ÖAW
Austrian Academy
of Sciences

The FOPI Experiment at GSI-SIS

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Austrian Physical Society

Stefan Meyer Institute for Subatomic Physics, Vienna

http://www.oeaw.ac.at/smi

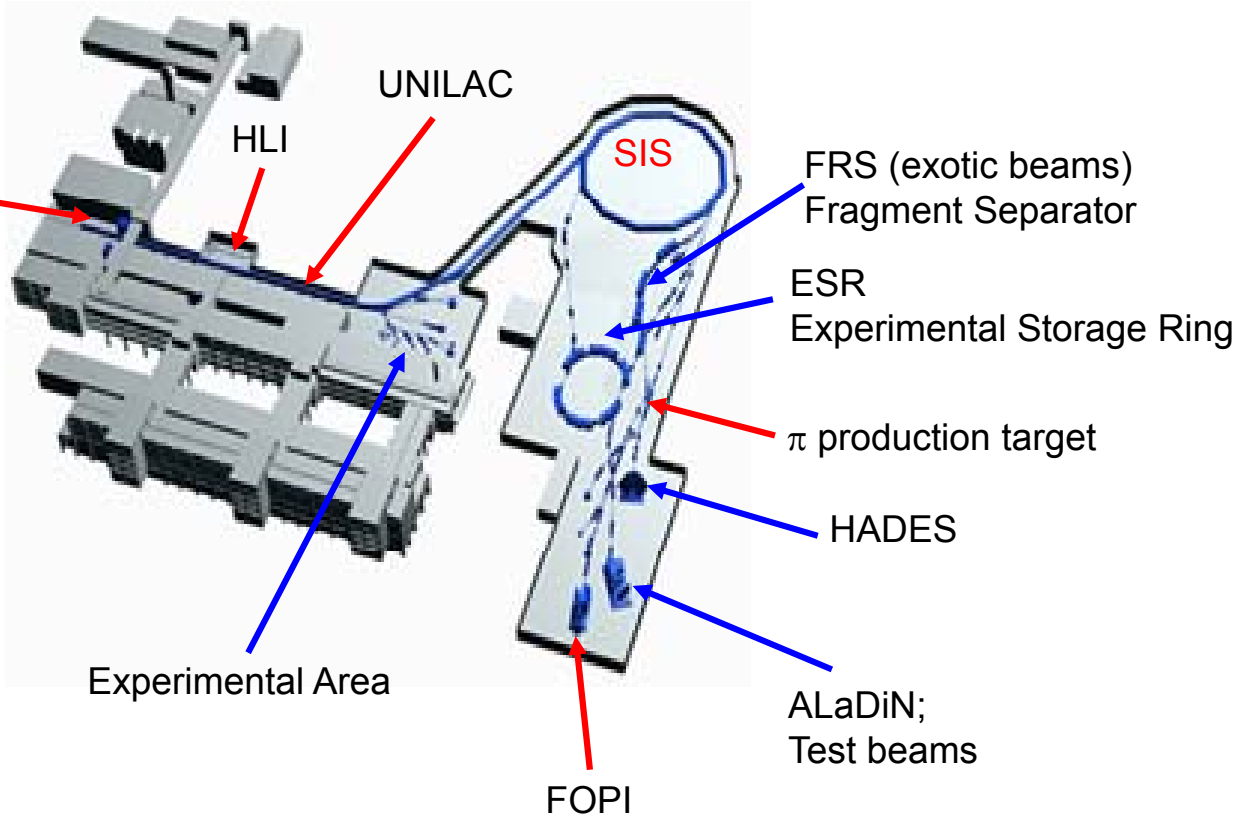
Contents

- The GSI and its Accelerators
- The FOPI Experiment
  - Setup and Performance
  - Heavy Ion Collisions
  - Proton and Pion induced Reactions
- Conclusions and Outlook

