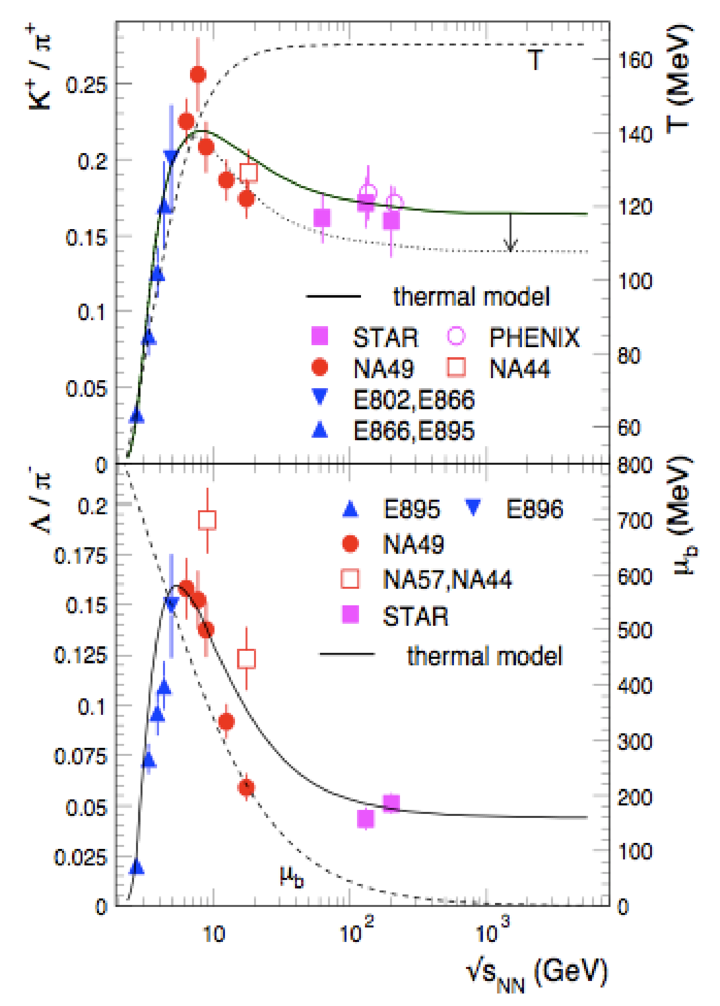
$$\Lambda K \rightarrow \Xi\pi \quad \Lambda\Lambda \rightarrow \Xi^- p \quad \Xi K \rightarrow \Omega\pi$$



