Summary talk – Experiments low energies

Yvonne Leifels

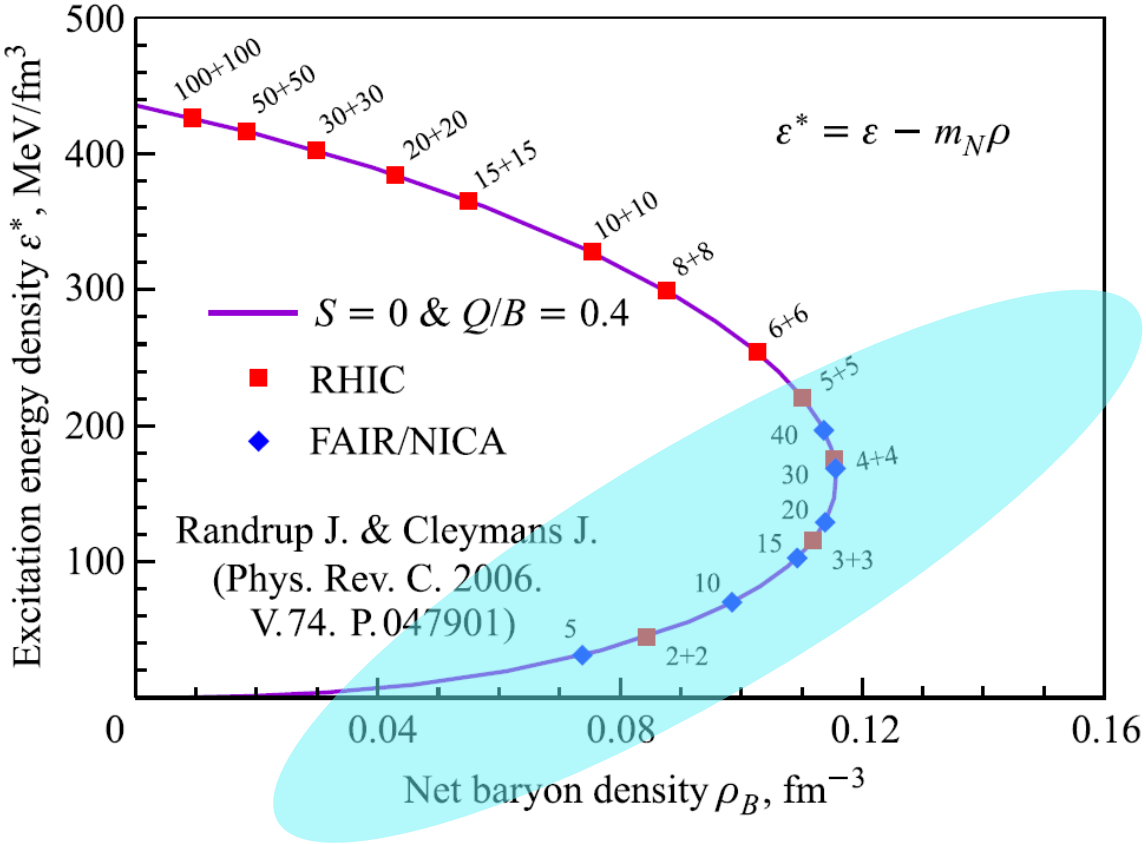
GSI Darmstadt

Investigation of Strangeness in Quark Matter at Low Energies

SQM DUBNA 2015

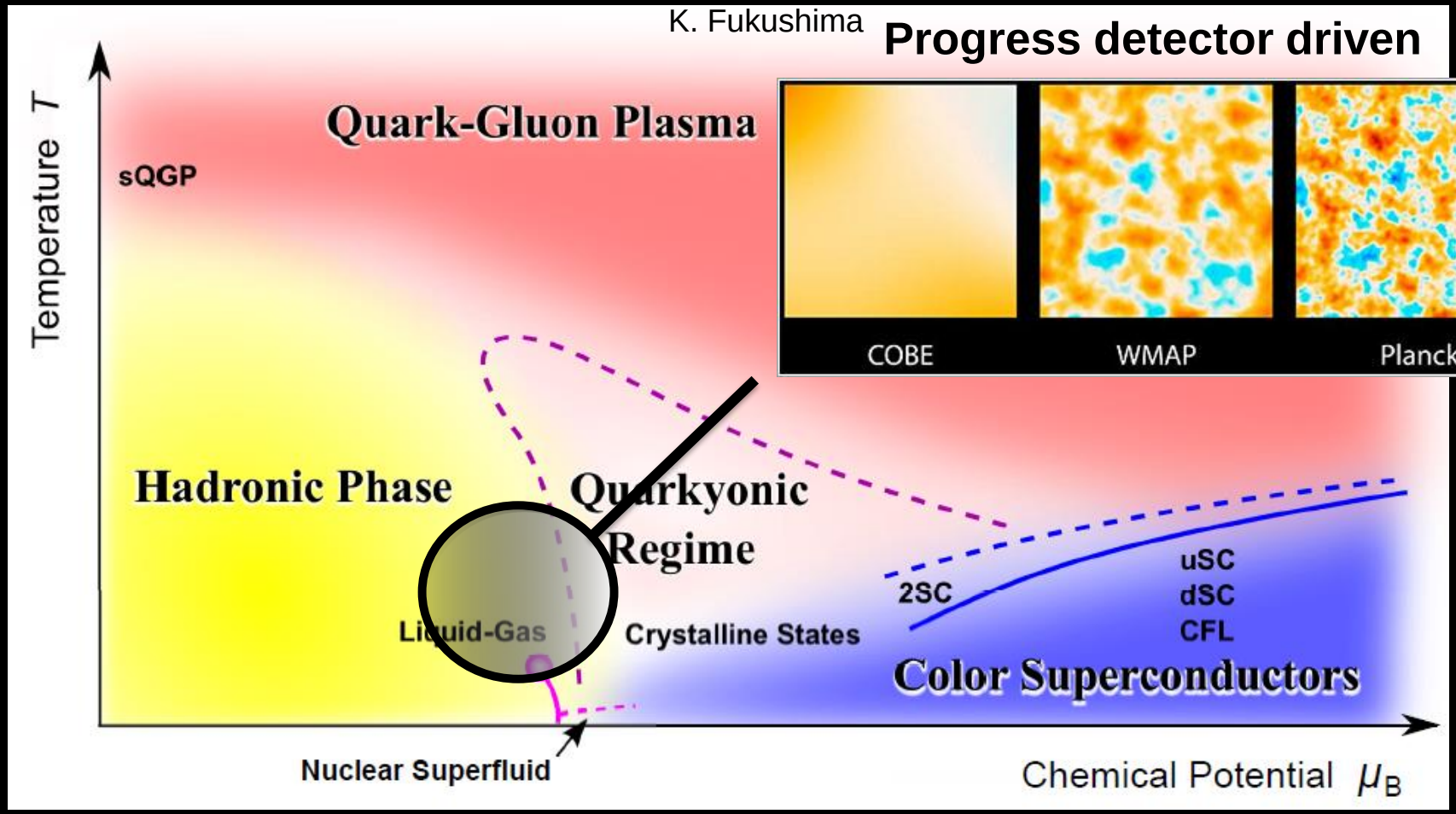
Environment

- moderate temperatures and high baryonic densities



Heavy-ion collisions and QCD phase diagram

Systematic probing of the phase diagram by varying kinetic beam energy



SIS 18 energy regime:
beam energies of 1-2 AGeV for ions, baryon do

Manuel Lorenz

Investigation of Strangeness in Quark Matter at Low Energies

Environment

- moderate temperatures and high baryonic densities

Study

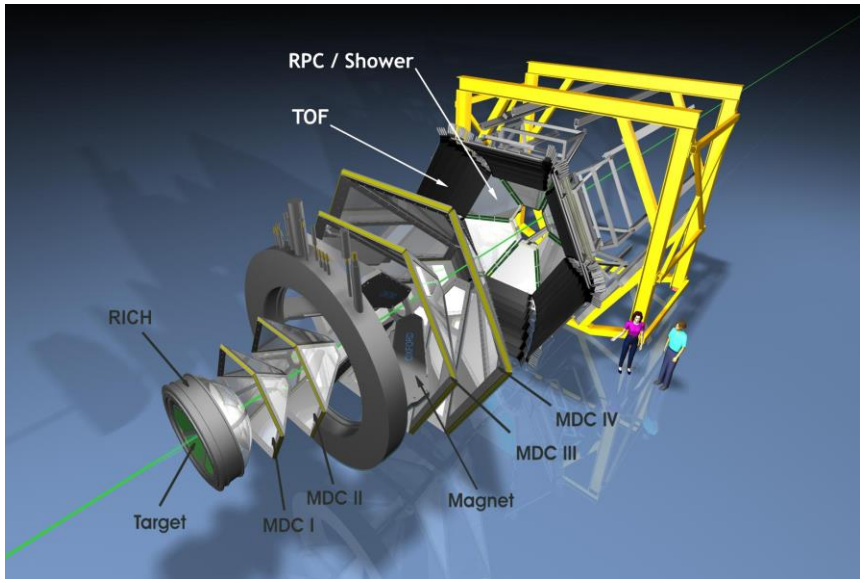
- strange particle production
  - produced during the collision
  - strangeness is conserved, high thresholds, sensitive to density
  - limited experimental information on elementary reactions under strange particles
  - strong couplings
- collective flows (radial, v_1, v_2)
  - in – medium modifications of particles $K^{+/-}$, ρ, ω
- excitation of resonances
- study thermalization
- production of (hyper)nuclei and search for exotica $\Lambda\Lambda$ and Λn
- search for the critical point

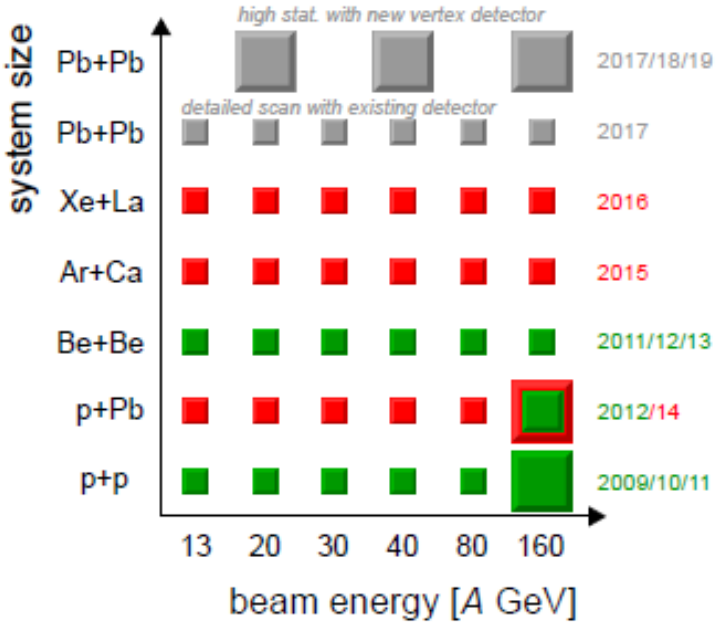
Key players

HADES and SHINE/NA61

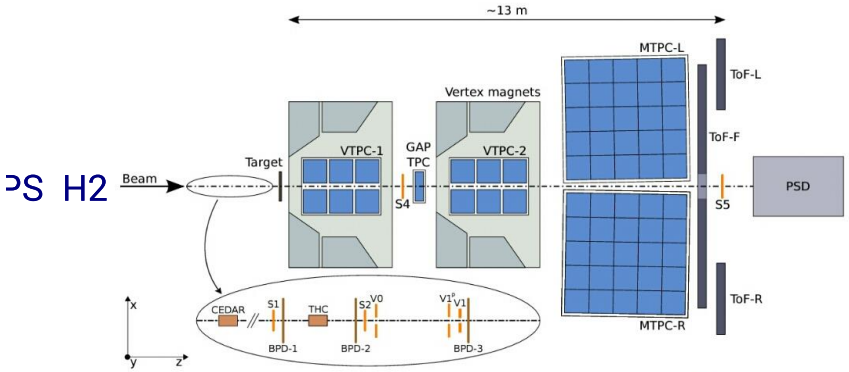
Data taken:

p+p, p + Nb	3.5 GeV
Ar+KCl:	1.76A GeV
Au+Au:	1.25A GeV





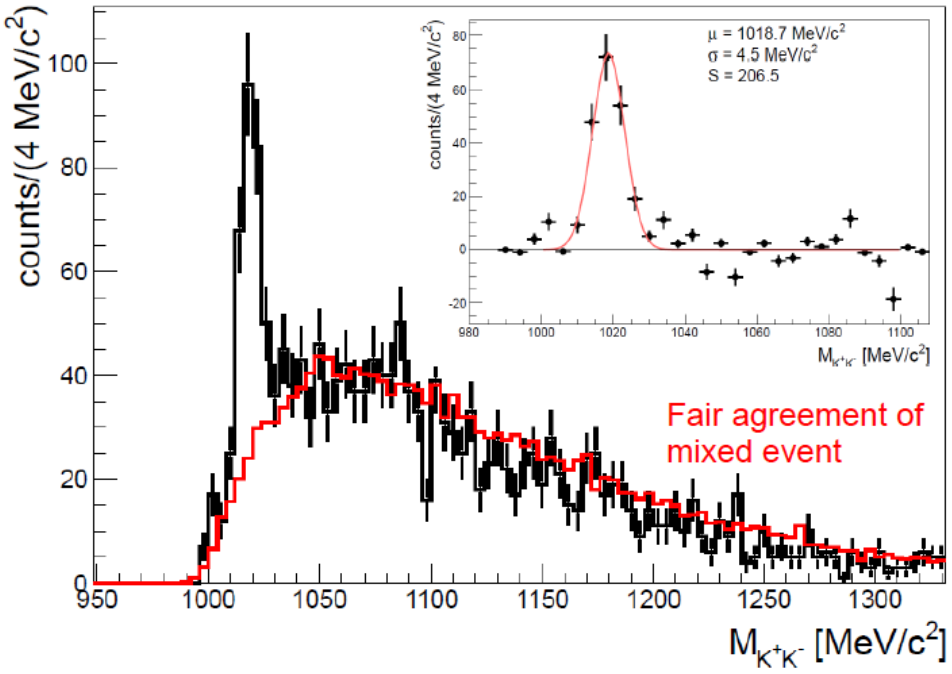
NA61/SHINE detector

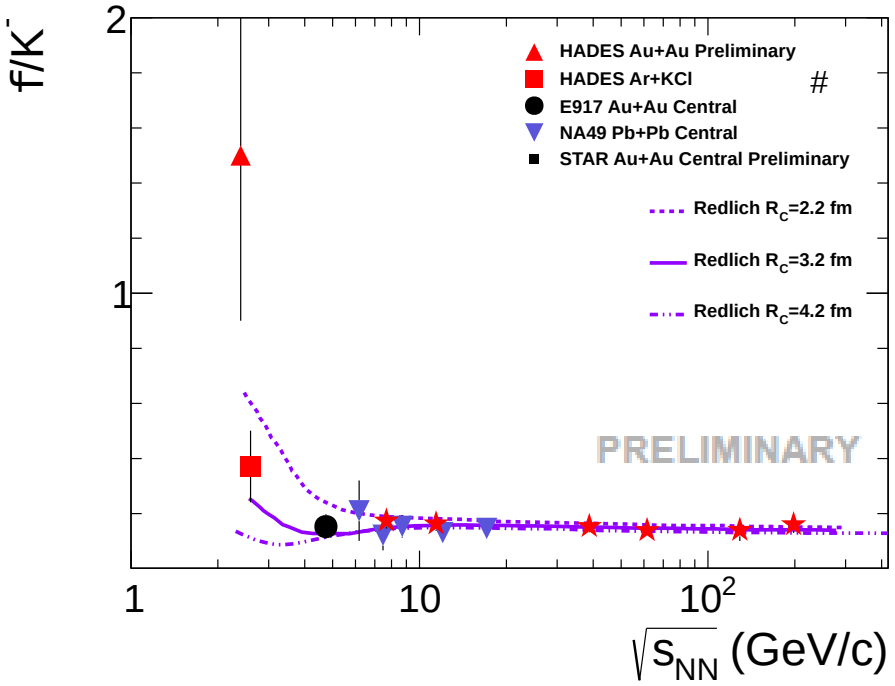


Strangeness at SIS energies 1-2A GeV

Φ and K$^-$

Au + Au 1.25A GeV





Φ meson reconstructed via charged kaons

Strong rise of Φ/K$^-$ ratio with decreasing beam energy as predicted by stat. model

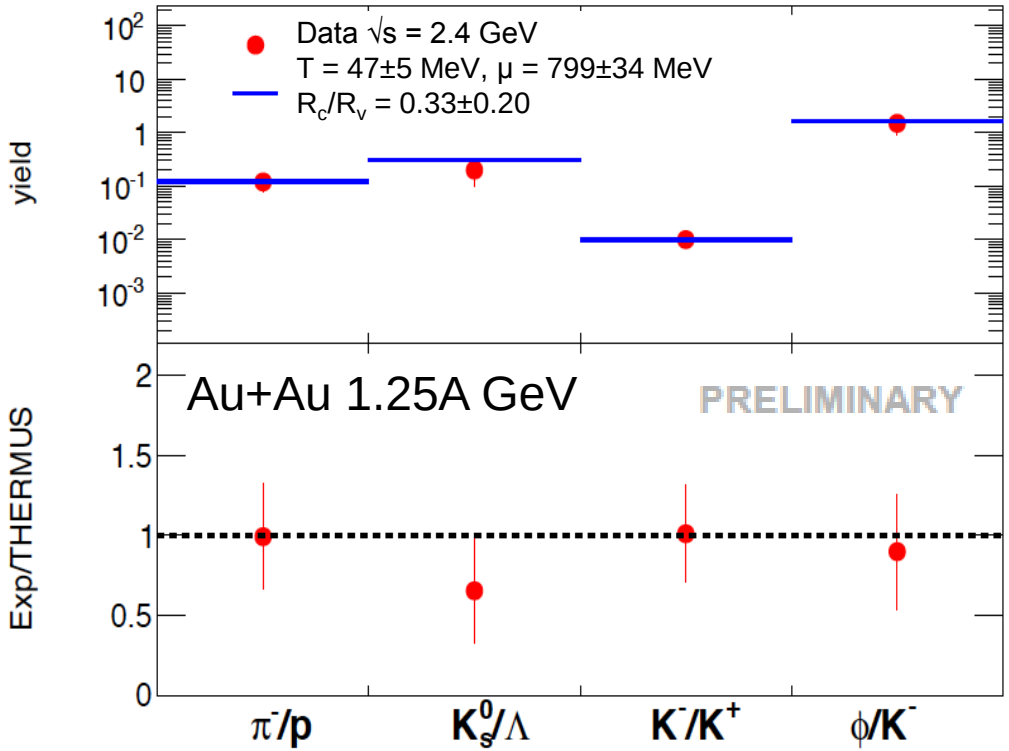
HADES

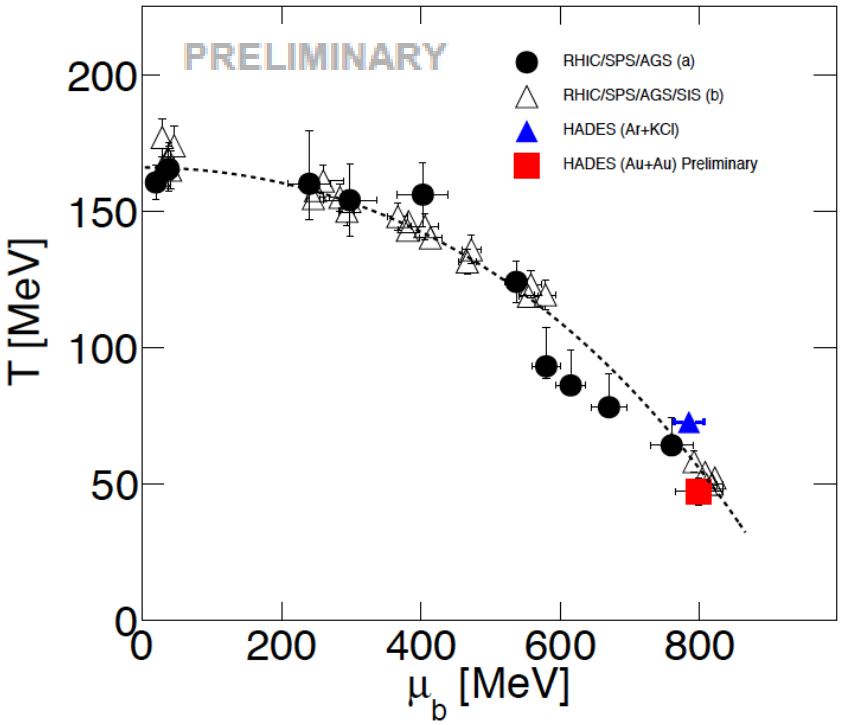
Manuel Lorenz

PhD H. Schuldes

ratio at mid-rapidity

Statistical model fit: first attempt Au+Au





First attempt of statistical model fit to ratios gives reasonable values:

T= 47±5 MeV

μ_B= 799±34 MeV

R_c/R_v= 0.3±0.2 (no systematical errors!!)

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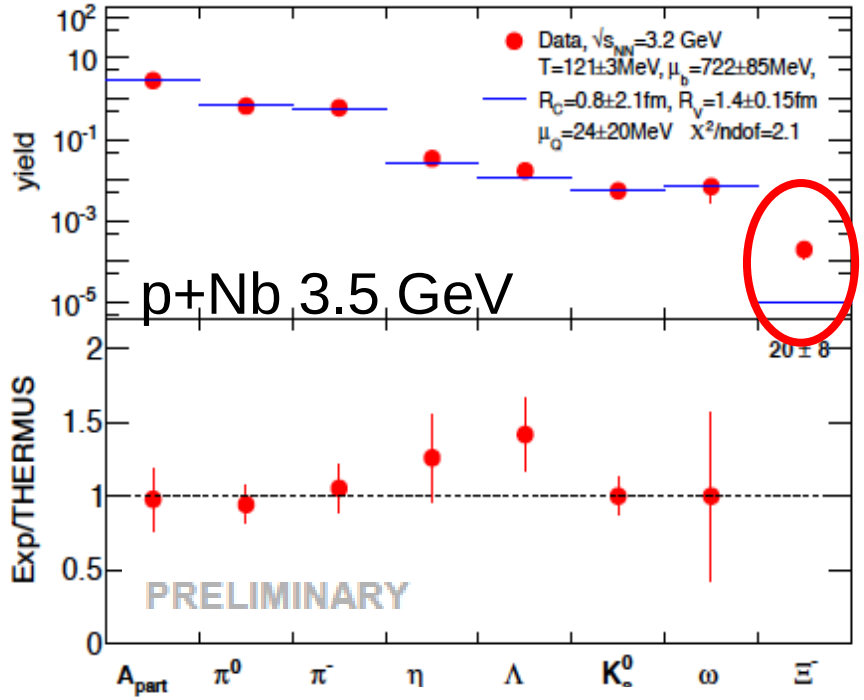
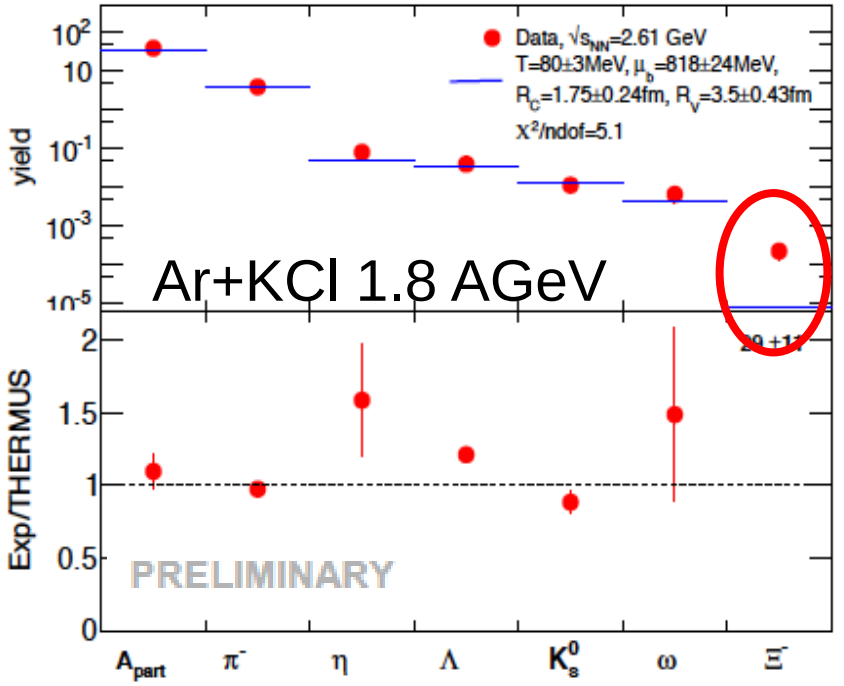
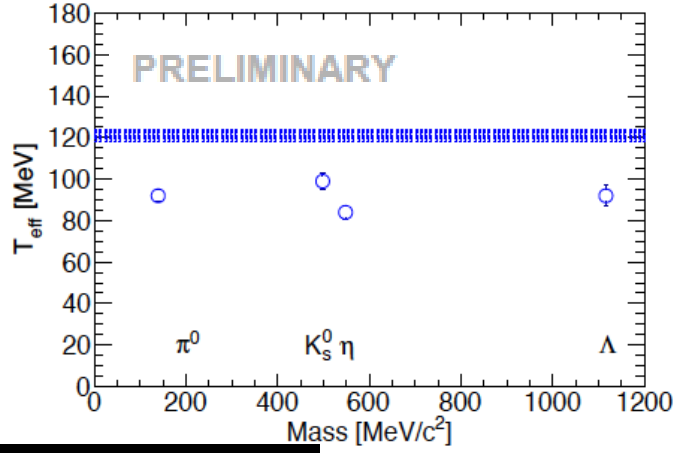
Statistical model fit to p+Nb data