Helmholtzzentrum für Schwerionenforschung GmbH

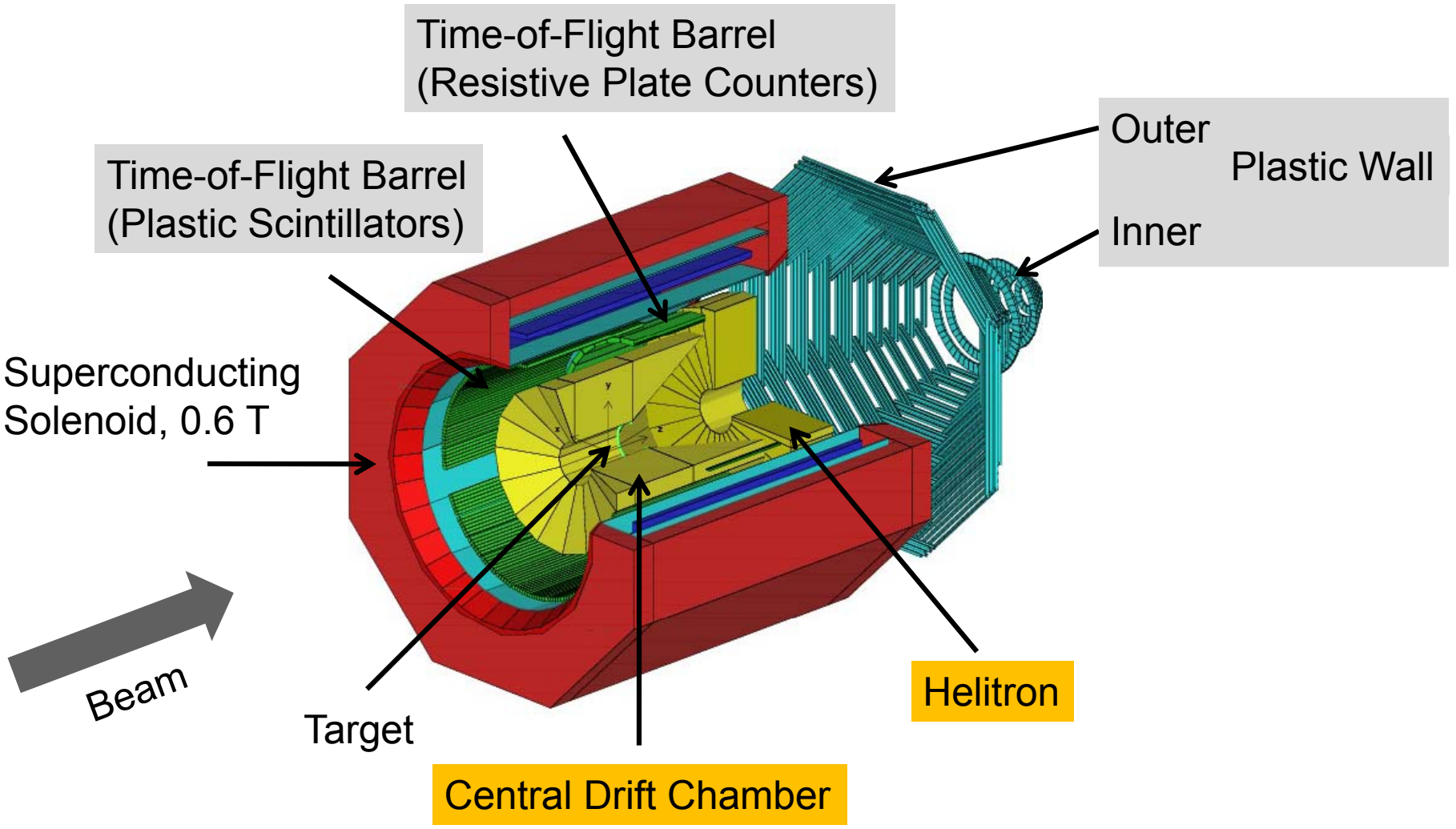
Schwerionensynchroton SIS
216 m circumference
18 Tm bending power

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



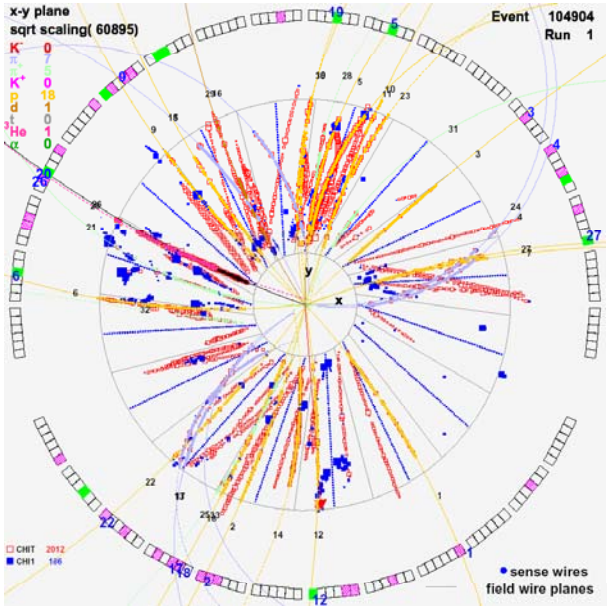
- Accelerator physics
- Atomic physics
- Nuclear physics
- Bio physics
- Plasma physics
- Material research
- Theory