R. Holzmann, CBM Physics Workshop, April 2010

Strangeness: The „horn“, again

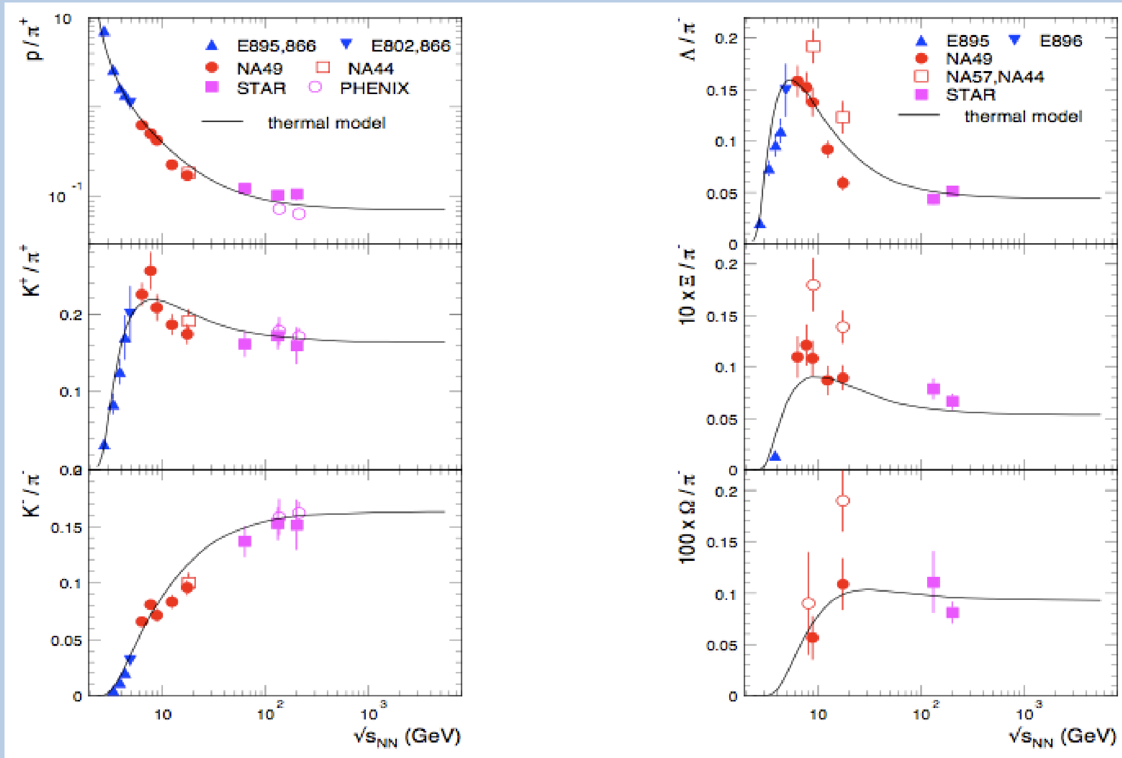




- Statistical model: broad maximum at ≈ 30A GeV (interplay of T and μ_b)
- No satisfactory description of the K/pi energy dependence, but
- Improvement when including high-mass resonances

A. Andronic, P. Braun-Munzinger und J. Stachel, Phys. Lett. B 673 (2009) 142

The need for data on multi-strange baryons

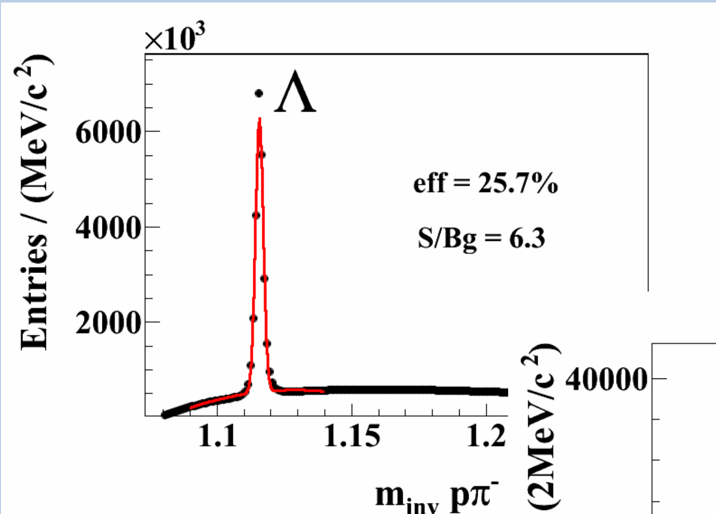


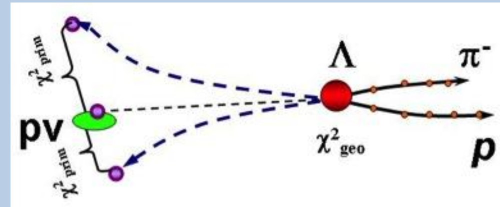
A long-lasting debate: pure hadronic description or signal of drastic change in matter properties?

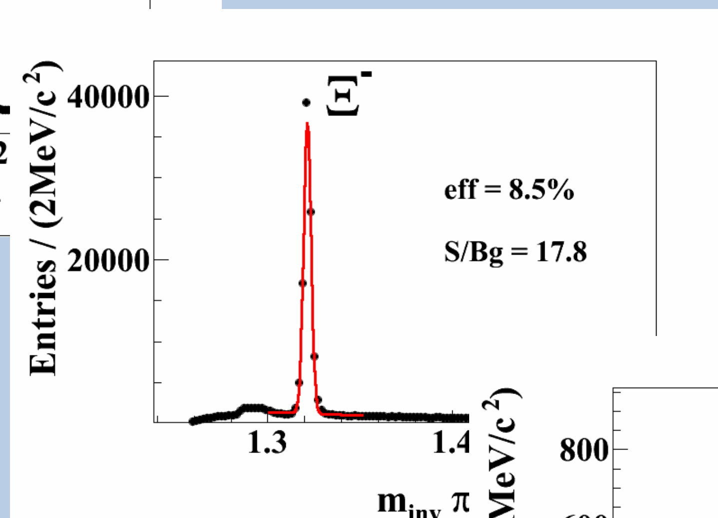
Data on multi-strange baryons will be decisive!

