FOPI and the Physics of Strangeness

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FWF
Der Wissenschaftsfonds.

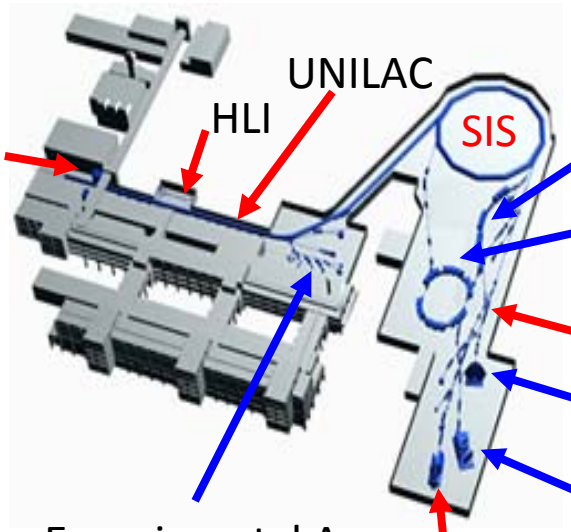
Contents

- The Heavy Ion Synchrotron SIS at the GSI
- The FOPI Detector
- Strangeness Production
  - Heavy ion collions (dense baryonic matter)
  - Proton+proton collisions
  - Pion induced reactions
- Future Plans
- Conclusions

SIS – Schwerionen-Synchrotron

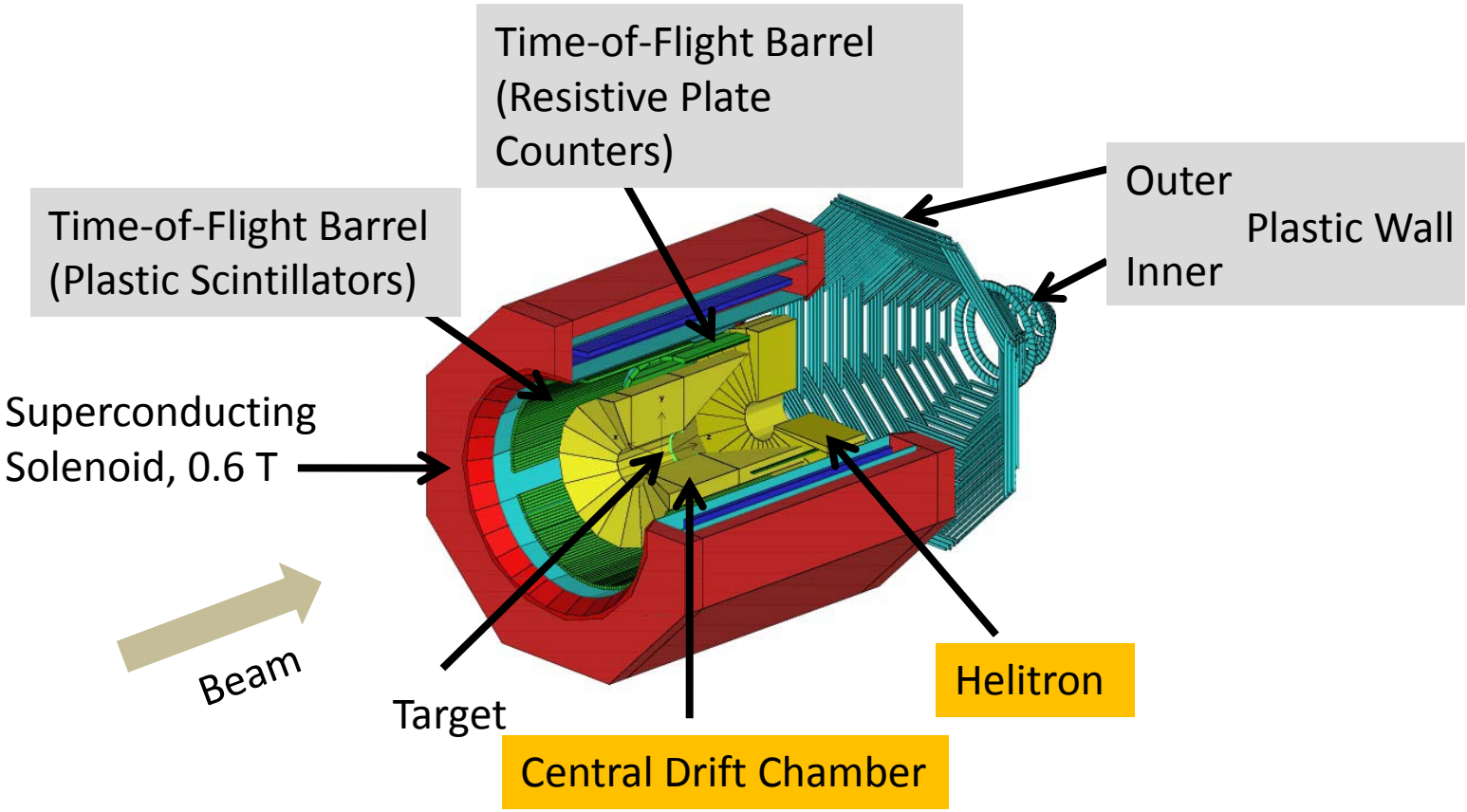
216 m circumference
18 Tm bending power

Beams at the SIS:
Ions (Li – U) ≤ 2 GeV/u (A/q=2)
Protons ≤ 4.5 GeV
Pions ≤ 2.8 GeV/c



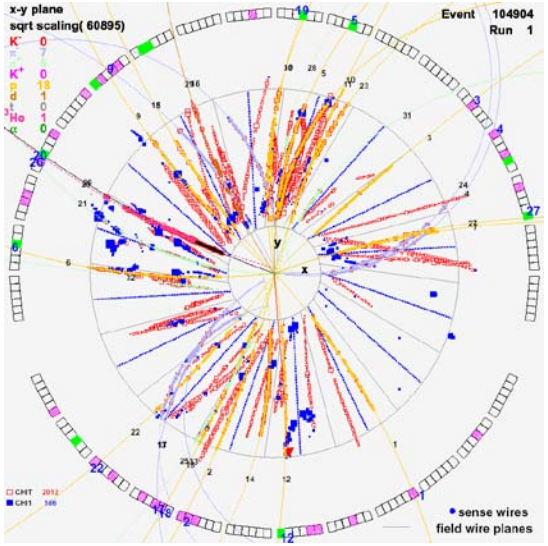
- Accelerator physics
- Atomic physics
- Nuclear physics
- Bio physics
- Plasma physics
- Material research
- Theory