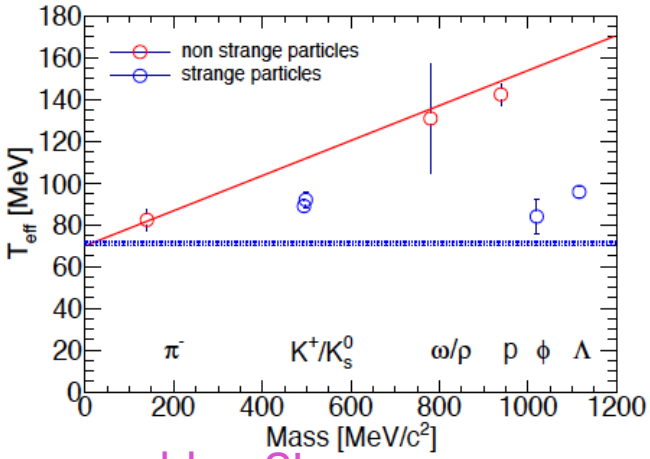




$T_{chem} > T_{kin}$



$T_{chem} \leq T_{kin}$



Fit to p+Nb looks more reasonable ..?!

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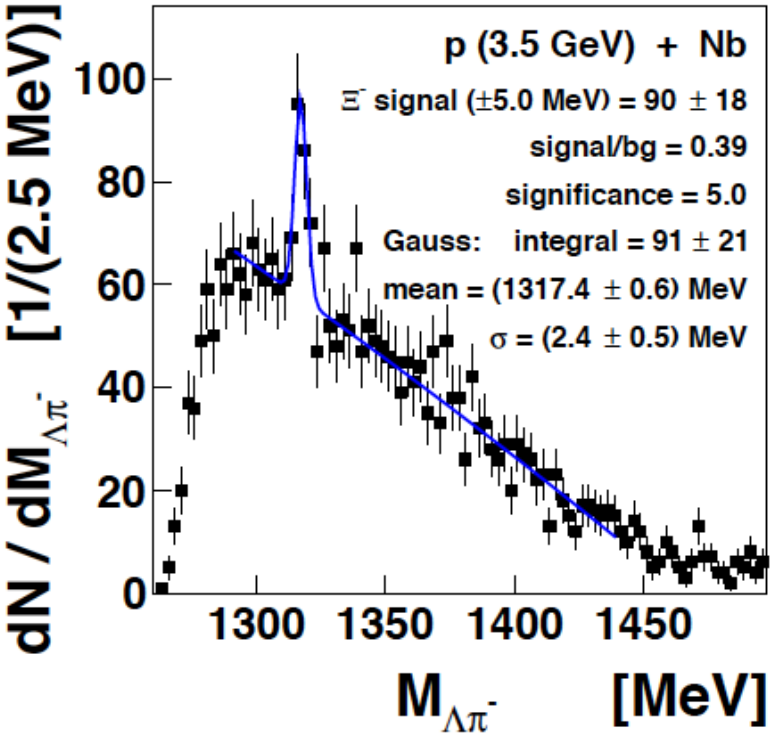
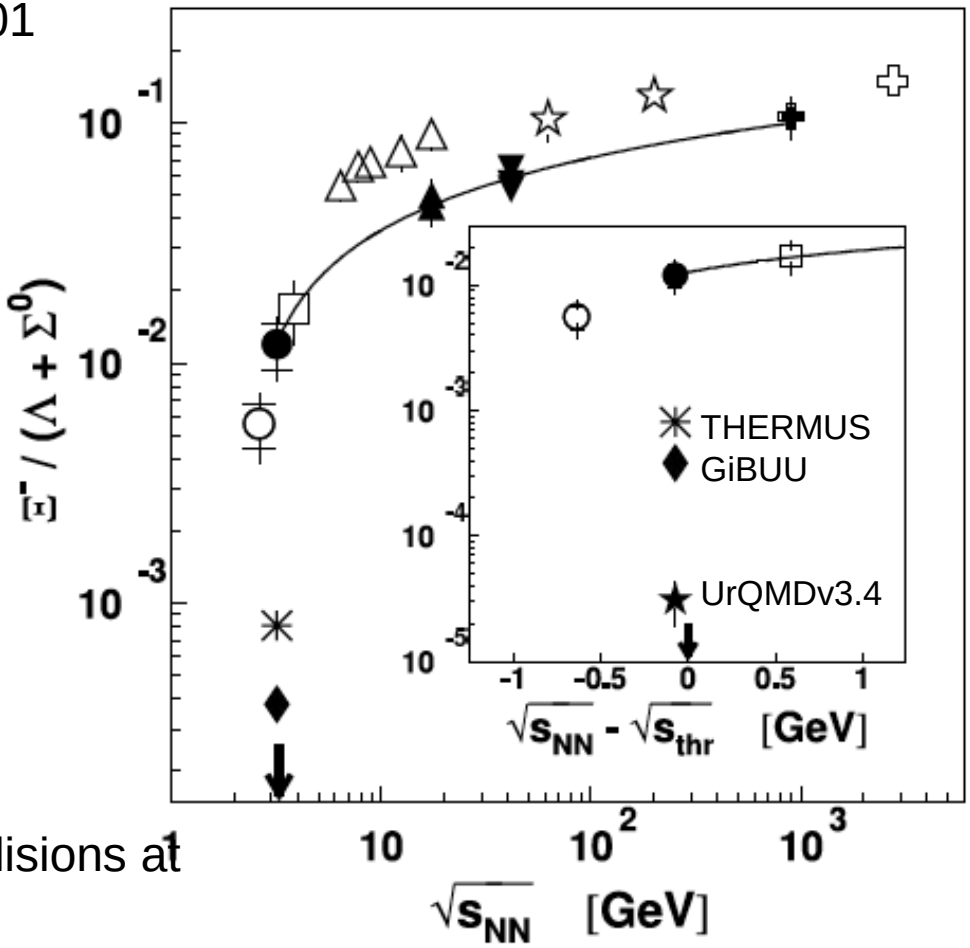
Exoticas: Subthreshold Ξ^-

Phys.Rev.Lett. 114 (2015) 21, 212301





Subthreshold Ξ^- production in p+Nb collisions at

E_{beam}= 3.5 GeV $\rightarrow \sqrt{s}-\sqrt{s_{th}}$=-70MeV

Parameterization: $f(x)=C(1-(D/x)^G)^H$

Excess already present in cold nuclear matter!

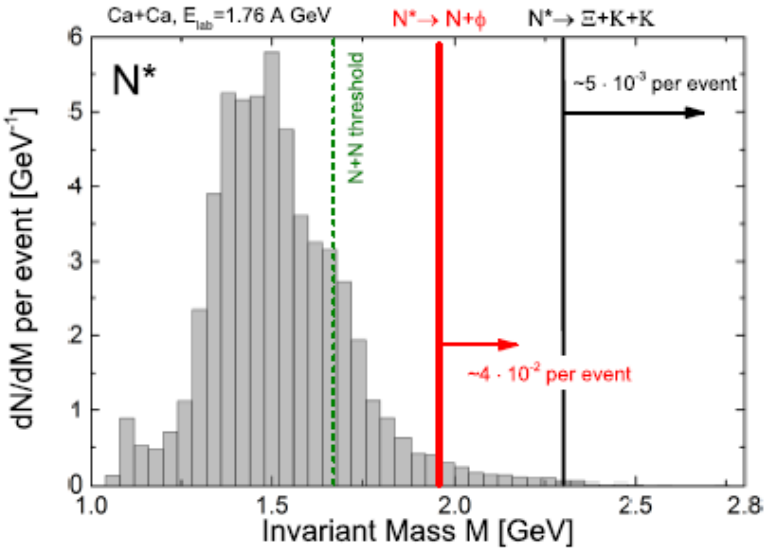
Manuel Lorenz

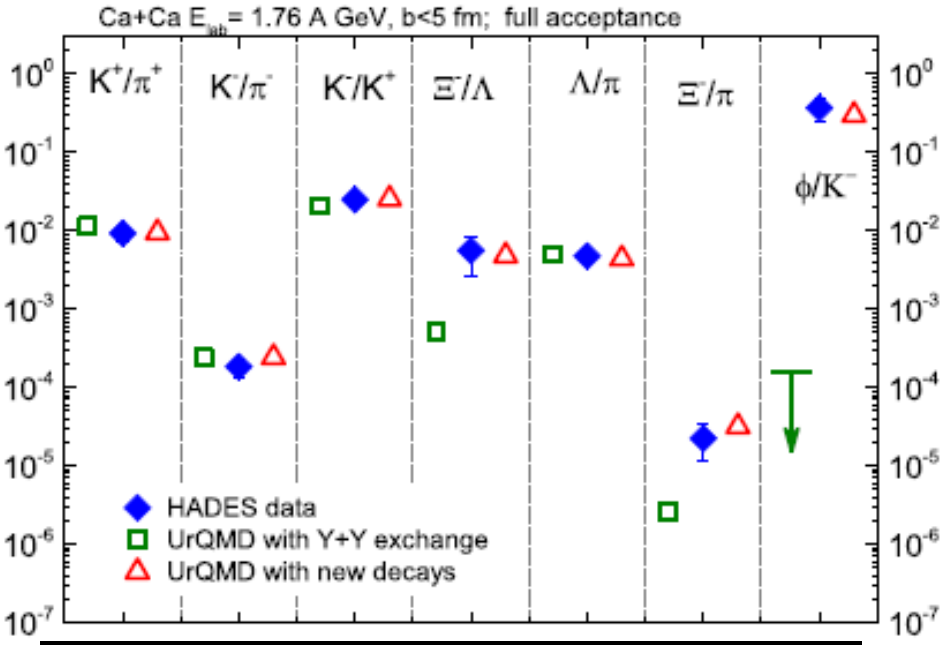
HADES

Modelling strangeness production in heavy ion reactions

Introducing branching ratios to Φ, Ξ
for heavy resonances:
constrained by elementary reactions (e.g. p+Nb or p+p data)

- small and consistent with OZI rule
- branching ratios needed in the tails of the resonances





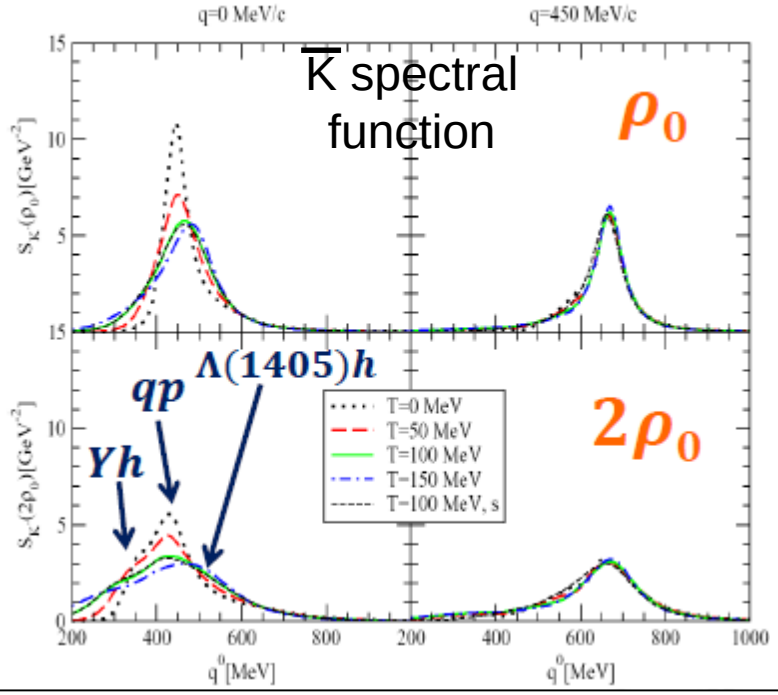
Markus Bleicher
UrQMD

PHSD:	Daniel Cabrera
	Pierre Moreau
URQMD:	Hendrik van Hees
Ref. calculations:	Boris Tomasik...