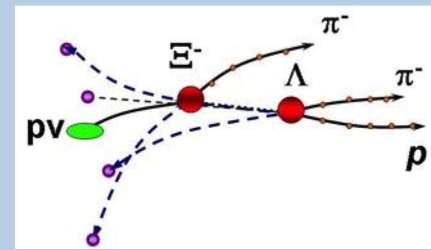
- "Onset" scenario: effect is due to increase in strangeness; sharp maximum at same location as K/pi; size of peak increases with strangeness content
- Hadron Gas Model: effect is due to net-baryon density; broad maximum; size of maximum decreases with strangeness content; position of maximum shifts

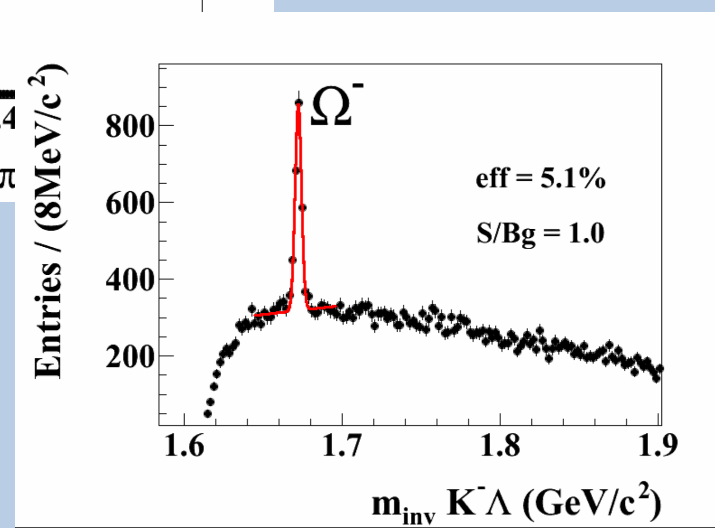
CBM Performance for Hyperons





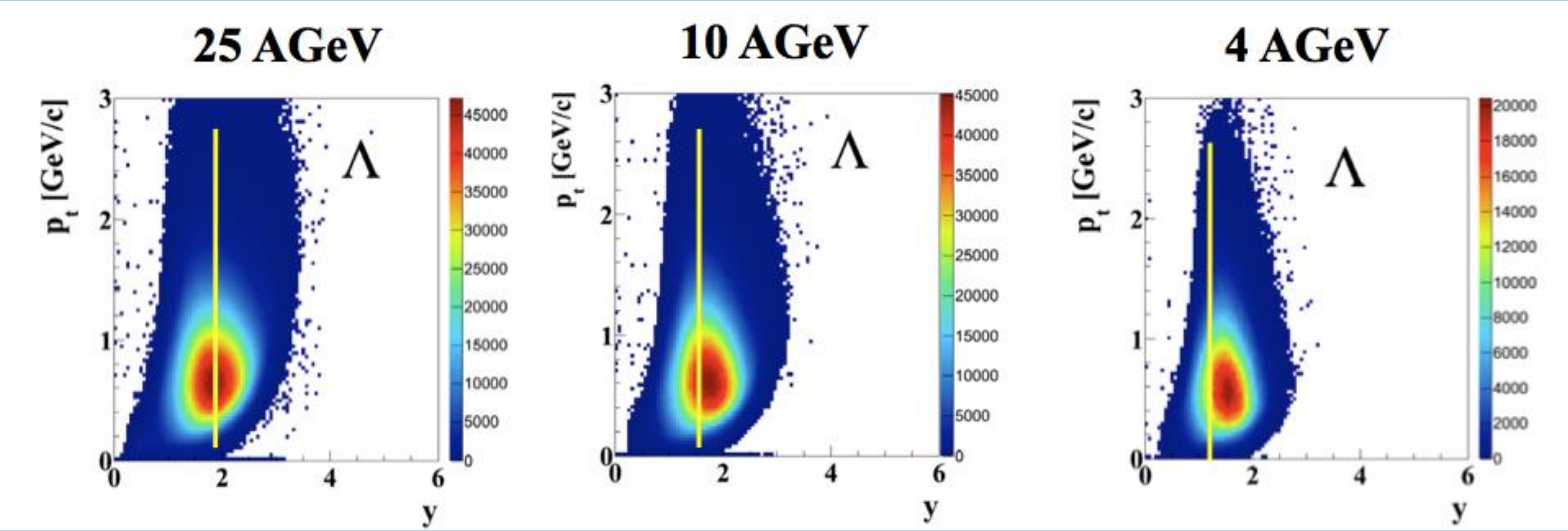






Input: UrQMD, central Au+Au, 10A GeV