The FOPI Detector

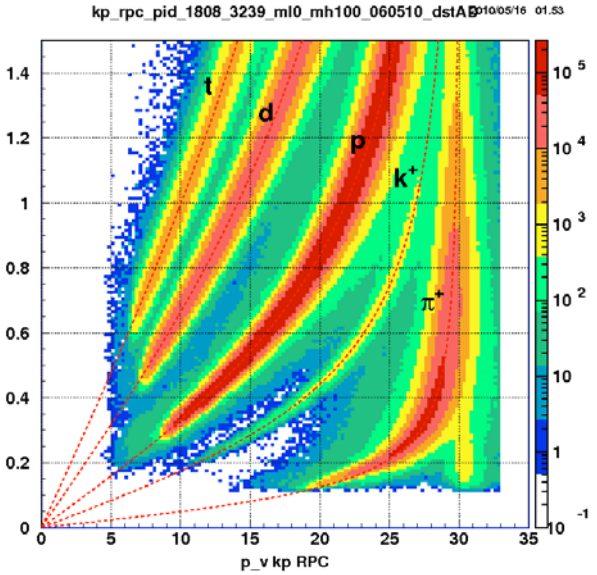


NIPNE Bucharest, KFKI Budapest, LPC Clermont-Ferrand, GSI Darmstadt, FZ Dresden-Rossendorf, University Heidelberg, ITEP Moscow, KI Moscow, TU Munich, Korea U Seoul, IReS Strasbourg, University Warsaw, SMI Vienna, RBI Zagreb

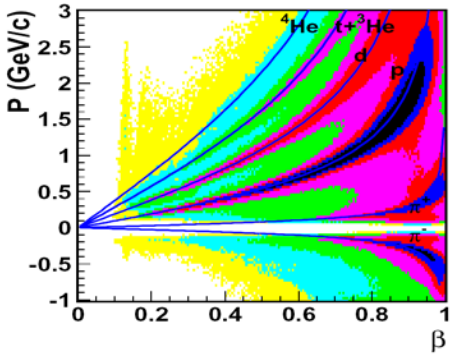
Particle Identification



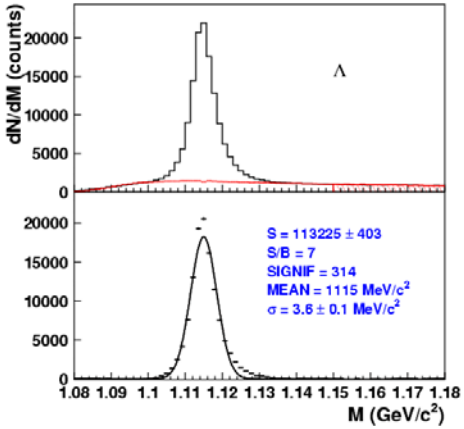
Event Display
Central Drift Chamber
(x,y) plane
Ni+Ni@1.93 AGeV



PID:
Matched tracks
CDC-RPC



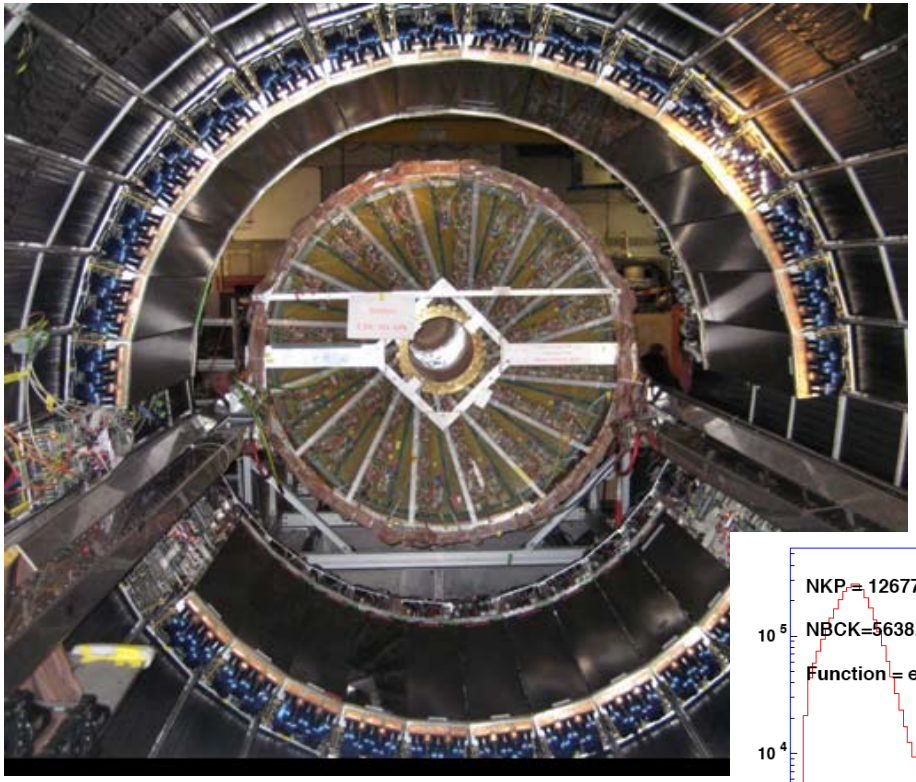
Forward
Detectors
Helitron+
Plastic Wall



Reconstruction
of neutral particles
like Λ, K^0_S
from their charged
decay products

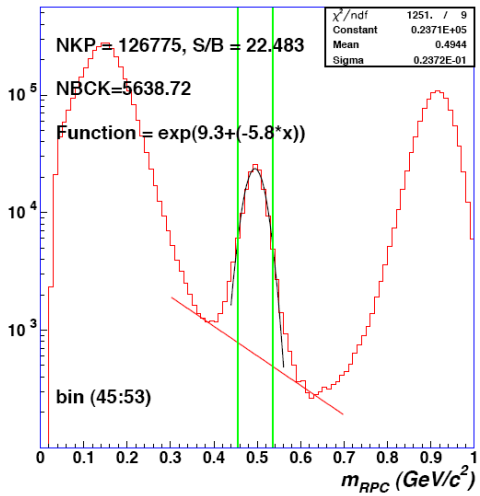
The RPC Time-of-Flight Barrel

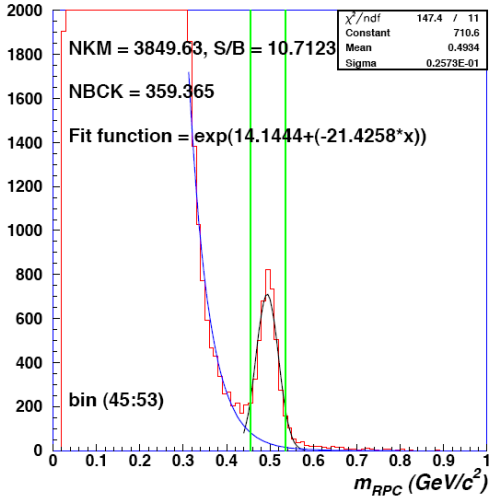
(FOPI Phase III)