The FOPI Experiment

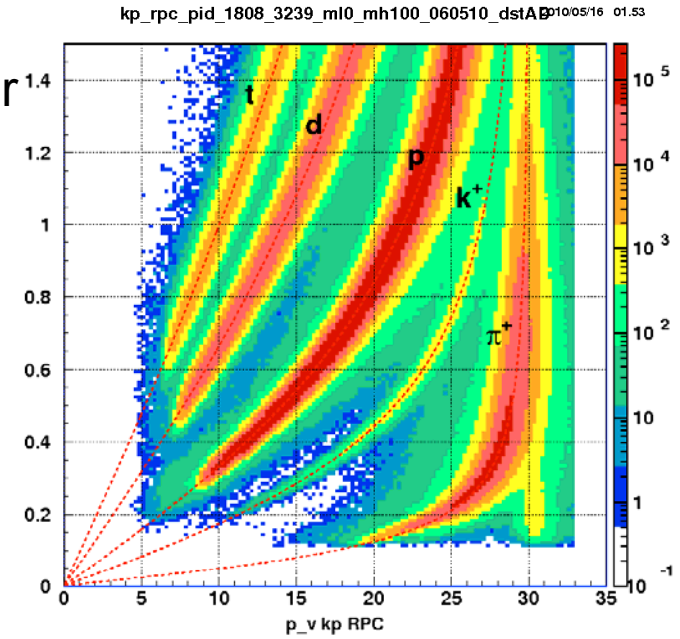


NIPNE Bucharest, KFKI Budapest, LPC Clermont-Ferrand, GSI Darmstadt, FZ Dresden-Rossendorf, University Heidelberg, ITEP Moscow, KI Moscow, TU Munich, Korea U Seoul, IReS Strasbourg, University Warsaw, SMI Vienna, RBI Zagreb

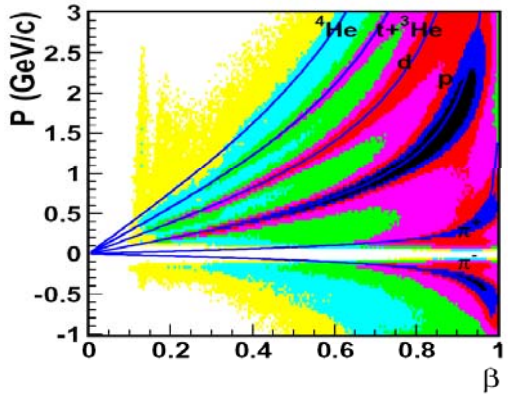
Particle measurement with FOPI



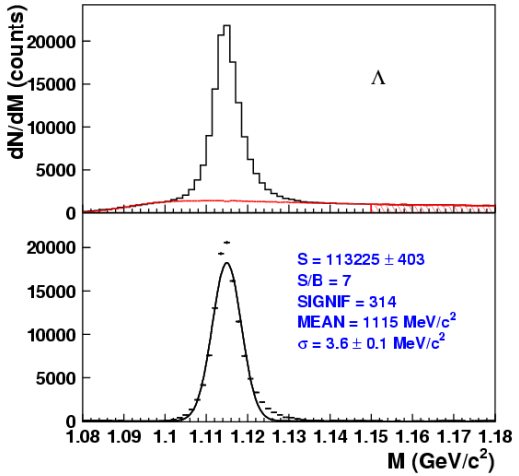
Event Display
Central Drift Chamber
(x,y) plane
Ni+Ni@1.93 AGeV