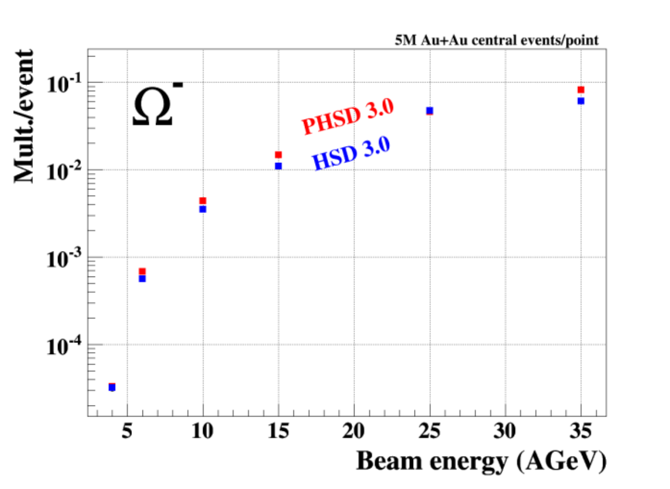
Hyperons: Phase-Space Coverage

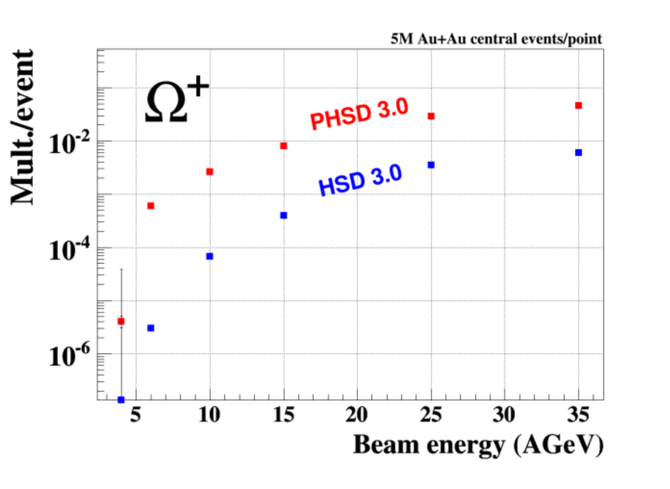


Hyperons: Expected Statistics

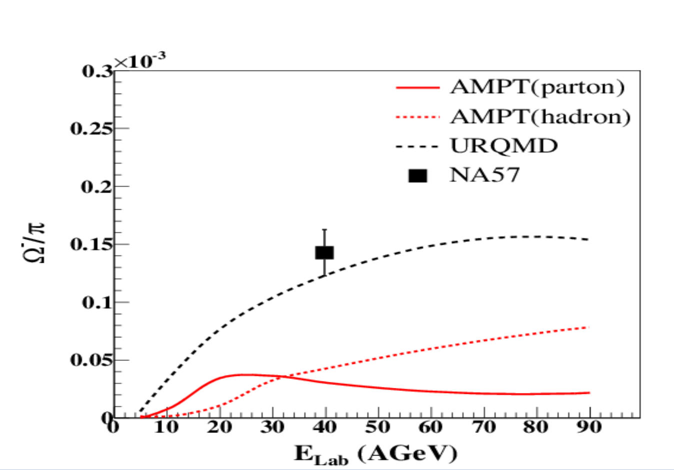
Au+Au 10 AGeV	Λ	Ξ^-	Ω^-	Ω^+
decay channel	$p\,\pi^-$	$\pi^- p\,\pi^-$	$K^- p\,\pi^-$	$K^+ \bar{p}\,\pi^+$
$M_{UrQMD\ 3.3}$	17.4	0.22	5.5E-3	6.7E-5
BR(%)	63.9	~100	67.8	67.8
total eff. (%)	**25.7**	**8.5**	**5.4**	**2.3**
$S/B_{2\sigma}$	**.3**	**17.8**	**1.0**	**~10**
Reco yield/sec. ~ 1MHz	**4.5M**	**20k**	**280**	**1.5**