Multigap-Multistrip RPC
σ(RPC): 67 ps
σ(system): ca. 90 ps

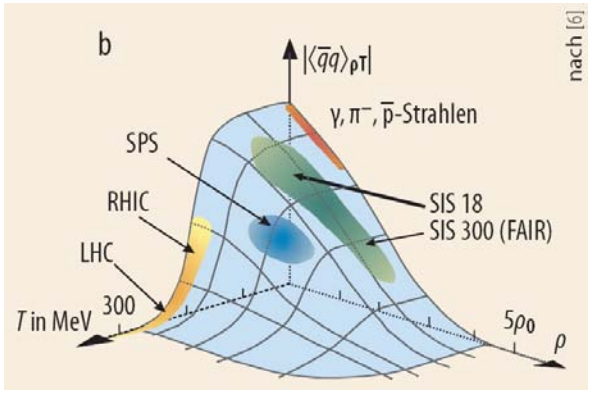
Charged Kaon Identification



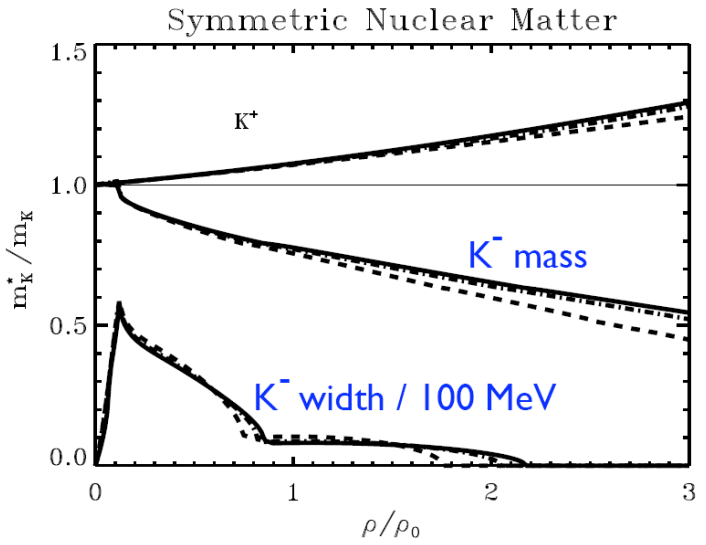


Why Strangeness?

Physik Journal 8, Nr. 3



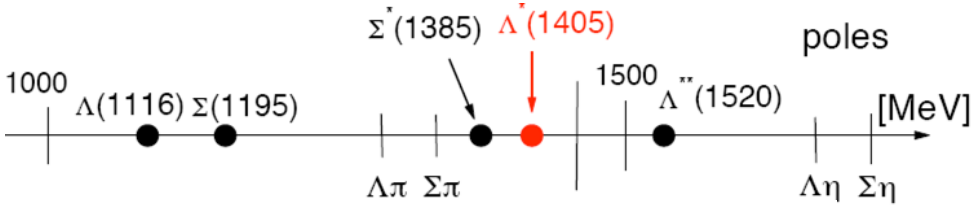
Modification of Particle Properties in Medium (density and temperature dependent)



T. Waas et al., PLB379(96)34

Strong attractive Interaction of the Antikaon in the Medium

- Flow
- Bound States



$\bar{K}N$-threshold

Complicated Situation due to the presence of resonances

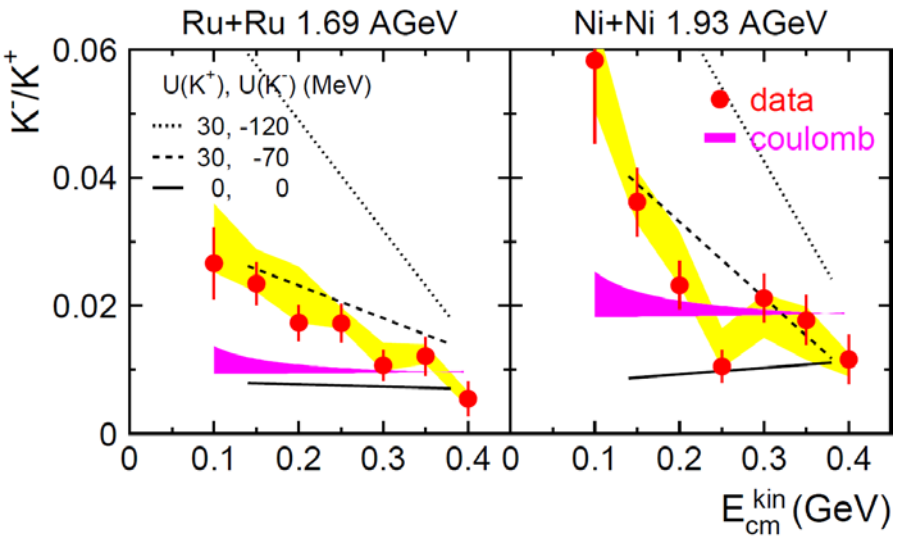
Systems studied by FOPI

2003-2011

- Heavy Ion Reactions
  K^0, $K^{\pm}$, Λ, ϕ, K^*, Σ^*
  Ni+Ni (1.93 and 1.91 AGeV), Al+Al (1.91 AGeV),
  Ni+Pb (1.91 AGeV), Ru+Ru (1.69 AGeV)
- Pion Induced Reactions
  K^0, $K^{\pm}$, Λ, ϕ
  π^- + C, Al, Cu, Sn, Pb (1.15 GeV/c, 1.7 GeV/c)
- Proton+proton 3.1 GeV
  search for ppK^- bound state