PID:
Matched tracks
CDC-RPC

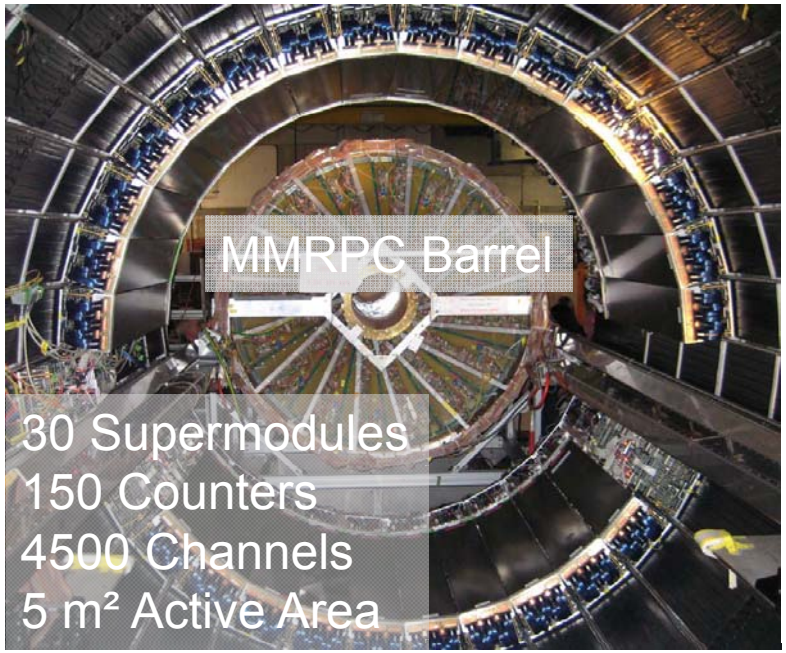


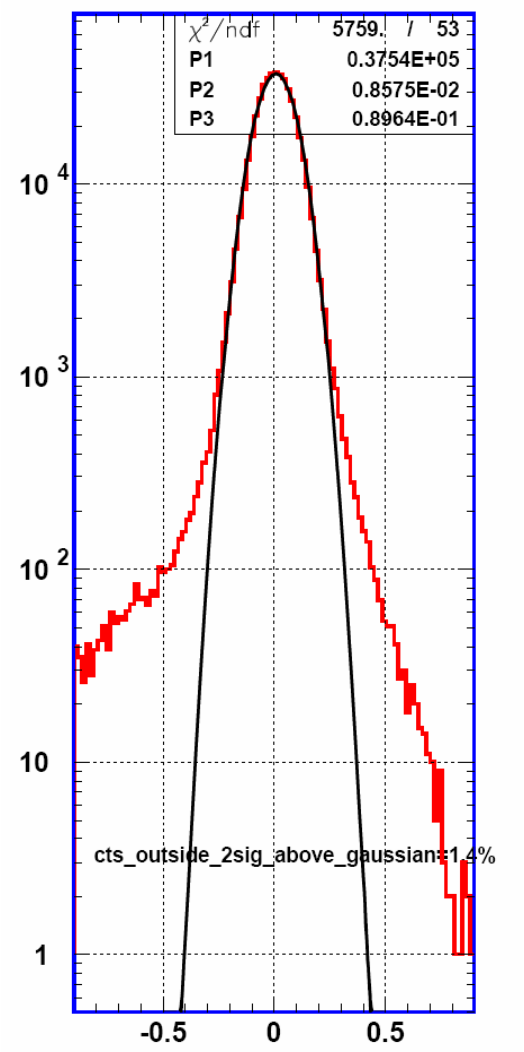
Forward
Detectors
Helitron+
Plastic Wall



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

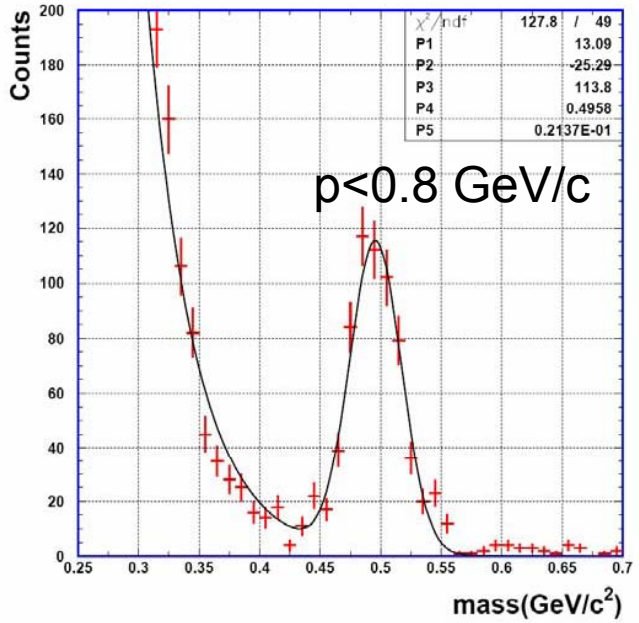
Particle measurement with FOPI





Time resolution
(fast pions,
p>0.5 GeV/c

σ_{System} ~ 90 ps
σ_{RPC} ~ 65 ps

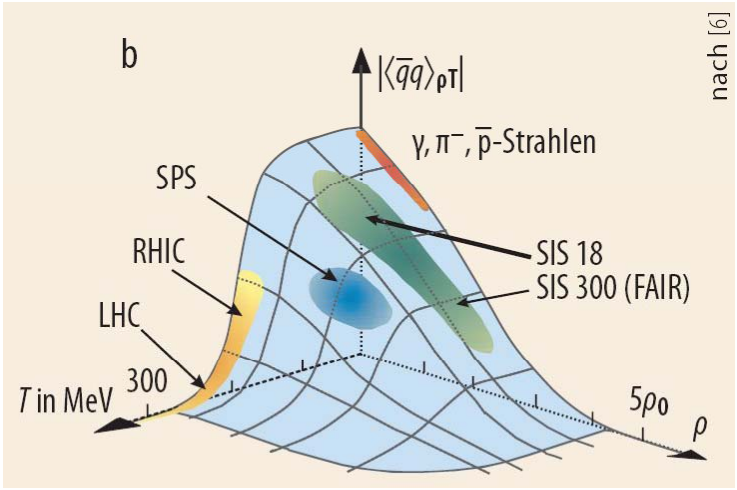


K^-
S/B > 10

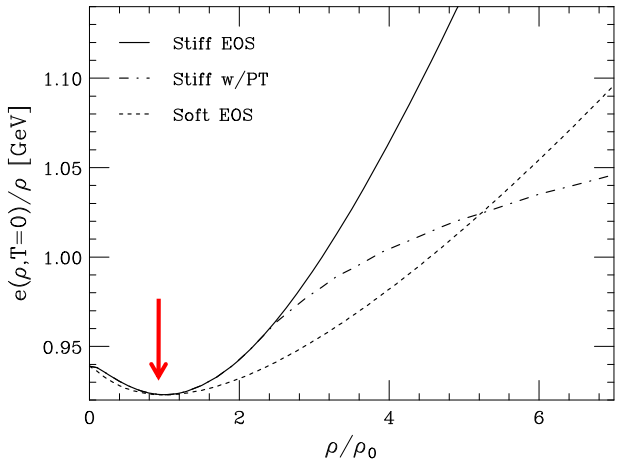
Systems studied by FOPI

- Heavy ion collisions (from 90 *A*MeV to 1.9 *A*GeV)
  - Al+Al, Ca+Ca, Ni+Ni, Ru/Zr+Ru/Zr, Au+Au, Pb+Pb
  - Ca+Au/Au+Ca, Ni+Pb
- Proton+Proton (3.1 GeV)
- π^- + C, Al, Cu, Sn, Pb (1.15 GeV/c)