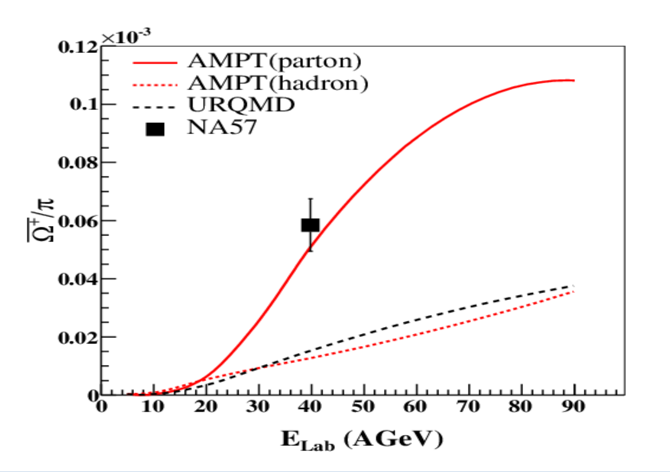
Strange anti-baryons at FAIR/NICA energies





HSD / pHSD

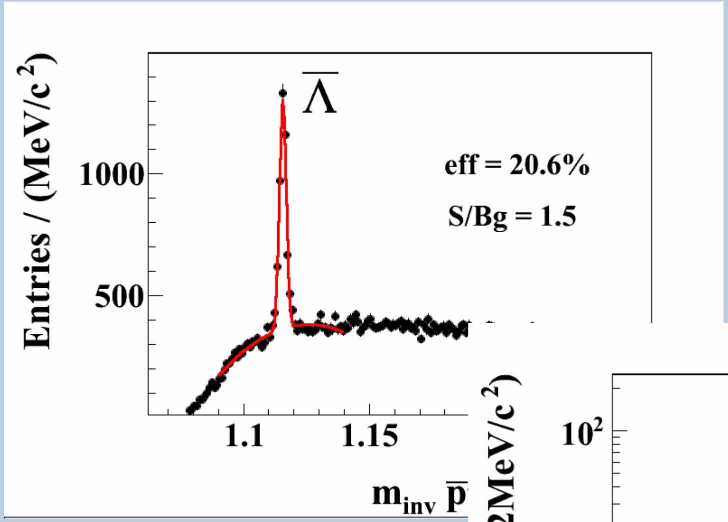




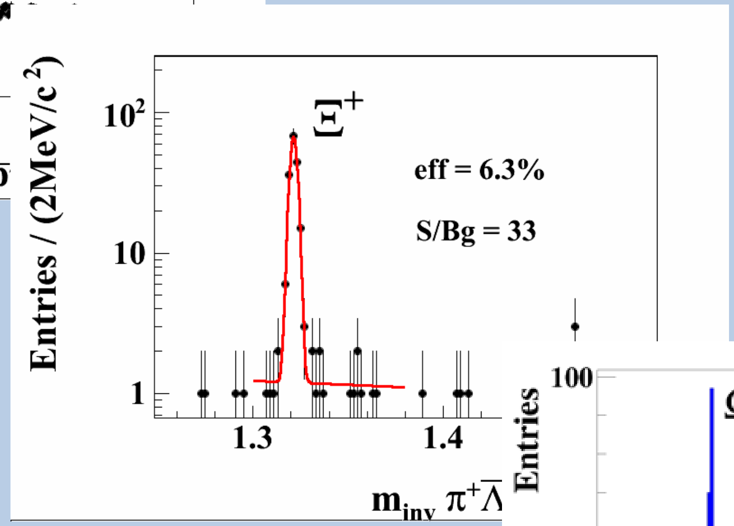
AMPT

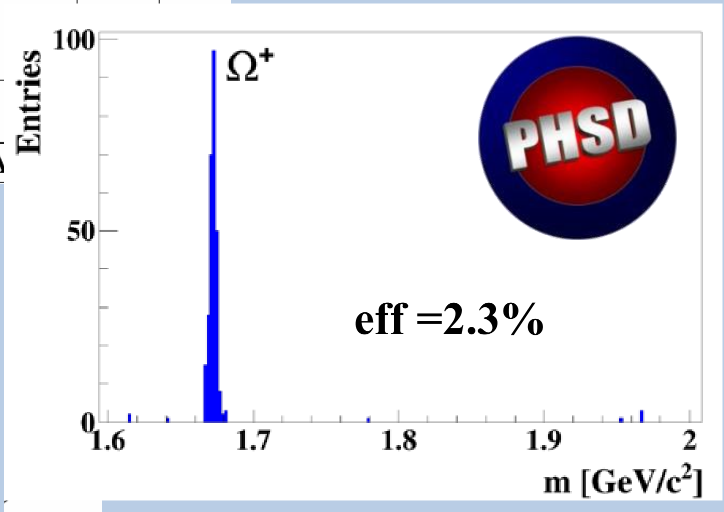
Microscopic models (including partonic production) predict the anti-hyperons to be very sensitive to partonic production mechanisms (hyperons much less)