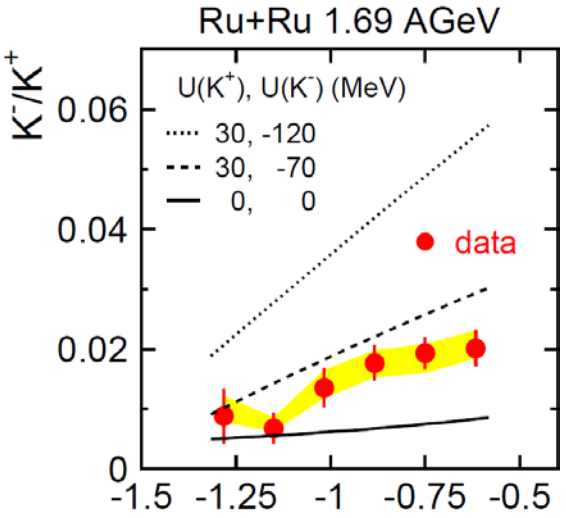
Charged Kaon Yields

K. Wisniewski et al., EPJA9(2000)



Comparison to transport Models (RBUU, filtered)

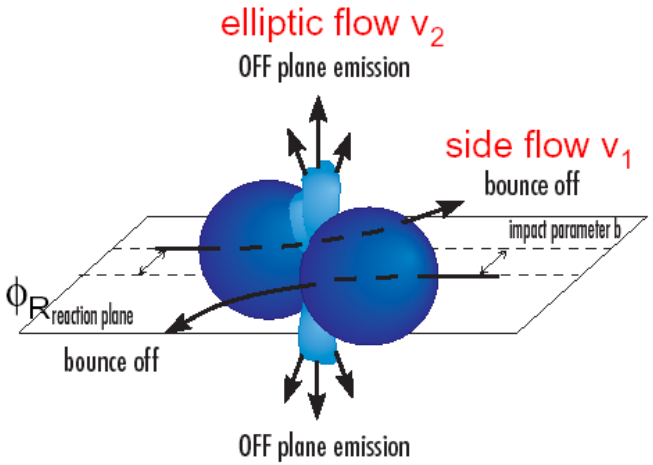
→ non-zero in-medium potentials suggested



Yield ratio varies of the studied region of phase space

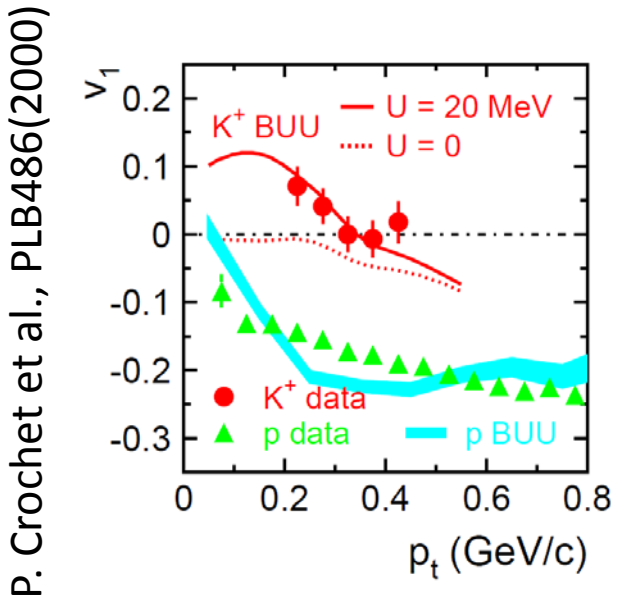
→ in-medium modifications of charged Kaon properties?

Charged Kaon Flow



Looking to Flow in terms of v_1 and v_2

$$\frac{dN}{d\phi} \propto 1 + v_1 \cos\phi + v_2 \cos 2\phi$$



P. Crochet et al., PLB486(2000)

Sideward Flow (v_1) of K^+
$-1.2 < Y^0 < -0.6$
low p_t → anti-flow

$\sigma_{geo} \approx 200$mb

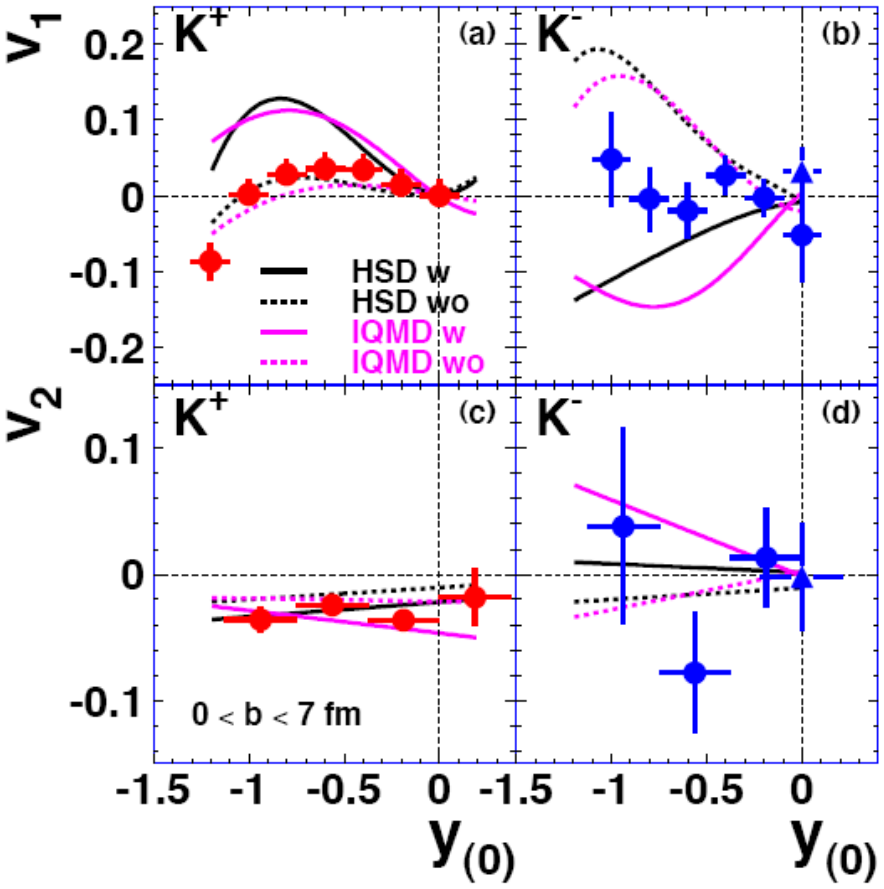
Comparison to transport model (filtered):
In-medium repulsive potential of 20 MeV

but: Proton flow not consistently described

K^- not available at this time

Charged Kaon Flow Updated

T.I. Kang, V. Zinyuk (Heidelberg)



Data consistent with previous ones

Ni+Ni. 1.91 AGeV (S325, S325e)