Physik Journal 8 Nr. 3



Relation between temperature, density and quark condensate

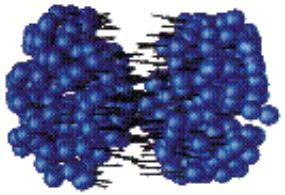


Equation of State of nuclear matter

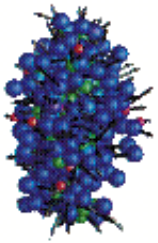
P. Danielewicz, PRL 81

Heavy Ion Collisions

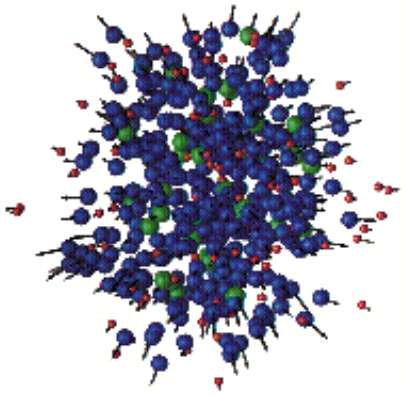
IQMD: 2 AGeV Au+Au (Δt = 10 fm/c)



central collision
b = 0



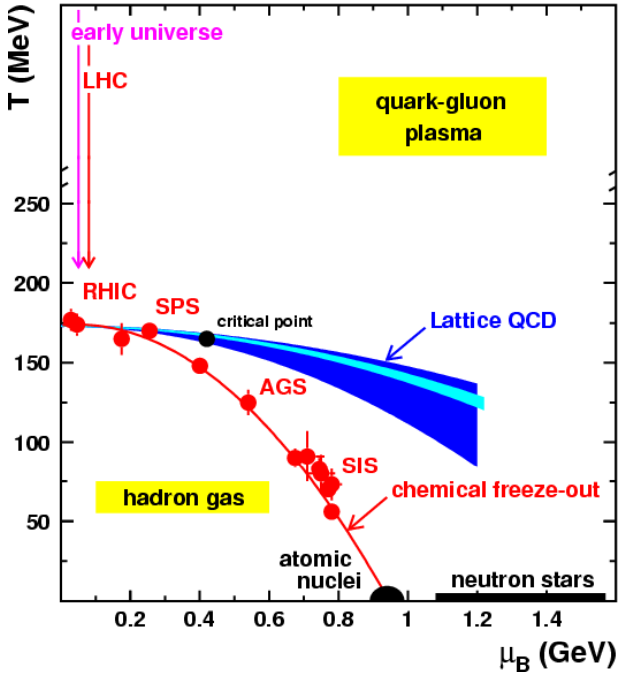
high density



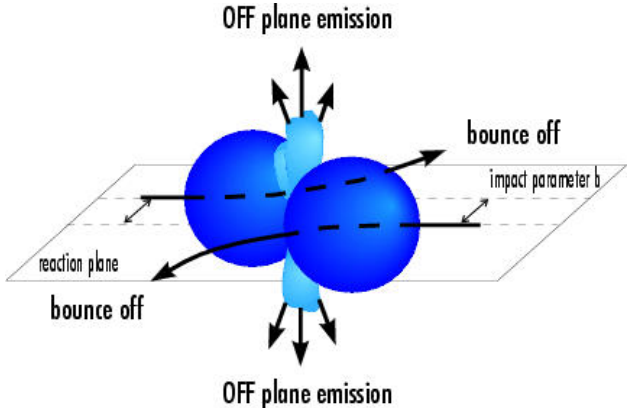
expansion

Phases of a
Heavy Ion Collision

Transport Model
Calculation
(IQMD, C. Hartnack)



Phase diagram of nuclear matter



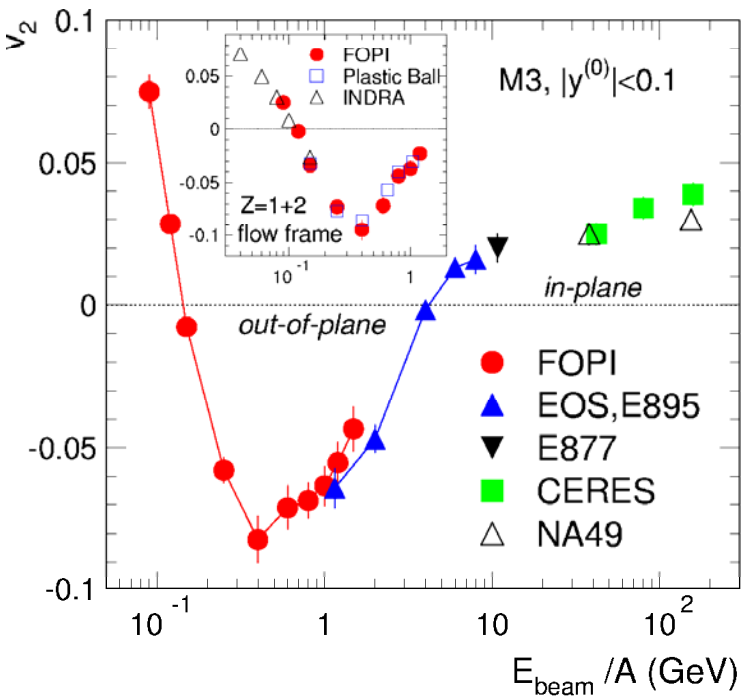
Impact parameter and beam axis define the reaction plane