CBM Performance: Anti-Hyperons



Input: central Au+Au, 10A GeV
UrQMD (PHSD for Ω^+)

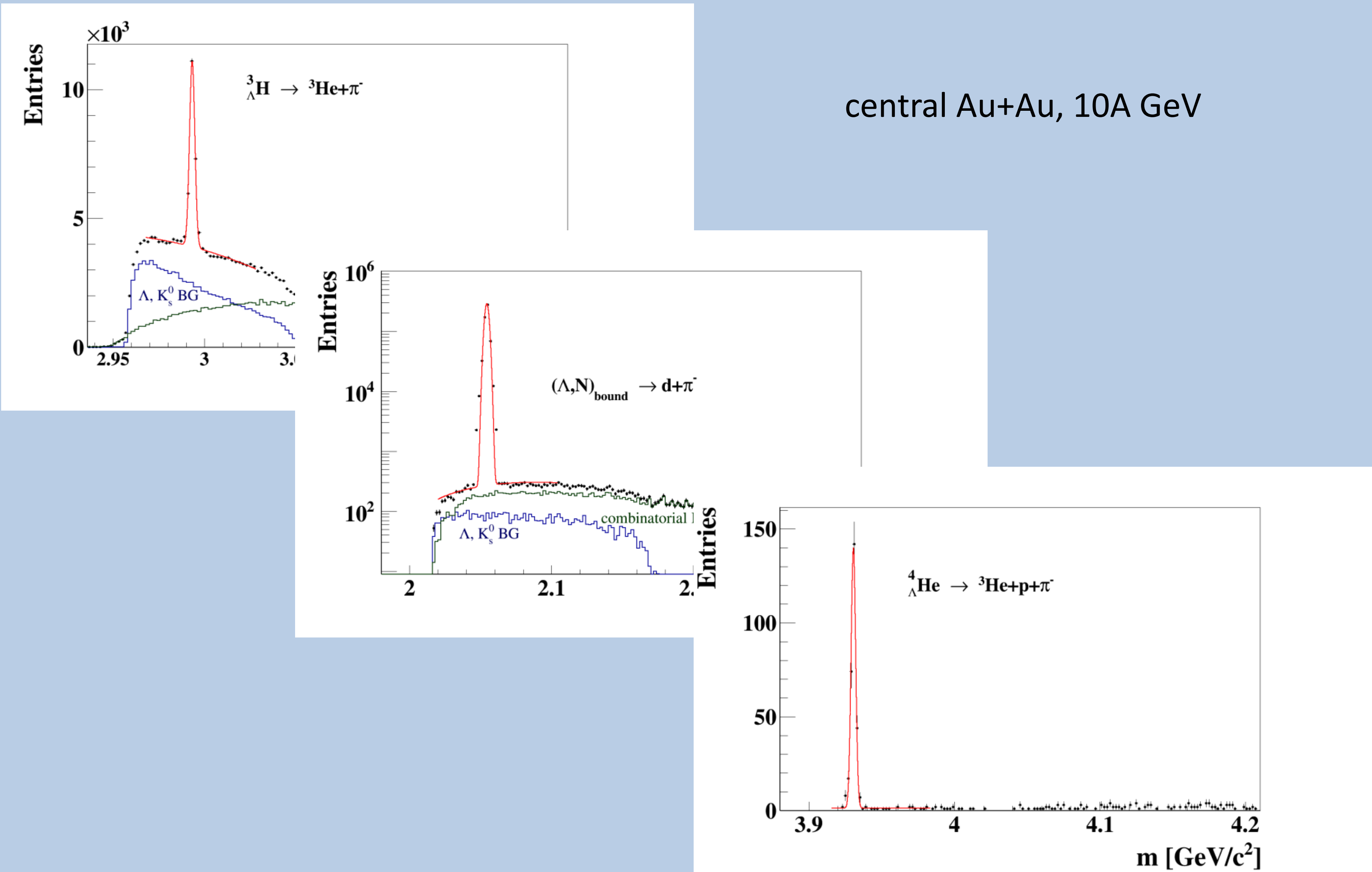




Very rare probes; require high interaction rates and online selection!