σ=1.5b, b_{geo}=7 fm

Transport models (filtered)
Potentials at $\rho=\rho_0$:
HSD:
$U(K^+)$=20 MeV, $U(K^-)$=50 MeV
IQMD:
$U(K^+)$=40 MeV, $U(K^-)$=90 MeV

Small sideflow of K^+
Vanishing K^- sideflow

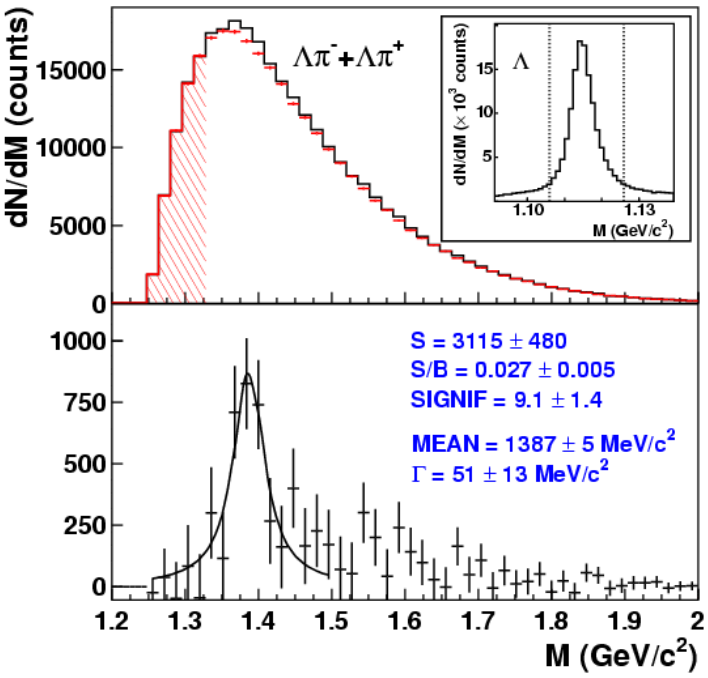
K^+ elliptic flow <0 (out of plane)
K^- sideflow consitent with zero

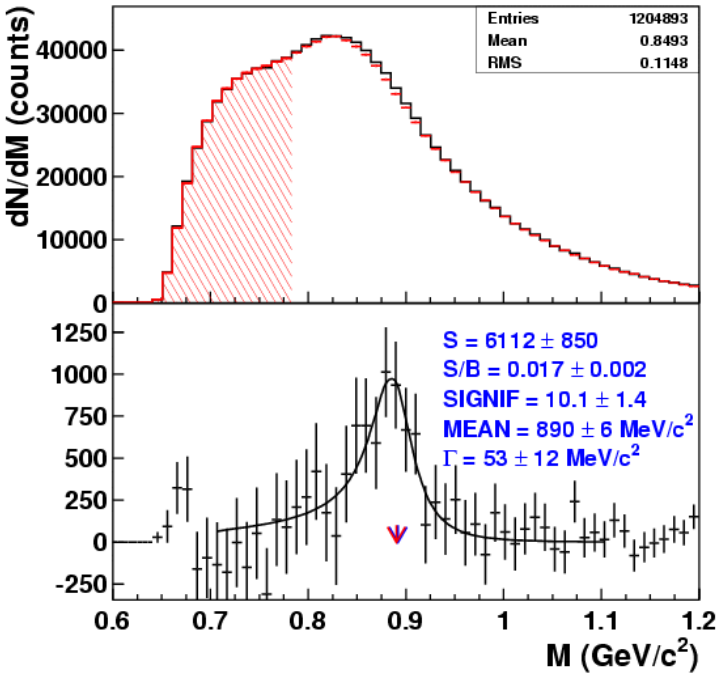
Short lived Strange Resonances

$\Sigma^* \rightarrow \Lambda + \pi$ (88±2%)
Γ = 39.4 MeV, $c\tau$ = 5 fm
NN-threshold 2.33 GeV

$K^* \rightarrow K + \pi$
Γ = 50.7 MeV, $c\tau$ = 4 fm
NN-threshold 2.75 GeV

X. Lopez et al., PRC76(2007)052203



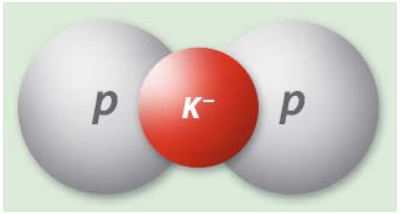


X. Lopez et al., PRC81(2010)061902

Al+Al 1.92 AGeV, $5 \cdot 10^8$ events, $P_{det} \sim 10^{-5}$

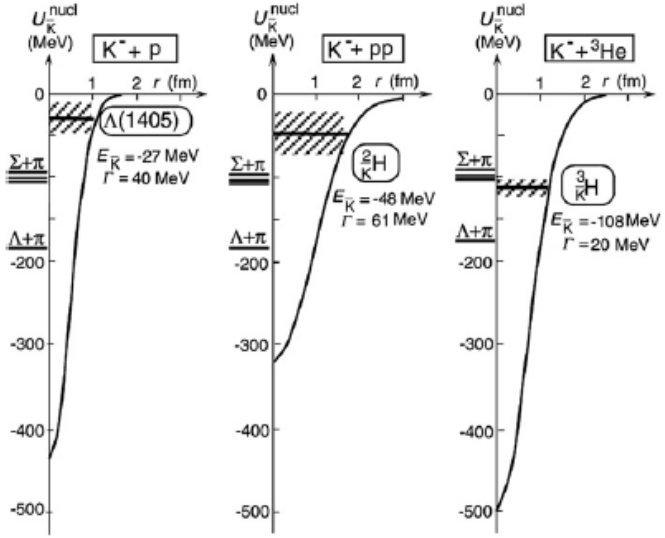
Reconstructable
consistent with PDG values