Collective Effects: Flow
"sideward flow"
"squeeze-out"

Flow and Stopping

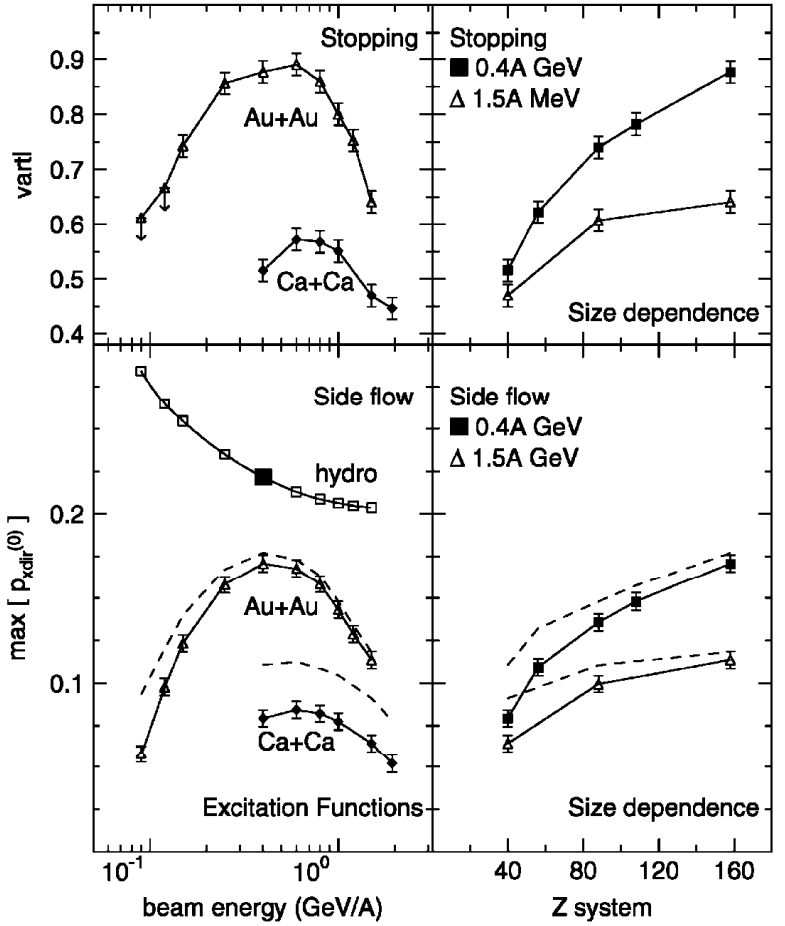
$$\frac{dN}{d\phi} \propto 1 + v_1 \cos\phi + v_2 \cos 2\phi$$

A. Andronic et al., PLB 612



SIS energies:
flow and stopping reveal extrema
- high pressure
- high density
- correlated

σ_{NN} smaller than vacuum value

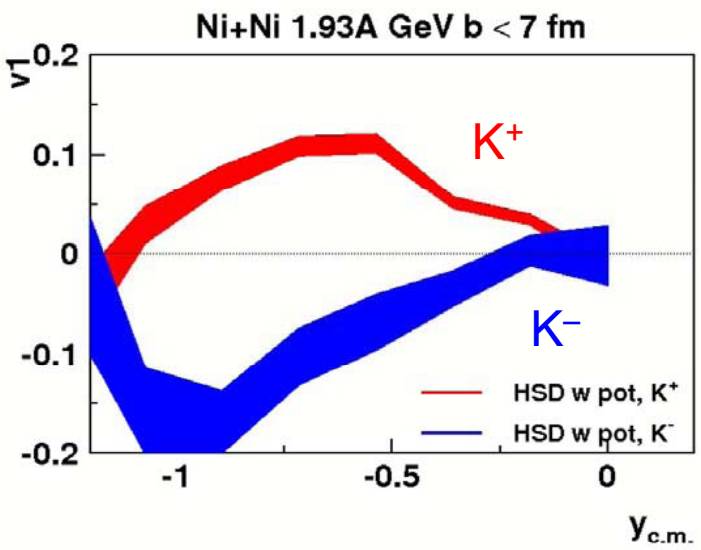


W. Reisdorf et al., PRL92

Stopping or partial transparency?
- maximum around 500 AMeV
- full stopping never reached
- no saturation in system size