Modelling strangeness production in heavy ion reactions

K/$\bar{K}$N in hot/dense matter: self-consistent and unitary coupled-channel approach

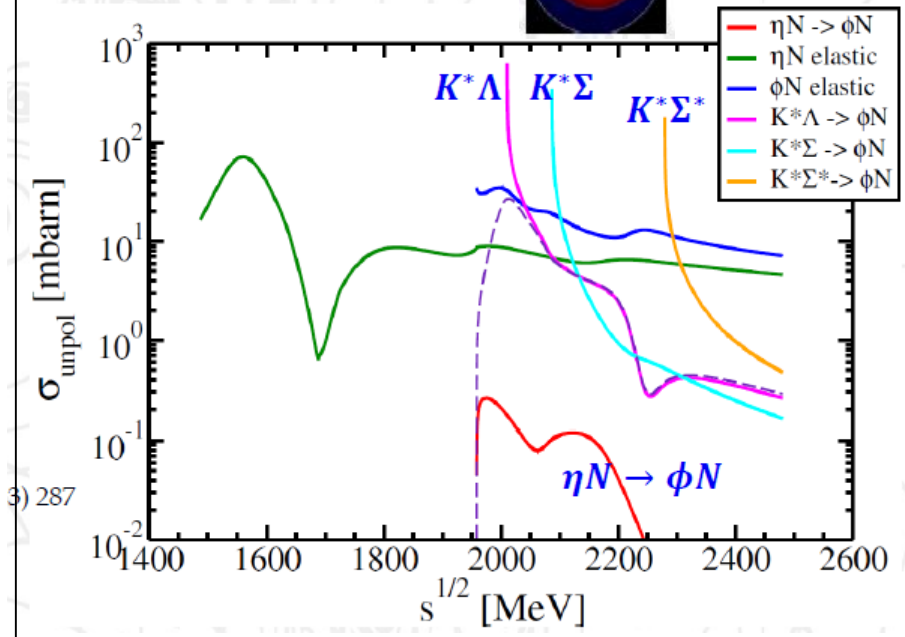
Binary reactions:
cross sections/transition rates
Propagation:
K, $\bar{K}$ and Y optical potentials
Production:
K, $\bar{K}$ (off-shell) spectral functions



ϕ and Ξ production in the hadronic phase

- ηN channel small
- strangeness exchange

Daniel Cabrera



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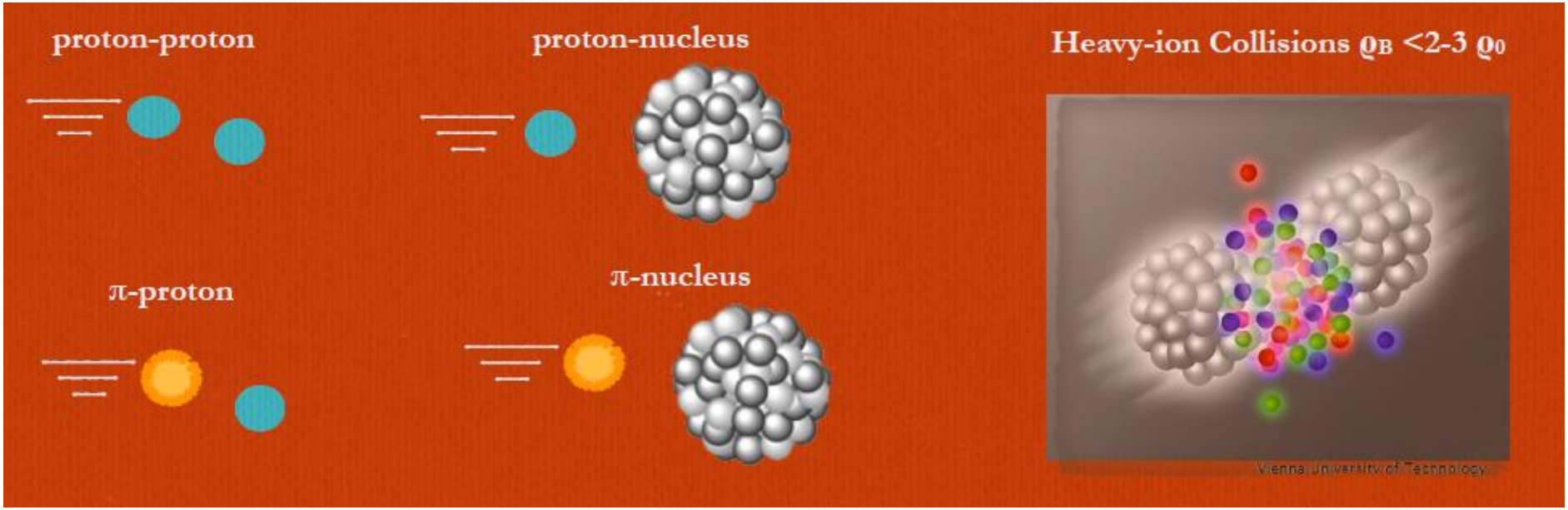
Strangeness production mechanisms at SIS energies

Elementary reactions



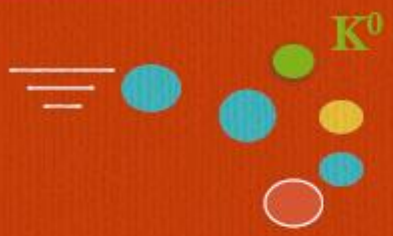
p+p/Nb	Laura Fabbietti *Rafal Lalik* *Oliver Arnold*

Inclusive Kaon production in elementary collisions

p+p @ 3.5 GeV

J.-C. Chen

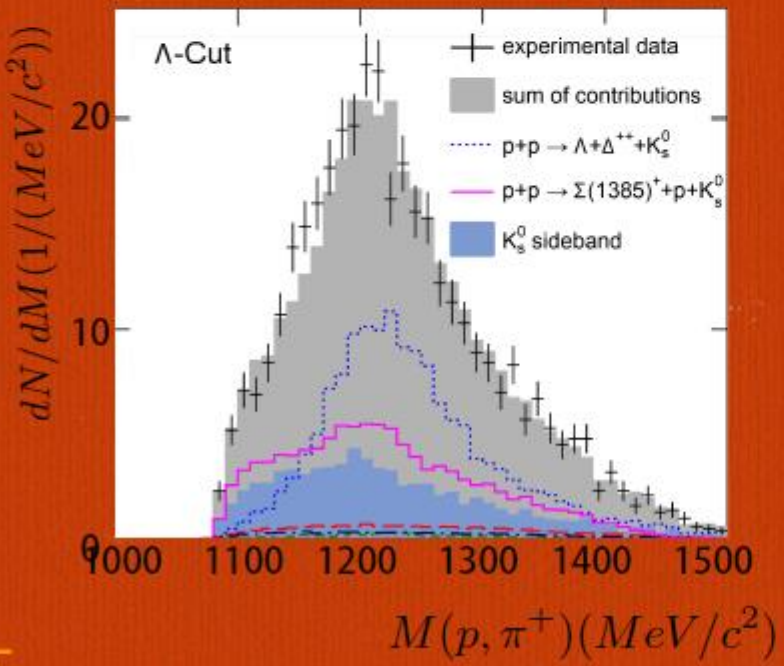
HADES Coll.], Phys. Rev. C 90, 015202 (2014)
" Medium effects in proton-induced K^0 production at 3.5 GeV"
HADES Coll., Phys. Rev. C90 (2014) 054906



X

Reference Measurement of the K^0_S production in p+p to "calibrate" the interpretation of the p+A data, where the interaction between Kaons and nucleons is studied

$$p + p \rightarrow K^0 + \Lambda + p + \pi^+$$



New Data Base from our exclusive Measurements

Reaction: p + p →	$\sigma_{anisotropic}$ [μb]
$\Lambda + p + \pi^+ + K^0$	$2.57 \pm 0.02^{+0.21}_{-1.98} \pm 0.18$
$\Lambda + \Delta^{++} + K^0$	$29.27 \pm 0.08^{+1.67}_{-1.46} \pm 2.06$
$\Sigma^0 + p + \pi^+ + K^0$	$1.35 \pm 0.02^{+0.10}_{-1.35} \pm 0.09$
$\Sigma^0 + \Delta^{++} + K^0$	$9.26 \pm 0.05^{+1.41}_{-0.31} \pm 0.65$
$\Sigma^+ + p + K^0$	$26.27 \pm 0.64^{+2.57}_{-2.13} \pm 1.84$
$\Sigma(1385)^+ + p + K^0$	$14.35 \pm 0.05^{+1.79}_{-2.14} \pm 1.00$

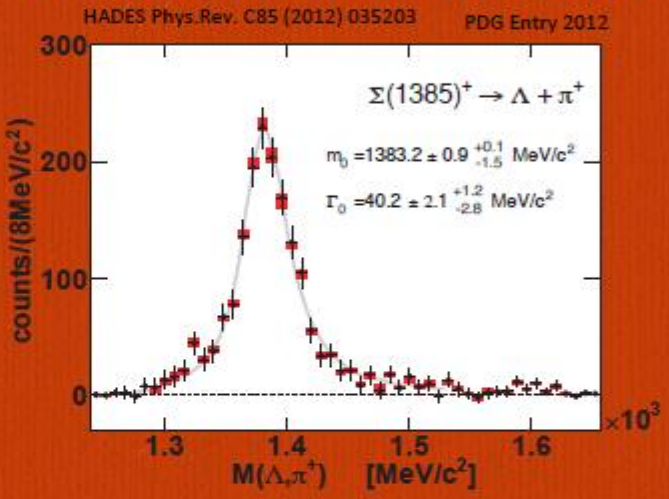
Laura Fabbietti

Resonances measured in elementary collisions

p+p @ 3.5 GeV

J. Siebenson

Resonance production
Coupling to different final states

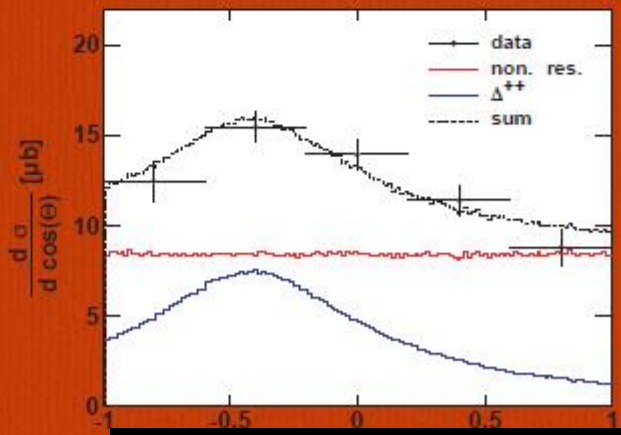


$$p + p \rightarrow \Delta^{++} + n \rightarrow \Sigma(1385)^{+} + K^{+} + n$$

$$\Delta(1900-2000)^{++} \rightarrow \Sigma^{+}(1385) + K^{+}$$

$$\Gamma = 150 - 200\ \mathrm{MeV/c^2}$$

~ 30%



Chinowsky, W. *et al.* Phys.Rev. 165 (1968) 1466-1478

Role of the Δ*(1940) in the π+*p*→*K*+Σ+(1385) and *pp*→*nK*+Σ+(1385) reactions
Ju-Jun Xie, En Wang, Bing-Song Zou