Strange Baryon Clusters

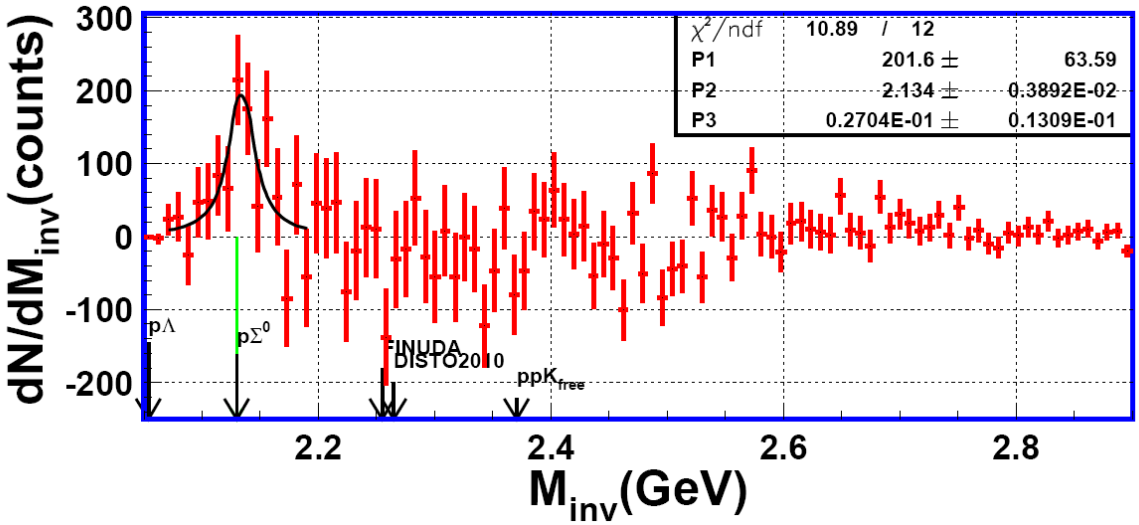


Deeply bound $\bar{K}$ clusters?

N. Herrmann, J.Phys.G(2010)



Y. Akaishi and T. Yamazaki, PRC65(2002)044005



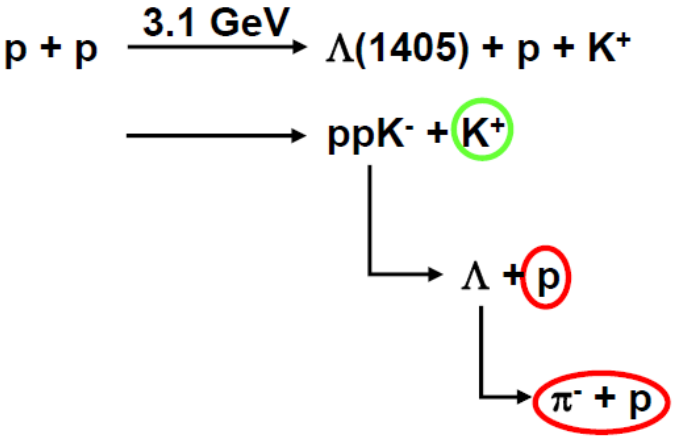
Λ-p correlations

m=2.134 GeV ± 4 MeV
Γ = 26 ± 14 MeV (statistical err.)

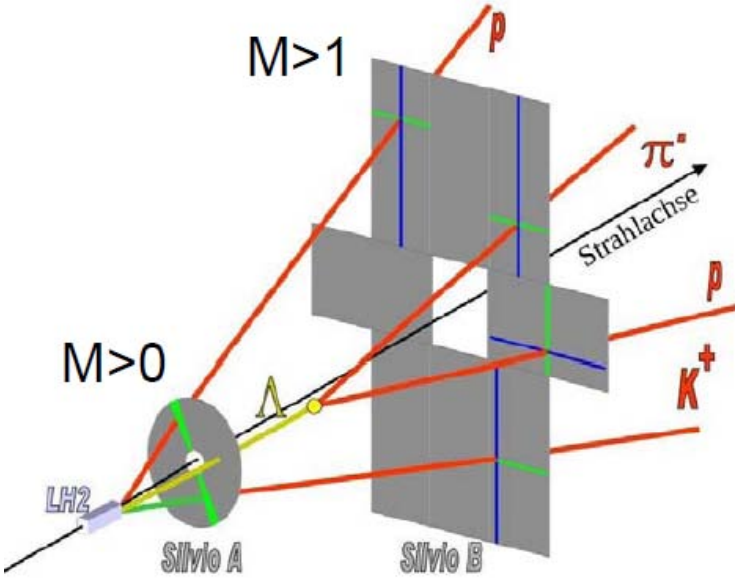
Peak (cusp) at NΣ threshold ?
seen in p+p collisions
FSI ?

Search for ppK⁻ in p+p

R. Münzer, München



LH2 target + SIΛVIO
(silicon strip detectors)



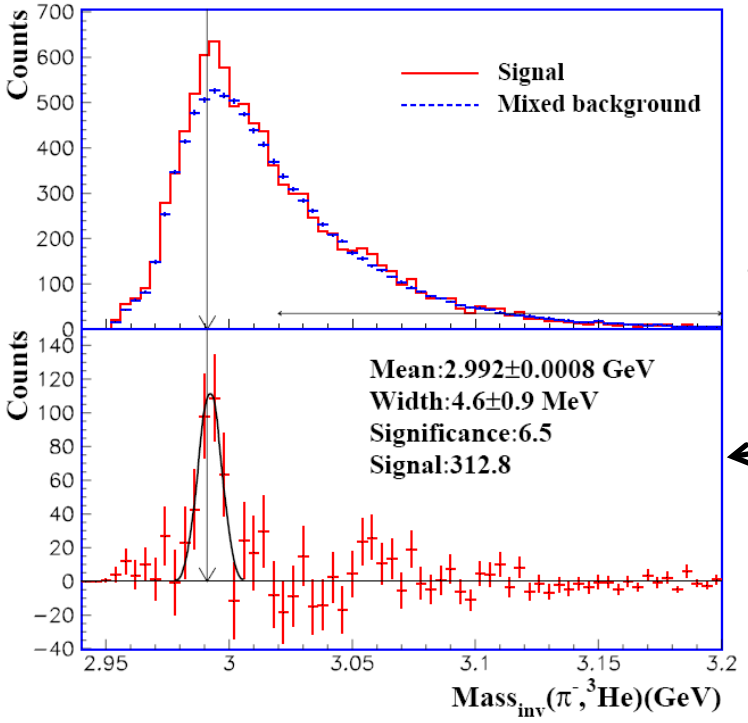
Analysis still in progress

- Λ reconstruction
- K^+ identification
- Λp correlation
- K^+ missing mass

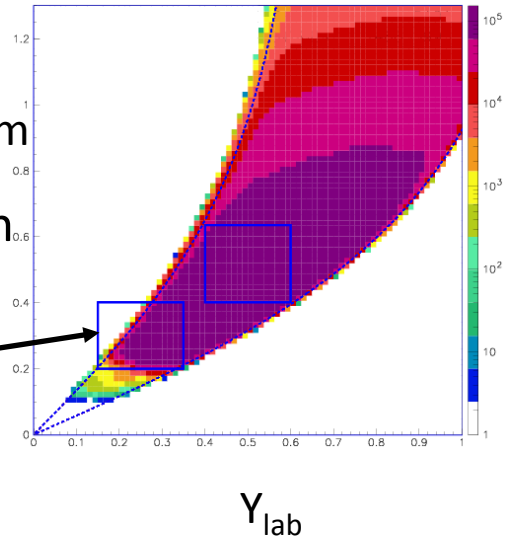
Suppression of non-strange background by factor 20 (simulation with UrQMD)