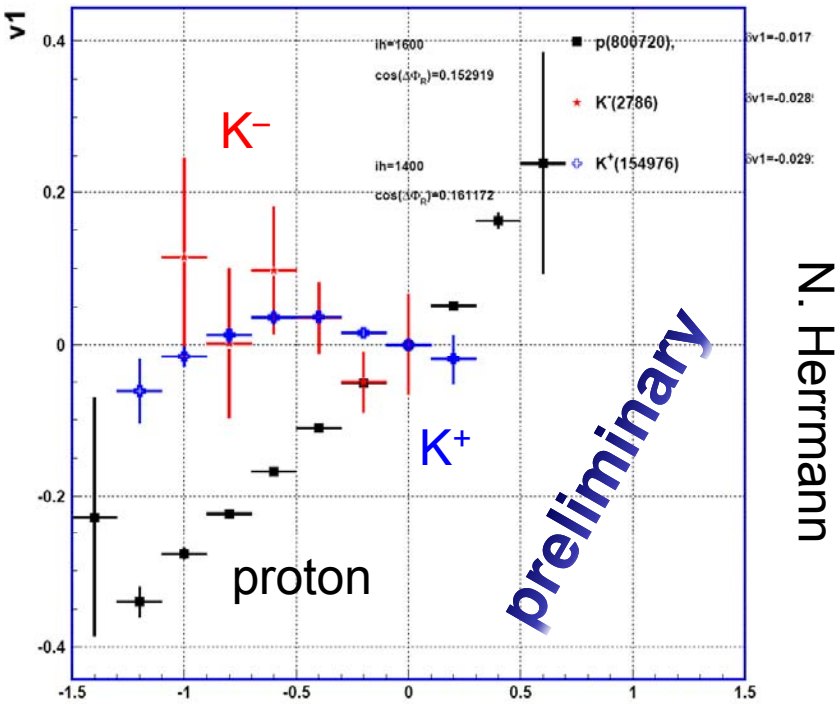
Flow of Strange Particles

HSD – E. Bratkovkaya et al.



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

Ni+Ni@1.91 AGeV



Scaled rapidity

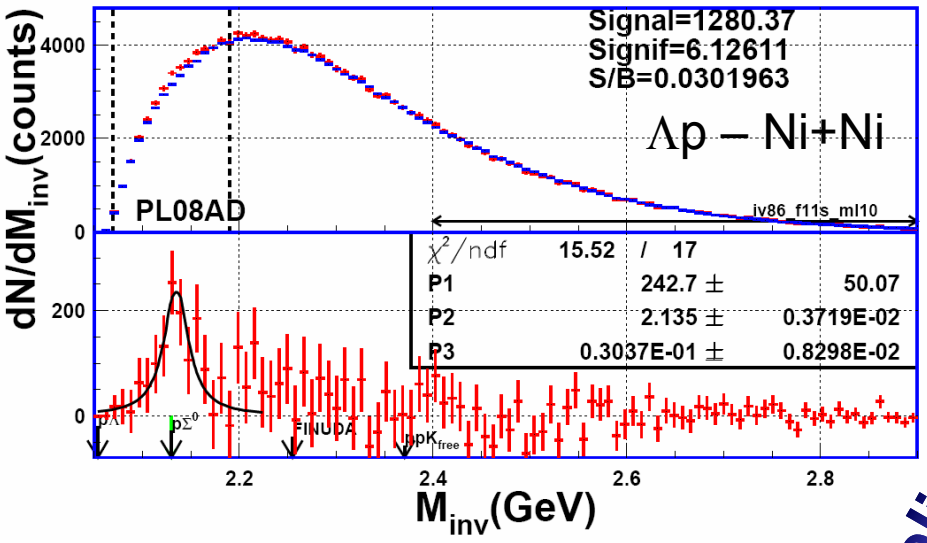
N. Herrmann

Kaons are produced in the
High density phase of the collisions
("messengers from the fireball")

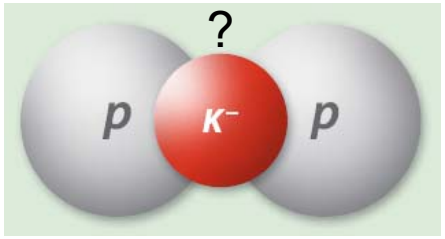
K^- -Flow very stringent test for transport models