arxiv.1405.5586

Laura Fabbietti

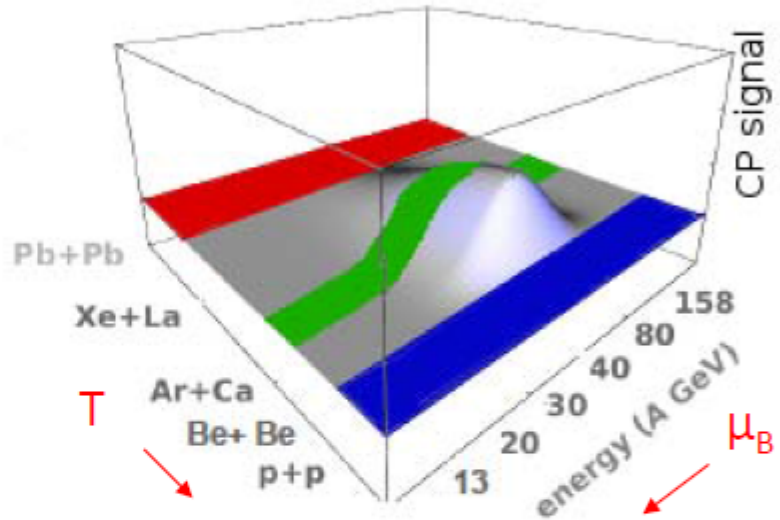
Search for the critical point

search strategy: 2-d scan of phase diagram in E, A → μ_B

Peter Seyboth

expect "hill" of fluctuations

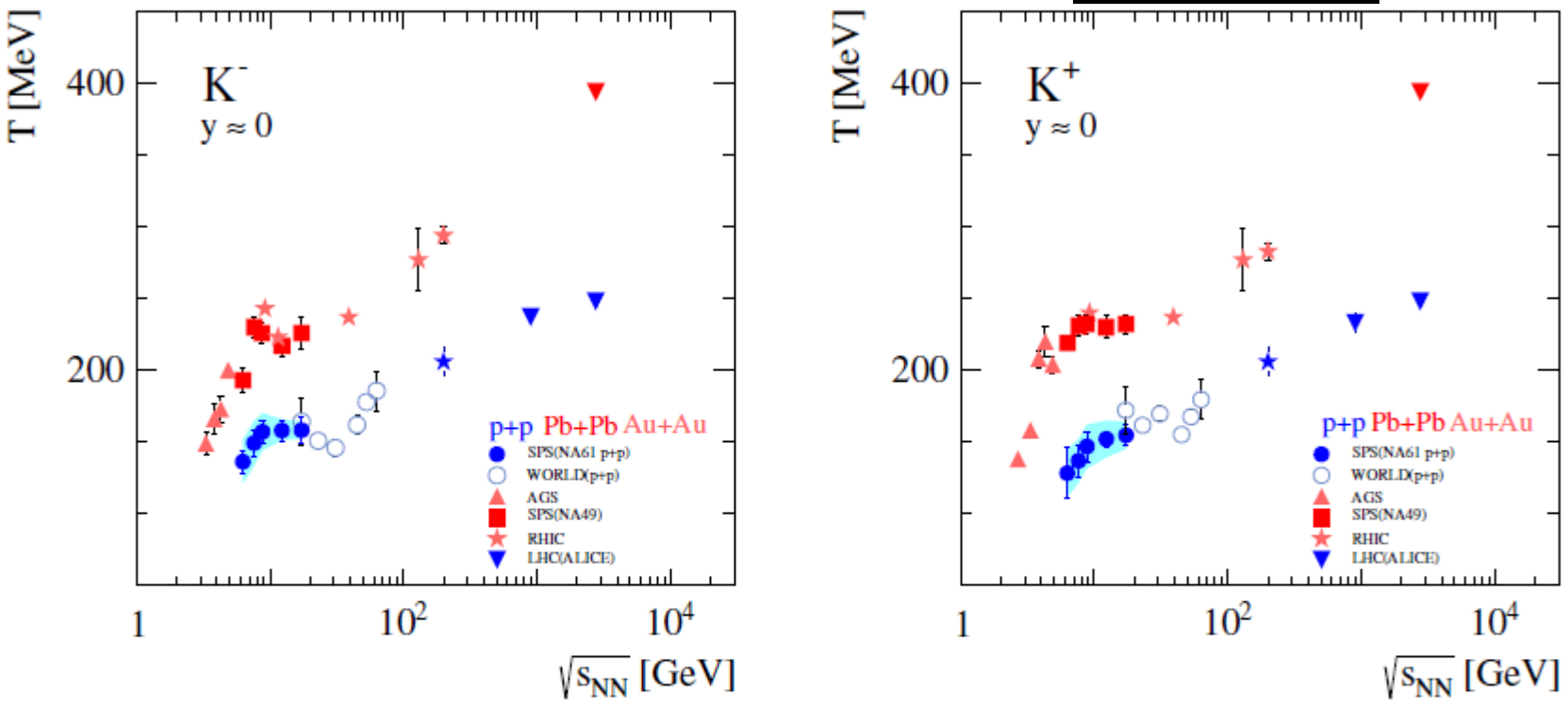
experimental control parameters:
- collision energy → μ_B, T
- size A of colliding nuclei, and/or centrality of collision
  → duration of evolution after phase transition
  → slight change of T



- expected size of fluctuation signals (ω, Φ_x ,… $\propto \xi^2$) is limited by short lifetime and size of collision system (M.Stephanov, et al., PRD60,114028(1999)
- correlation lengths ξ estimated to increase from 0.5 fm in hadron matter to only 1.5 - 3 fm in central Pb+Pb collisions near the CP
- evolution of collision system after phase transition may erase CP signals
  → collisions of medium size nuclei may be the best reactions for the search

p+p: K inverse slope parameter T – step

Dag Larsen



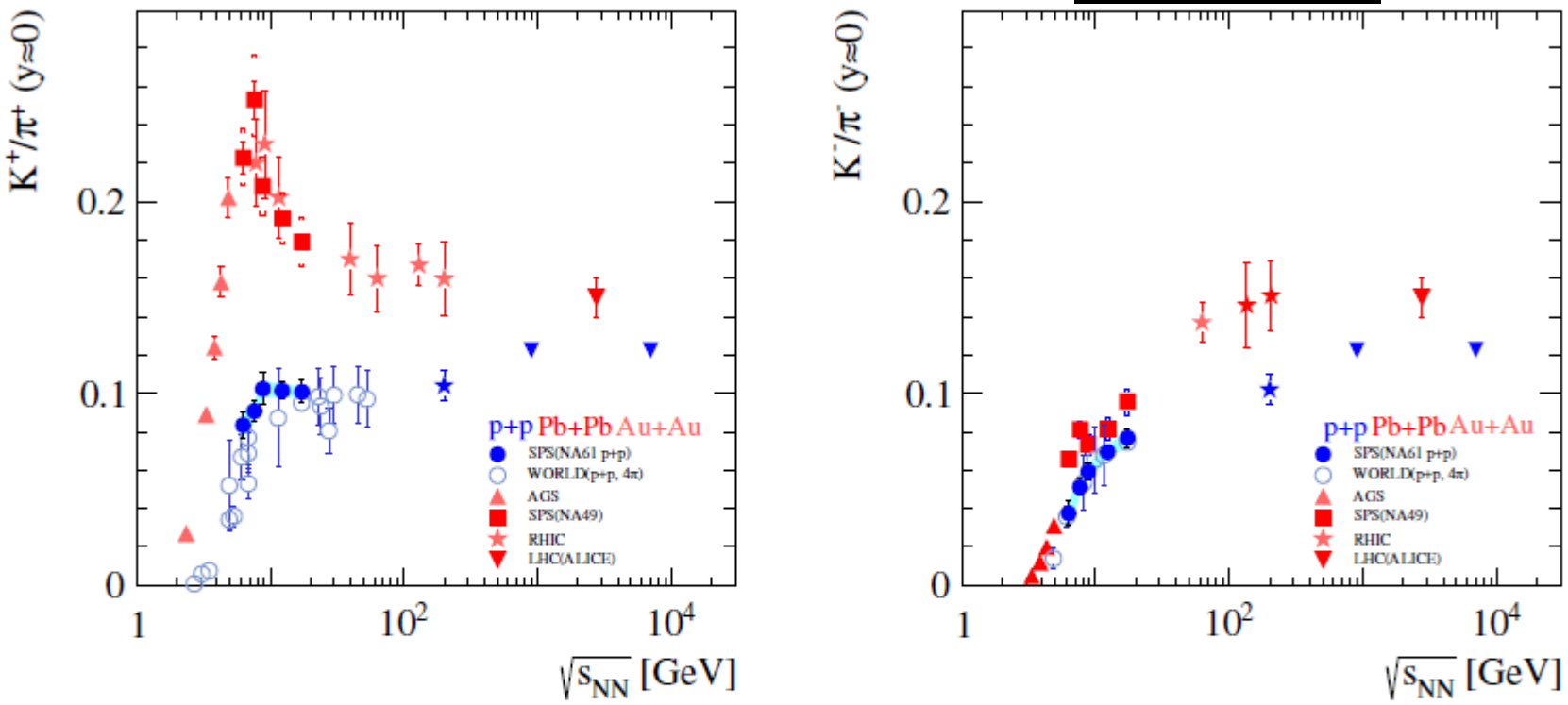
- In p+p collisions energy dependence of K inverse slope parameter T exhibits rapid changes like in Pb+Pb interactions

Phys.Rev. C69 (2004) 044903, STAR: Phys.Rev.C79:034909,2009;
ALICE: PLB 736 (2014) 196-207, Eur. Phys. J , C (2011) 71:1655

Andrey Seryakov
Evgeny Andronov

p+p: K/π – horn

Dag Larsen

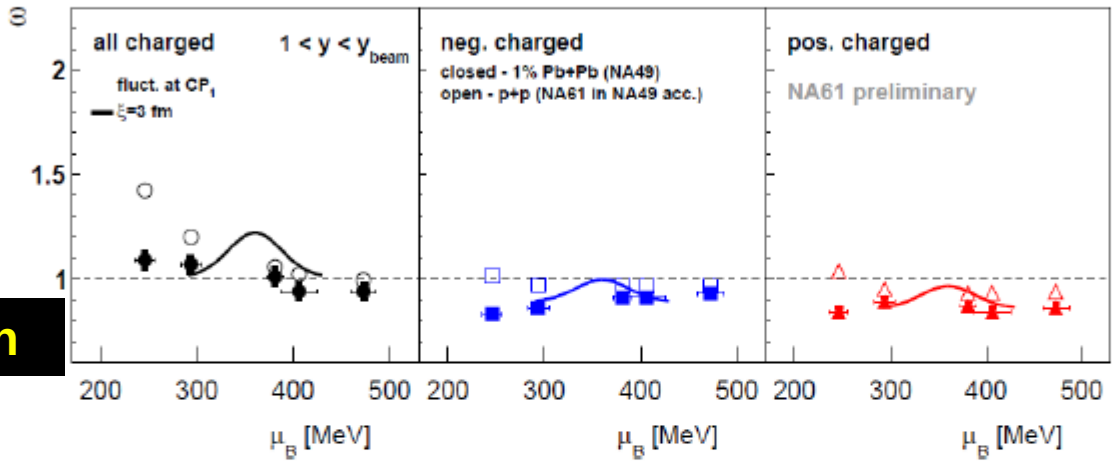


- A shadow of the Pb+Pb horn structure is visible in p+p but significantly reduced

NA61/SHINE: 2014 status report http://cds.cern.ch/record/1955138
Z.Phys. C65 (1995) 215-223 (), Z.Phys. C71 (1996) 55-64 (K); BRAHMS: Phys.Rev.C72:014908,2005;
ALICE: Eur. Phys. J , C (2011) 71:1655, PRL 109, 252301 (2012), PhD thesis of Chojnacki, M.