Light Hypernuclei

Y.P. Zhang (Heidelberg)



$${}_{\Lambda}t \rightarrow {}^{3}He + \pi^{-}$$



Signal only in a certain region of phasespace

Lifetime of Λ and $_{\Lambda}$t consistent with PDG resp. world data

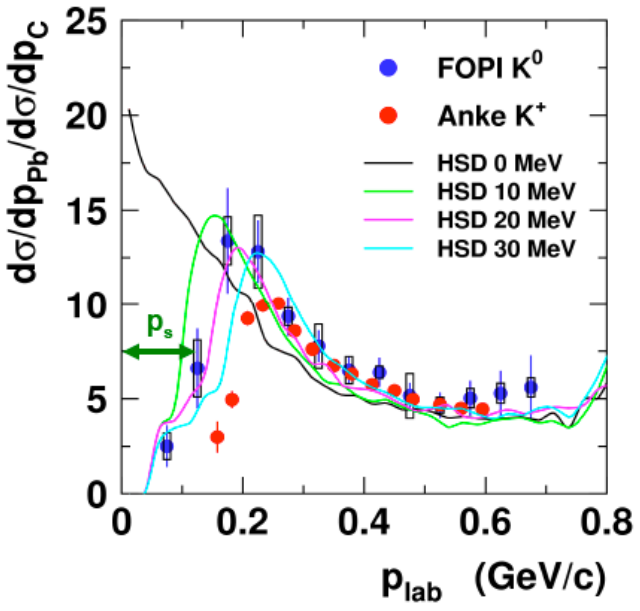
3-body decay and heavier hypernuclei under study

yields (ratios) not understood so far …

Pion Induced Reactions

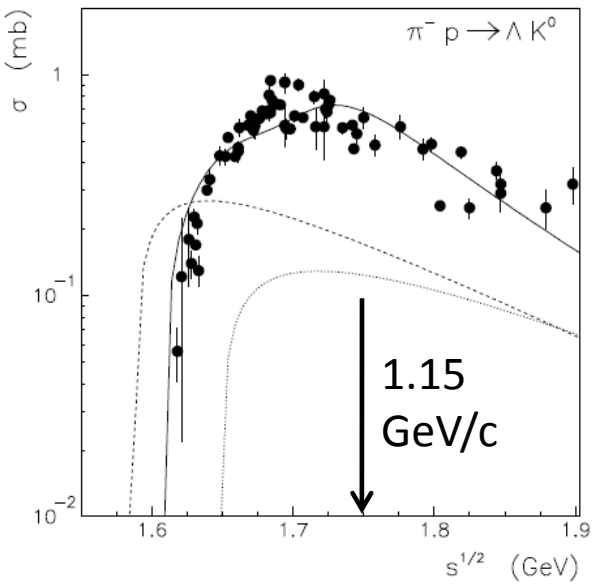
M.L. Benabderramahne et al., PRL102
M. Büscher et al., EPJA 22