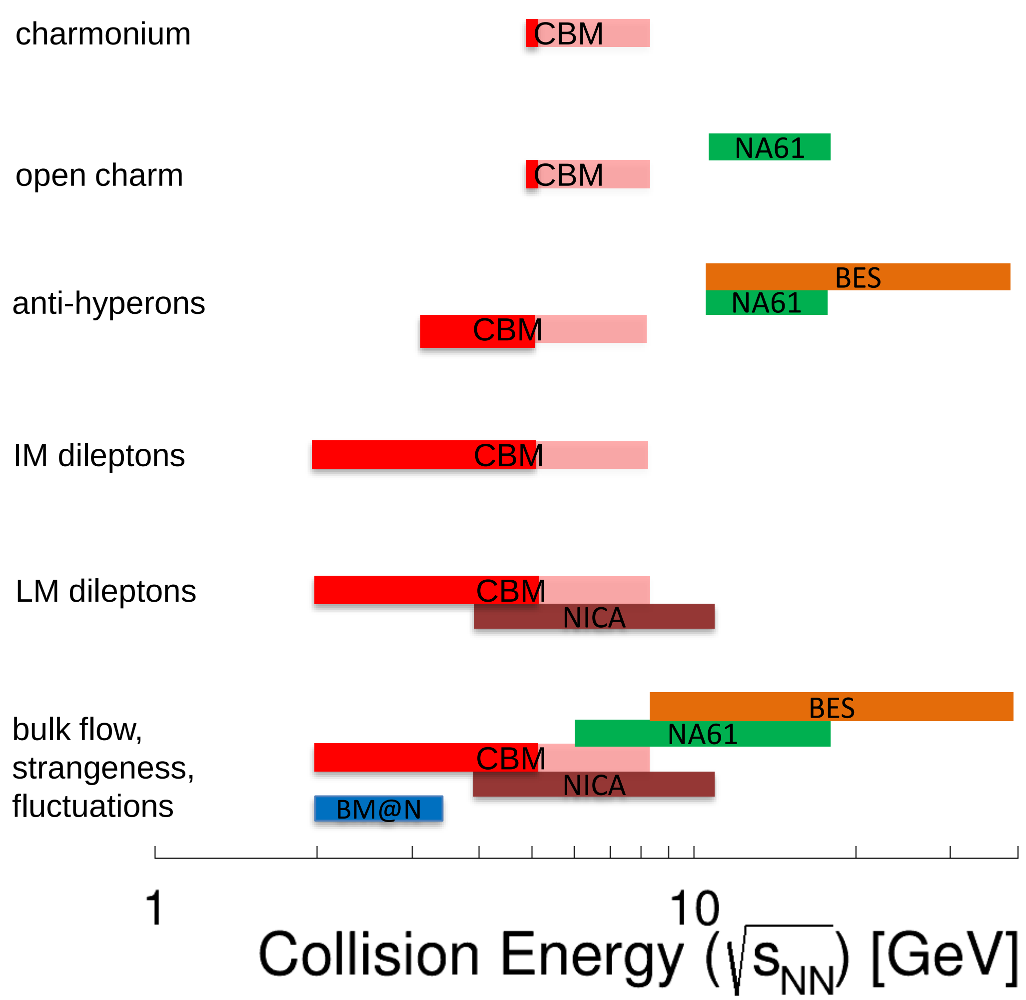
Sensitivity to Hypermatter

central Au+Au, 10A GeV



Comparison: Observables

restrictions: by rate and/or by instrumentation



Summary: What we can expect from CBM

- Charm:
  - D mesons and J/psi in Ni+Ni @ 15A GeV
  - J/psi in Au+Au at 10A GeV
  - Charm production in p+A up to 30 GeV
  - With SIS-300: systematic charm measurements up to 35A (45A) GeV
- Multi-strange hyperons:
  - Excitation function of Xi and anti-Xi from 4A to 10A GeV
  - Omega and anti-Omega at 8A and 10A GeV
  - With SIS-300: extension of energy range to 35A / 45A GeV; coverage of maximal net-baryon density ("horn") region