NA49/NA61: scaled variance of the multiplicity distribution

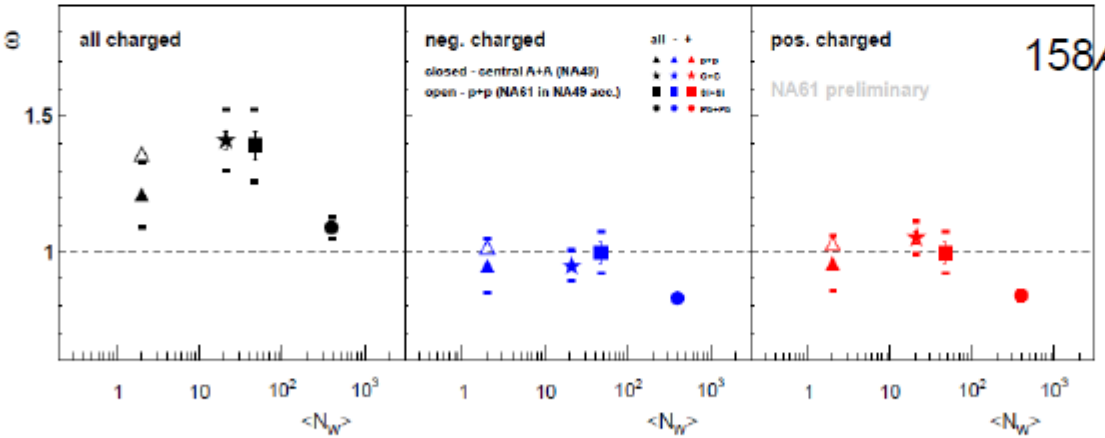
NA49 results for 1% most central Pb+Pb collisions (C.Alt et al.,PRC78,034914(2008))
NA61 results for inelastic p+p collisions (preliminary)



$\kappa_2 = \langle(\delta N)^2\rangle$
$\omega_2 = \kappa_2/\langle N\rangle$

predicted curves based on M.Stephanov for CP at μ_B=360 MeV

rapidity $y_\pi > 1.0$



158*A* GeV

NA61 p+p:
statistical errors only

- no significant peak in the μ_B (energy) dependence of scaled variance ω
- indication of a maximum for collisions of medium size nuclei at 158*A* GeV

P. Seyboth

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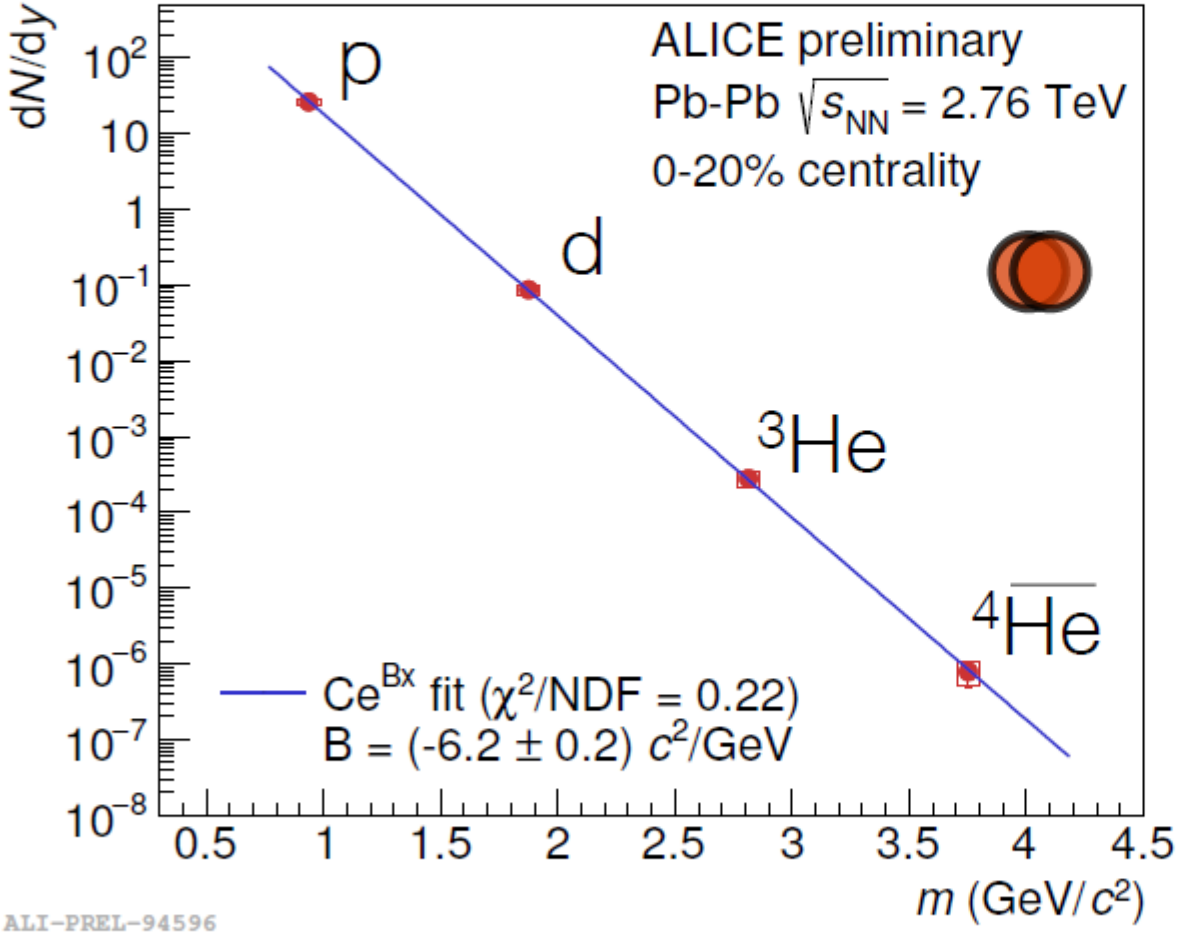
Production of nuclei and hyper matter

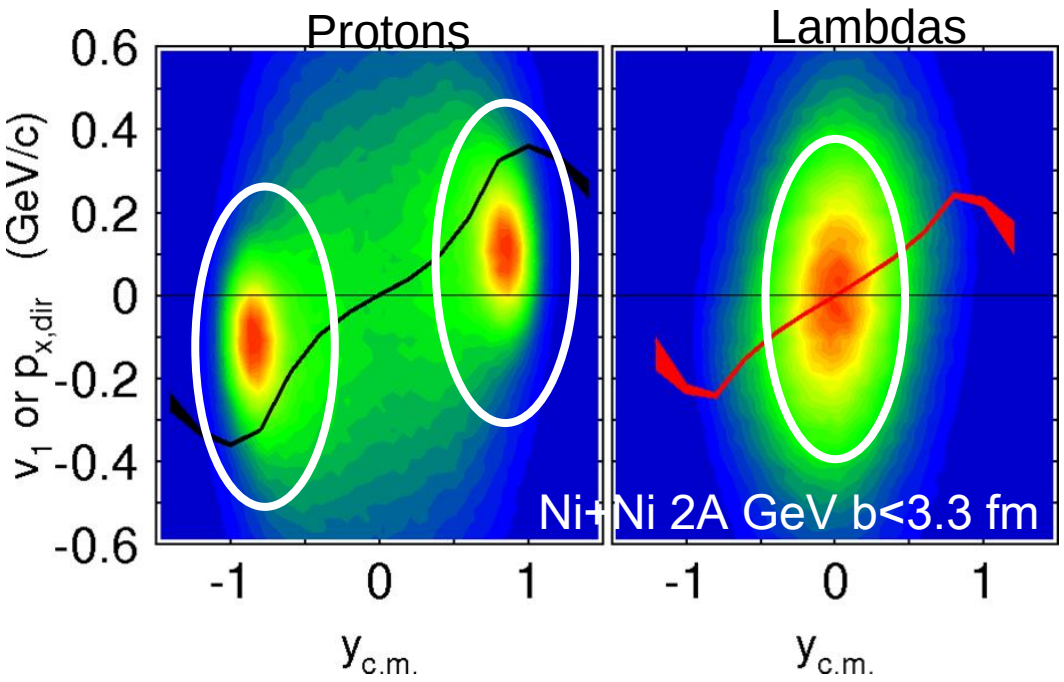
Anti-α production in Pb-Pb Collisions



- First observed at RHIC in heavy-ion collisions
- Production rates (dN/dy) follows expected exponential fall with mass
- Approximate 300x penalty factor for each added baryon
- Characteristic slope:
  - ~161 MeV/c^2

David Chinellato

Hyperon interactions and hypernuclei production in heavy ion collisions



- no missing mass – invariant mass
- rare fragments, population of n/p-rich isotopes
- multi-strange objects - production of XXL-Hypernuclei

Experiments

SIS: HYPHI, FOPI, HADES
AGS: E864
RHIC: STAR
LHC: ALICE

Hypernuclei:

HYPHI C. Rappold
ALICE D. Chinellato
F. Barile
Theory A. LeFevre, V. Kireev
A. Botvina

Interactions:

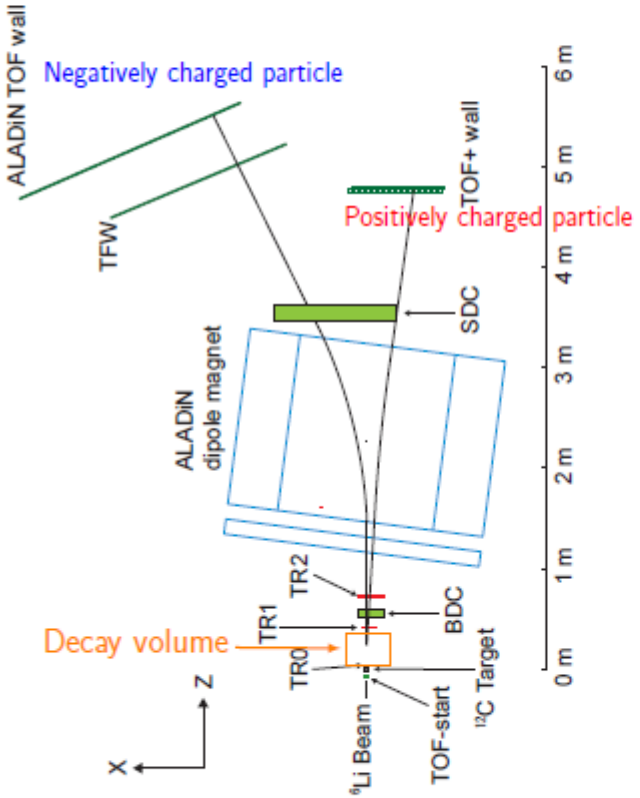
STAR J. Shen

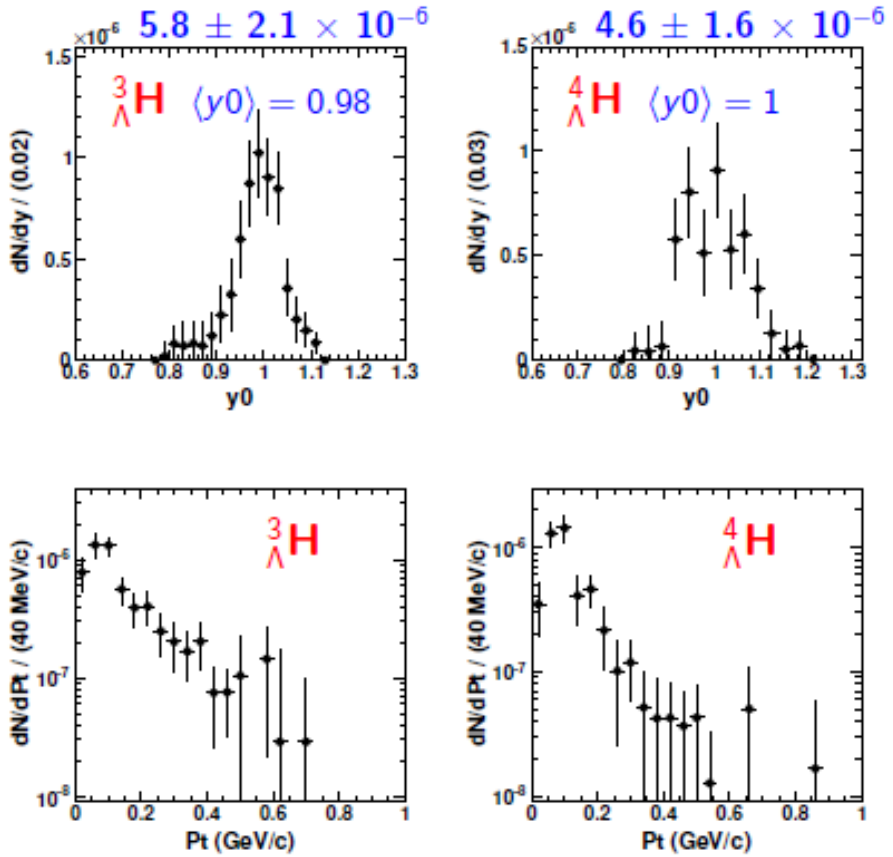
Hyperon puzzle:

I. Vidana, *E. Kolomeitsev, D. Alvarez-Castillo, ...*

Spectator region (projectile) : HypHI results

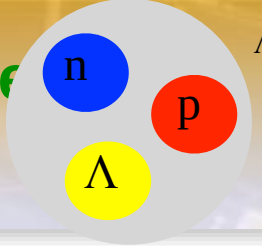
Fixed target, Reaction : ^{6}Li+^{12}C @ 2 *A*GeV or $\sqrt{s_{NN}} = 2.7$ GeV





[A. U. Abdurakhimov et al., N.Cimento A102, 645 (1989)]

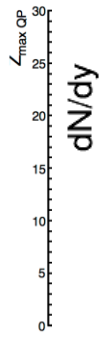
PHSD (IQMD) + FRIGA: Clusterisation time influe on hypernuclei (phase space and yields)