ratio Pb/C target



inclusive cross sections

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

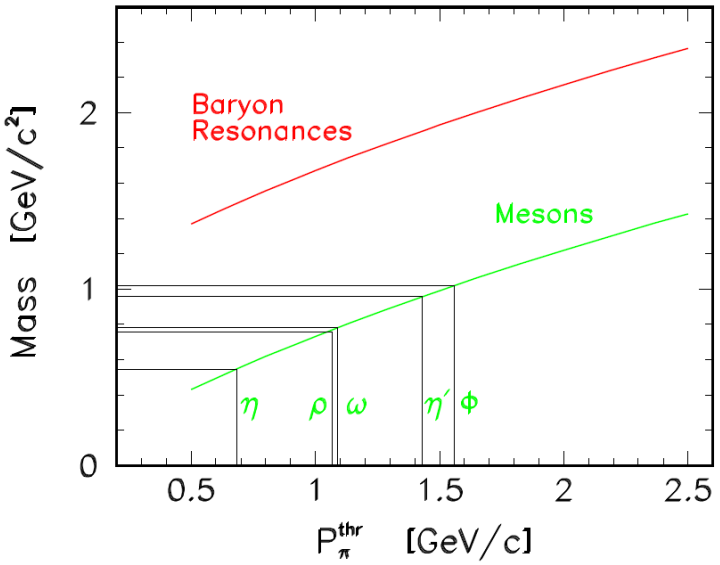


dashed: $\rho = \rho_0$

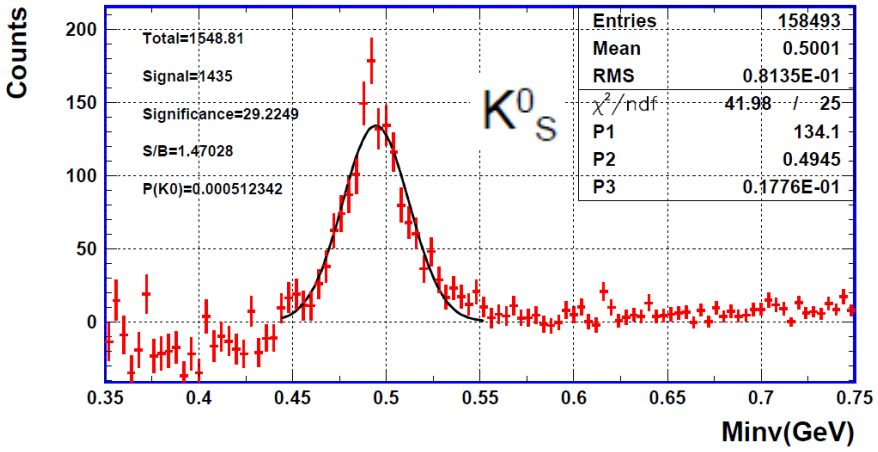
K. Tsushima et al., PRC62

Comparison to HSD → repulsive
Potential of ~ 20 MeV

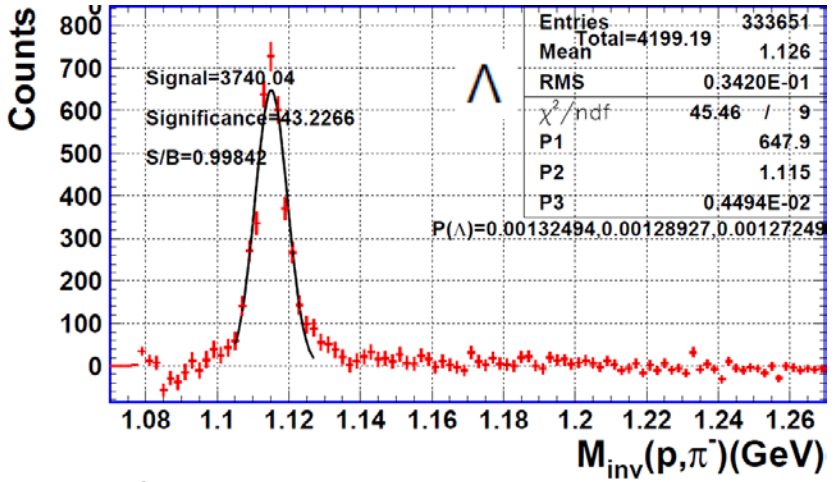
Pion Induced Reactions



S339 1.7 GeV/c π^-+A



PRELIMINARY



$\pi^- + p \rightarrow \phi + n \rightarrow K^+K^- + n$

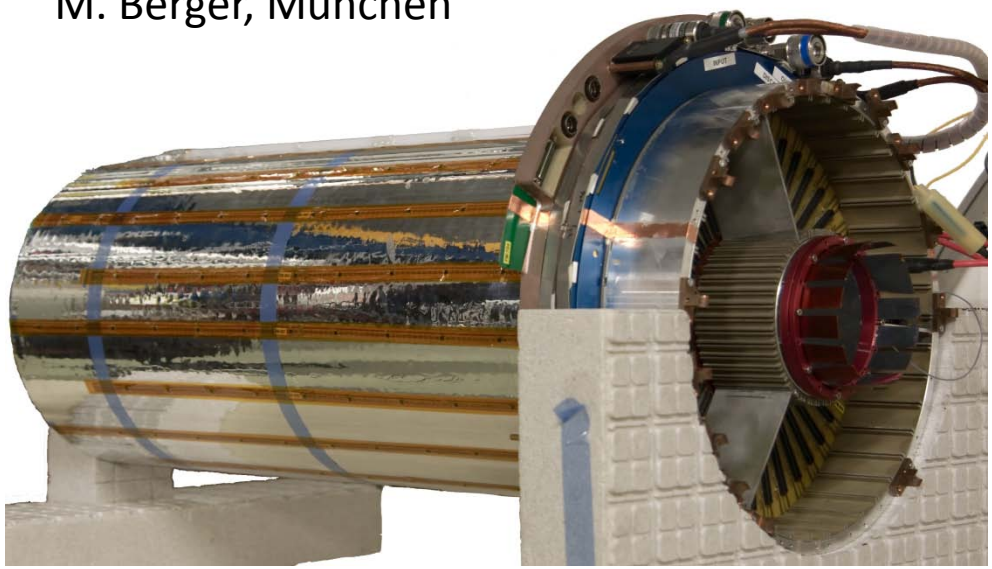
Data taking finished end of June 2011, calibration and analysis ongoing

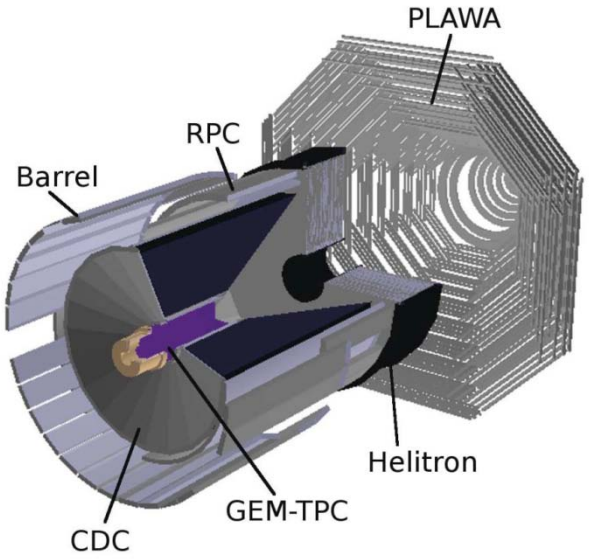
Special feature of this experiment: first use of a GEM-TPC

N. Herrmann, Heidelberg

GEM-TPC

M. Berger, München

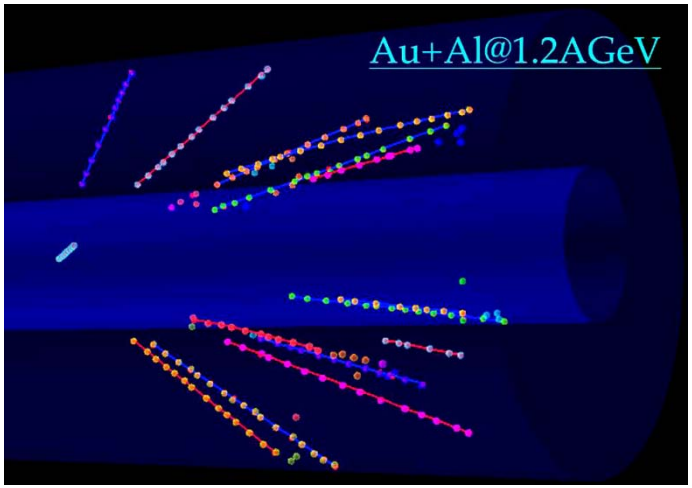




TPC as upgrade for FOPI:

- Vertex resolution: ~1 mm in X,Y + Z
- Larger geometrical acceptance for:
  - Λ and K^0_s
- Improved resolution of secondary vertices (min factor 10)

→ good for weakly decaying resonances



Future Plans

- The June 2011 pion beam experiment was the last official FOPI beamtime
- Replace/extend hardware with components for FAIR experiments (CBM, PANDA)
- Exploit improved resolution: GEM-TPC
- Physics case: double strangeness production ($\Xi^- X$, $K^- K^- X$)
  - Pion beam
  - ^{3}He beam

Conclusions

- FOPI@SIS since > 20 years
- New hardware (RPC, SIΛVIO, GEM-TPC, …)
- Measurement of reactions involving strangeness
- New results on charged kaon flow, associated strangeness production, bound states including hypernuclei
  - Still many open questions, theoretical effort needed
- Ongoing analysis (e.g. ϕ/K^+K^- production in medium)