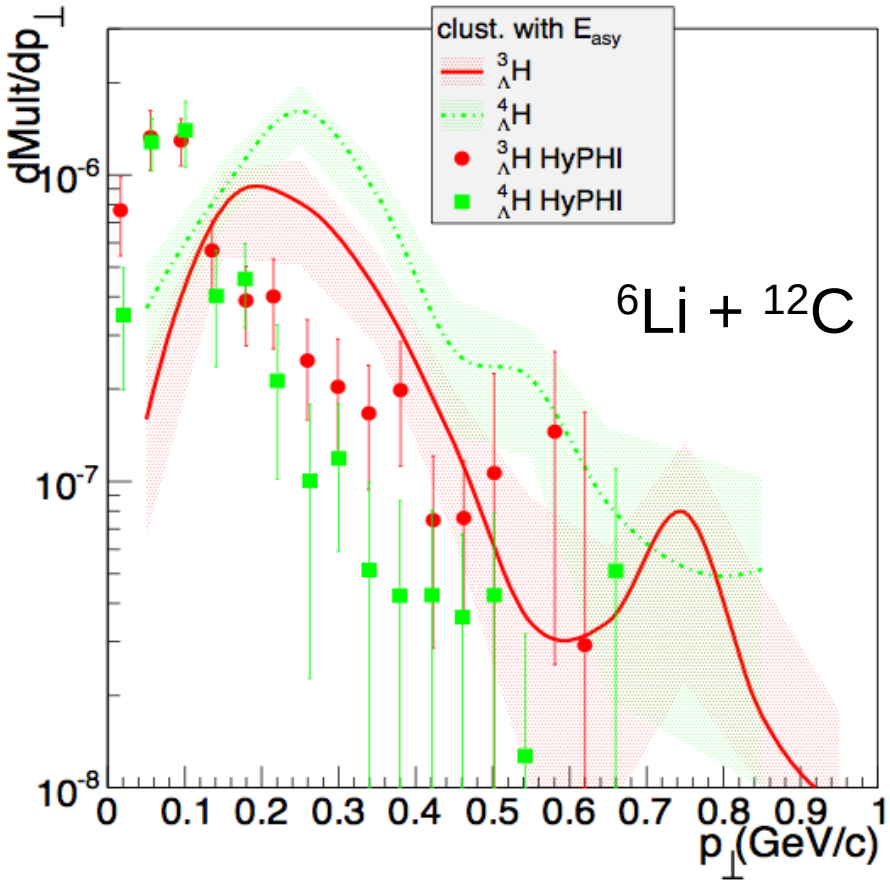


An example: Au+Au @ 11.45 A.GeV, b=6 fm (passing time = 7.5 fm/c) from

Ingredients to the binding energy of the clusters:

- Volume component: mean field (Skyrme, dominant), for NN, NΛ (Hypernuclei)
- Surface effect correction: Yukawa term.
- Asymmetry energy
- Extra « structure » energy $(N,Z,\rho) = B_{MF}(\rho).((B_{exp}-B_{BW})/(B_{BW}-B_{Coul}-B_{asy}))(\rho_0)$
- ^{3}He+n recombination.
- Secondary decays





Arnaud Le Fèvre

$\Lambda\Lambda$ correlation function

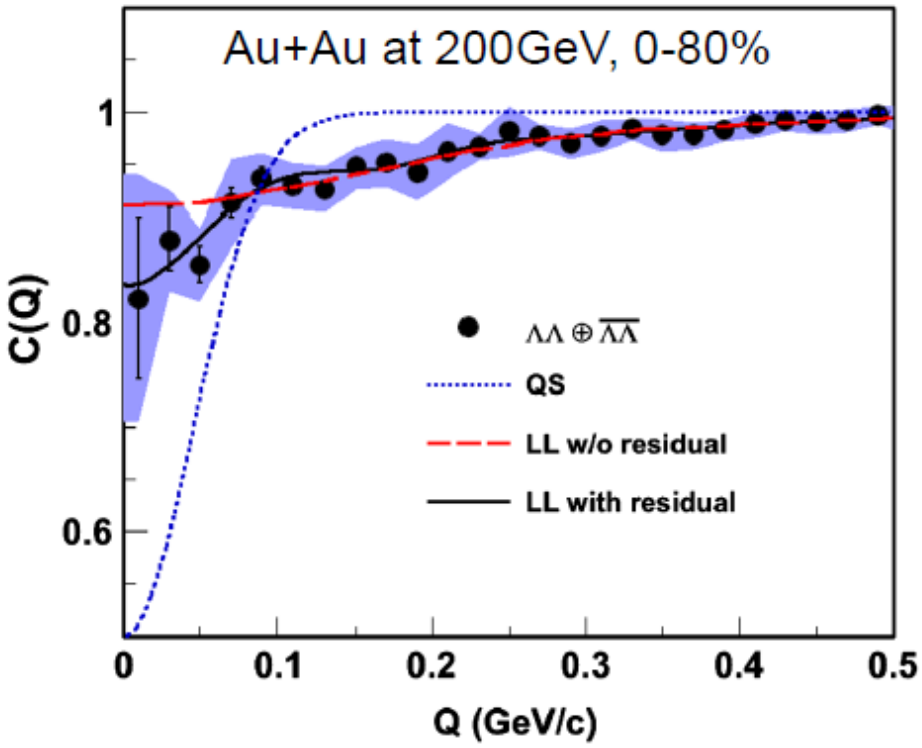
Fit using Lednicky-Lyuboshitz analytical model

$$CF=N(1+\lambda[\Sigma_S \rho_S (-1)^S \exp(-r_0^2 Q^2)+\Delta CF^{FSI}+a_{res}\exp(-Q^2 r_{res}^2)])$$

N- normalization, λ - suppression parameter

SJNP 35 (1982) 770

Jinhui Chen



STAR Col. Phys. Rev. Lett. 114, 022301(2015)

- ☑ CF(Q=0) > CF_{QS}(Q=0)
  - – interaction is attractive
- ☑ High Q tail -> residual correlations from Σ^0, Ξ
- ☑ Interaction parameters:

$$\chi^2/\mathrm{NDF} = 0.56$$

  - – Emission radius-

$$r_0 = 2.96 \pm 0.38^{+0.96}_{-0.02}\ \mathrm{fm}$$

  - – Scattering length-

$$a_0 = -1.10 \pm 0.37^{+0.68}_{-0.08}\ \mathrm{fm},$$

  - – Effective range-

$$r_{\mathrm{eff}} = 8.52 \pm 2.56^{+2.09}_{-0.74}\ \mathrm{fm},$$

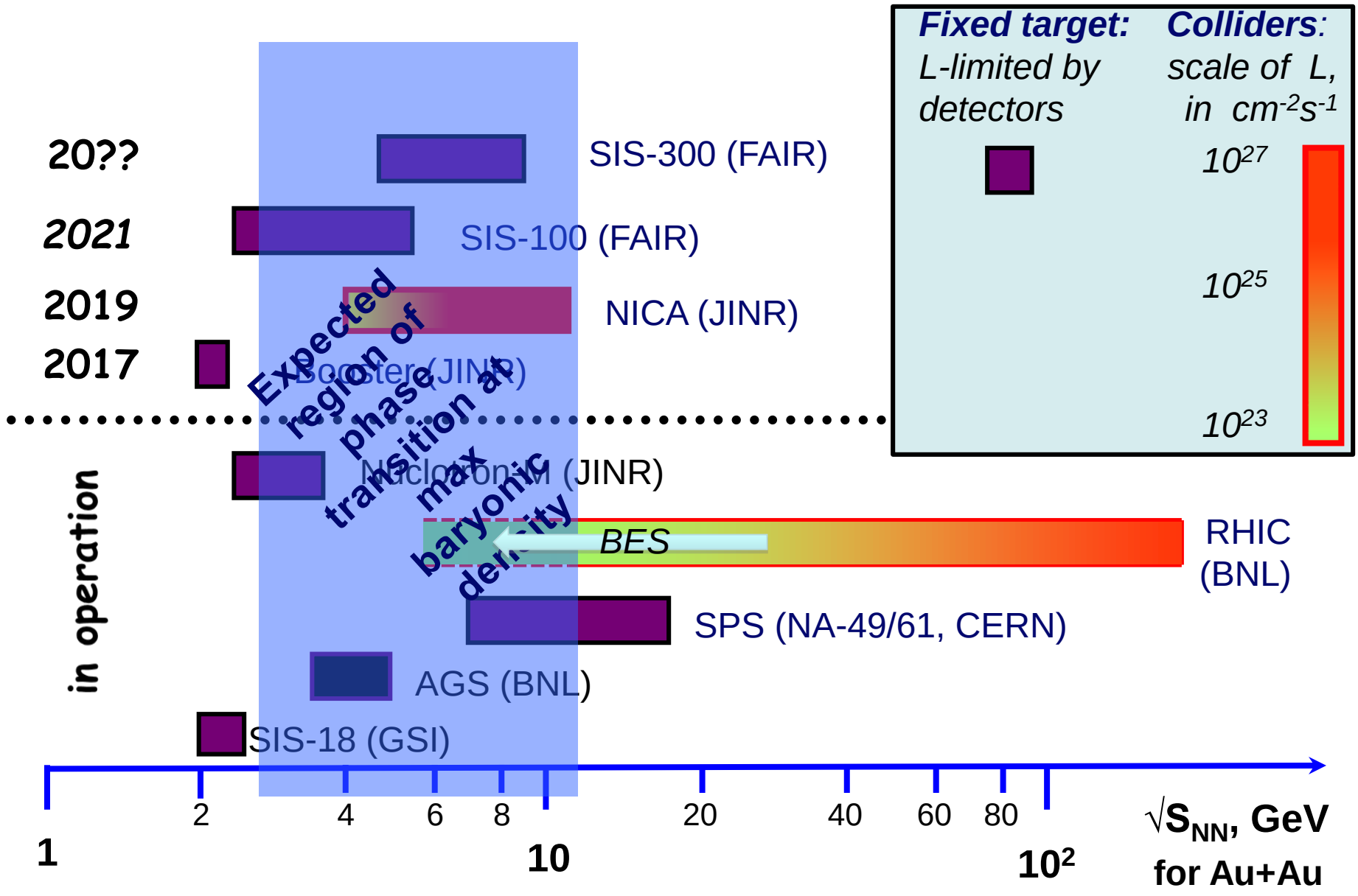
Summary of the summary

Summary

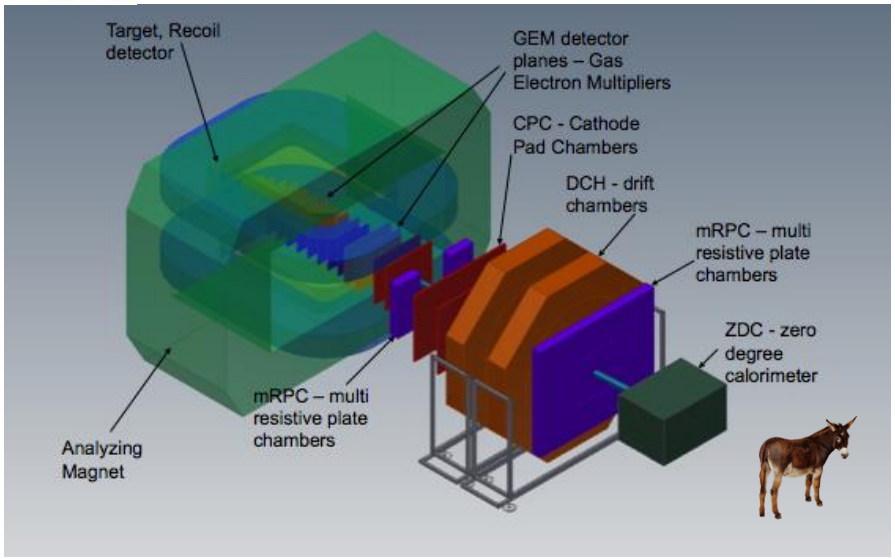
- New “high rate” experiments at SIS18 with
  - high intensity beams and high quality data and rare probes
  - exotica – double strangeness production at sub-sub-threshold energies
- Elementary reactions to understand
  - disentangle reactions channels for strangeness production at threshold energies, PWA analysis
  - contribution of high mass resonances to strangeness production
  - more data needed to disentangle role of resonances and production mechanisms of strange particles in HICs
- Search for critical point
  - baseline pp data from SHINE
  - interesting hints were found in the energy and system size dependence of critical point sensitive fluctuation observables
- Production of hyper matter
  - understanding the ΛN and ΛΛ interaction in dense matter
  - ΛΛ interaction at STAR
  - (Anti) Hypernuclei production mechanisms?

Outlook
New facilities

Present and future HI machines



BM@N (Baryonic Matter at Nuclotron): *the 1st stage*



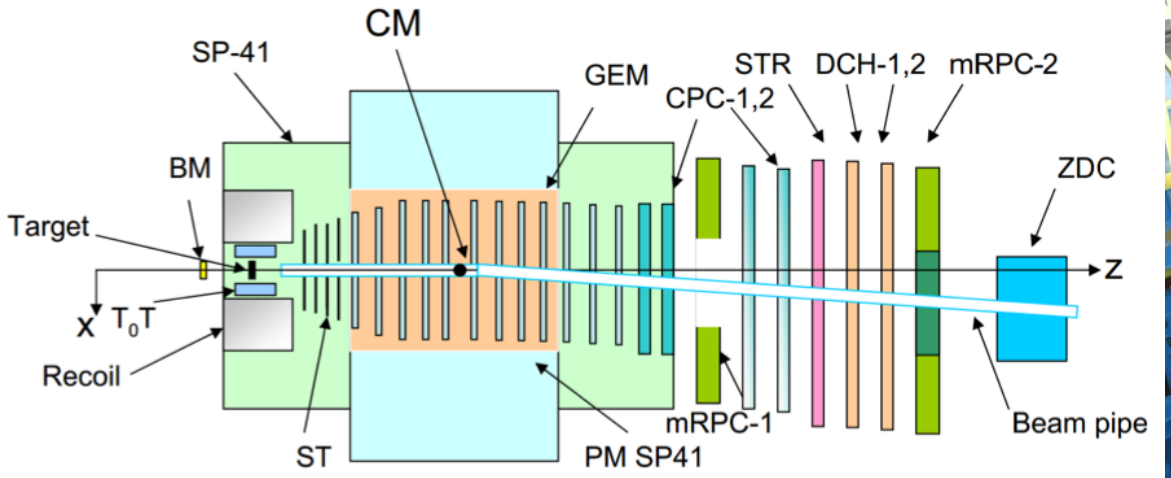
Expression of interest from scientists:

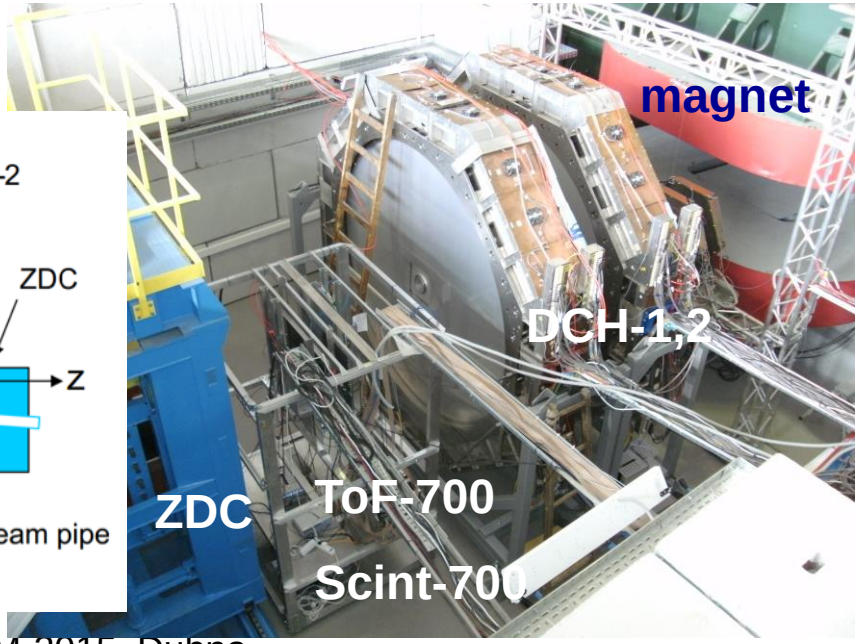
IN, SINP MSU, IHEP + S-Ptr Univ. (RF);
GSI, Frankfurt U., Gissen U. (Germany):
+ CBM-MPD IT-Consortium,

Physics:

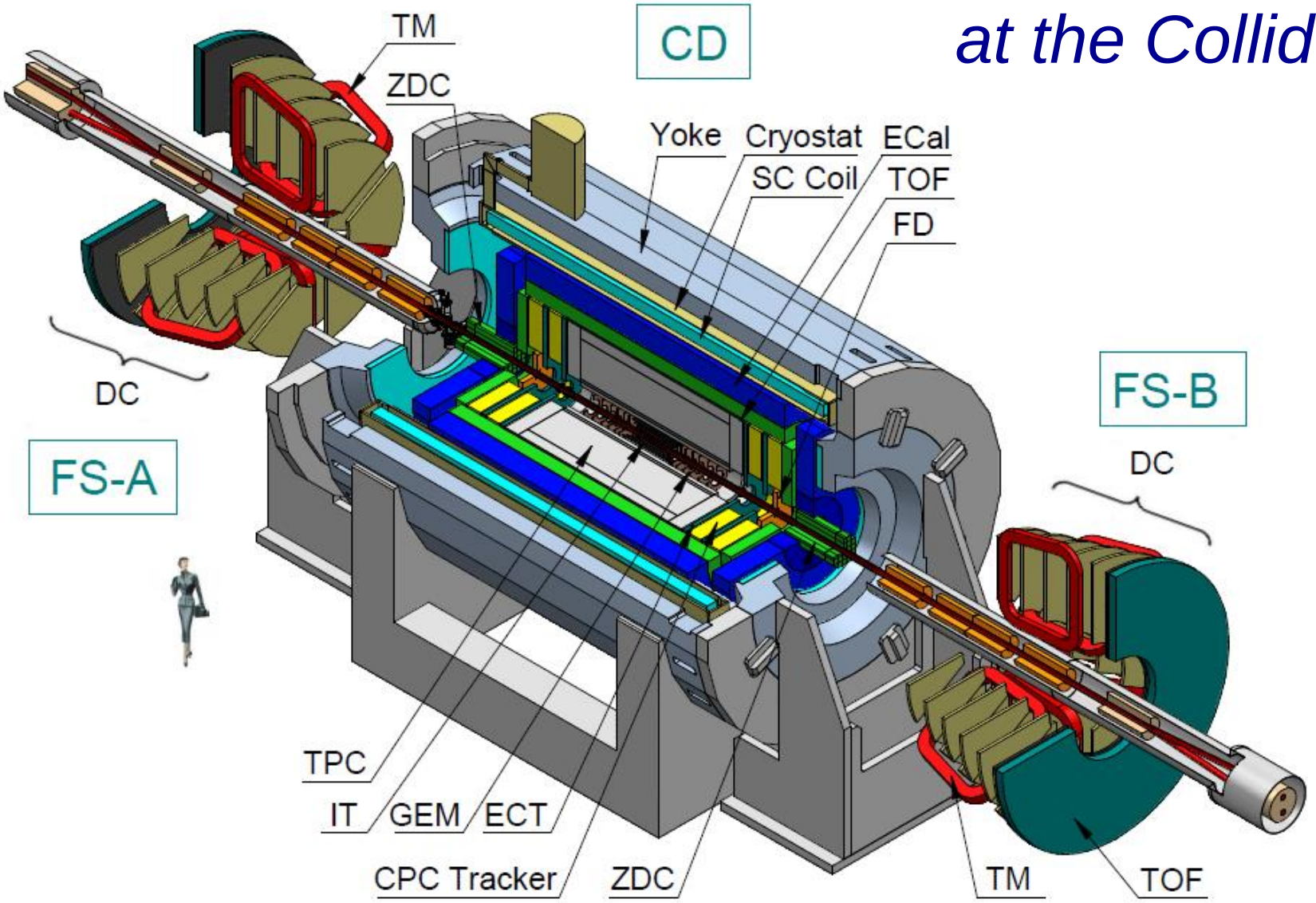
- ✓ *hyperon production*
- ✓ *hadron femtoscopy*
- ✓ *in-medium effects for strange & vector mesons*
- ✓ *electromagnetic probes (optional)*

BM@N *schematic view*

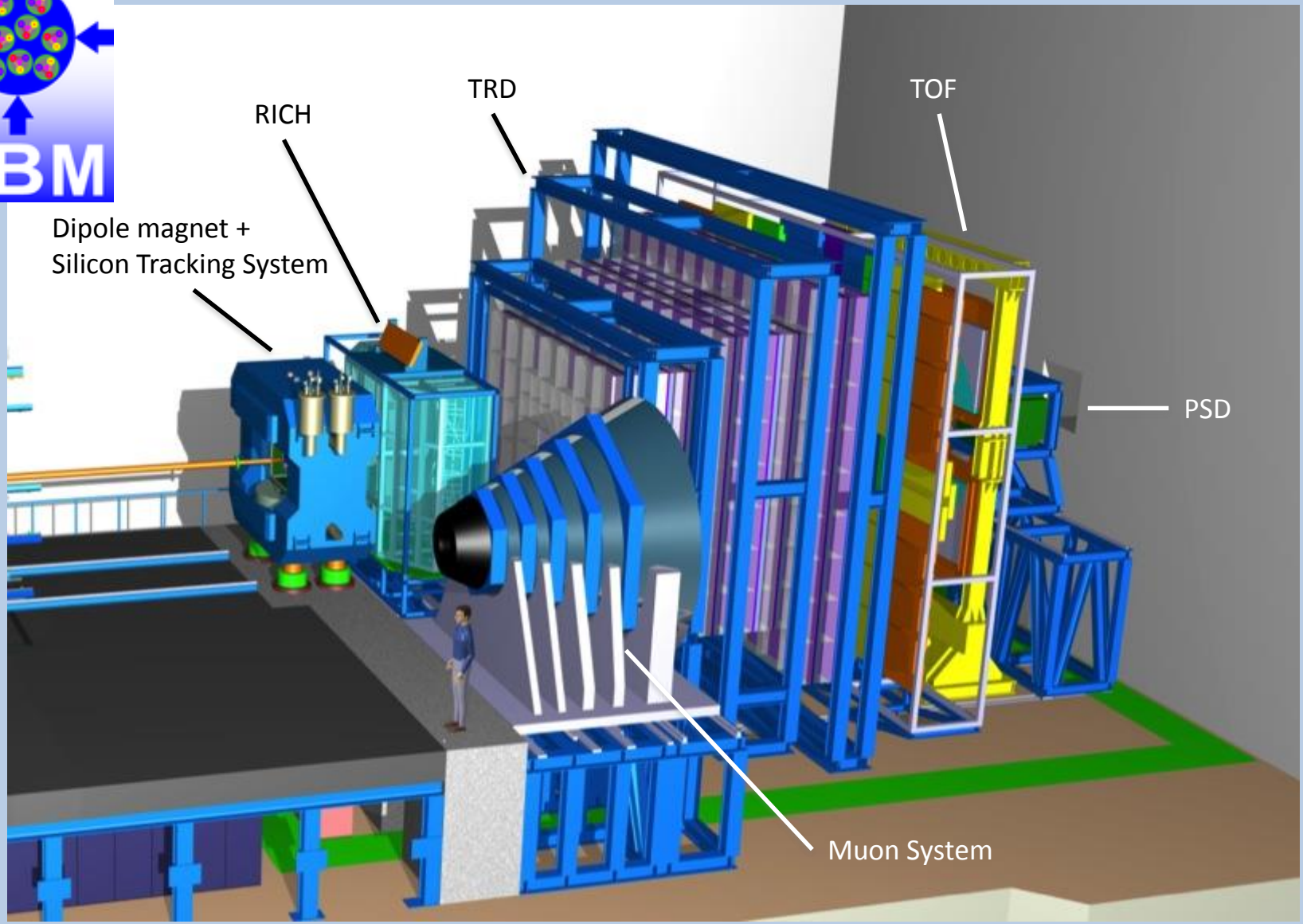




Experiments at NICA:
MultiPurpose Detector (MPD)
at the Collider



CBM: Experiment Systems



Thank you to all of you for making this conference a success and ...
thank you to the organizers

Oliver Arnold

Summary

- Correlation function for protons calculated and source size for proton pairs extracted
- The source size of protons used as input to extract an effective scattering length for Lambda-proton pairs

Extracted values:

$$R_G^{pp} = 2.016^{+0.04}_{-0.029} \text{ fm}$$

$$a^{\Lambda p} = 1.967^{+0.157}_{-0.169} \text{ fm}$$

$$r^{\Lambda p} = 3.824^{+1.096}_{-0.872} \text{ fm}$$