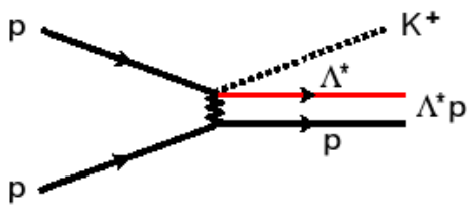
Strange Objects

- Kaonic nuclear clusters
- Hypernuclei

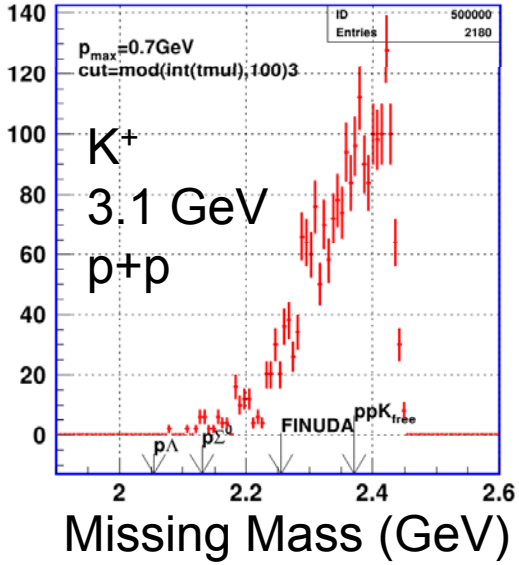


N. Herrmann

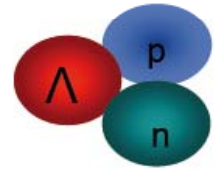


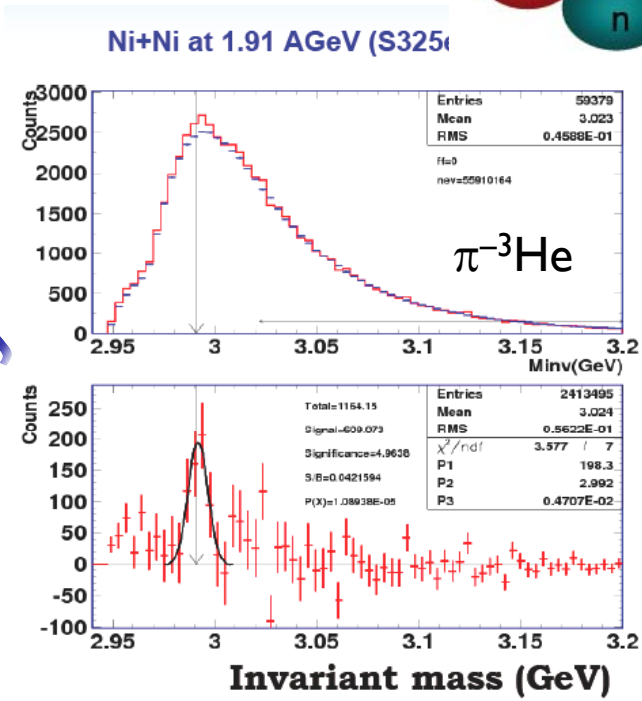


T. Yamazaki and Y. Akaishi



Invariant and Missing Mass Analysis

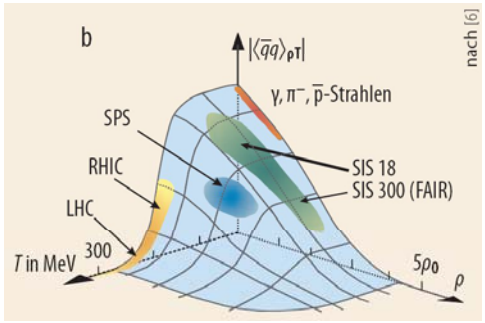




Y.P. Zhang

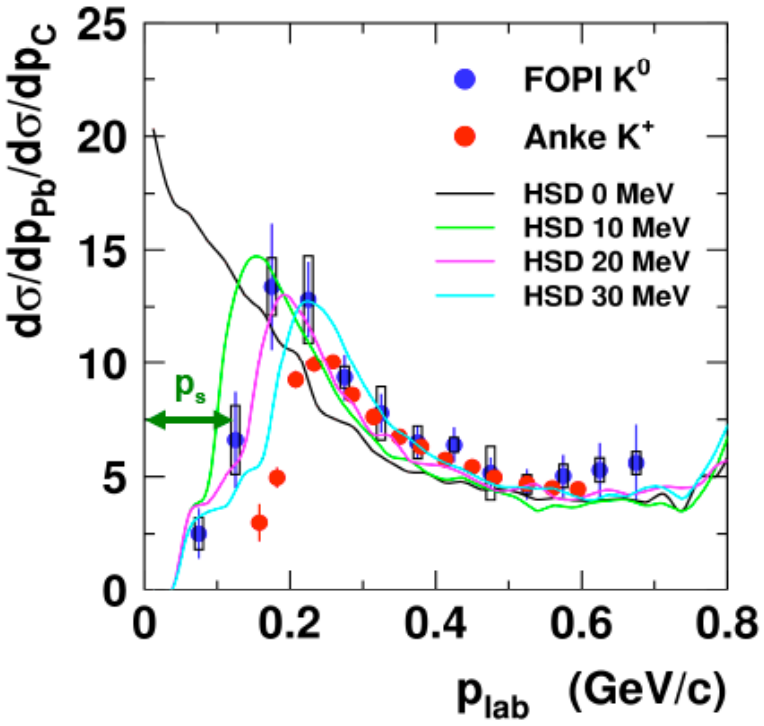
preliminary

In-Medium effects in pion induced reactions $\pi^- p \rightarrow K^0 \Lambda$



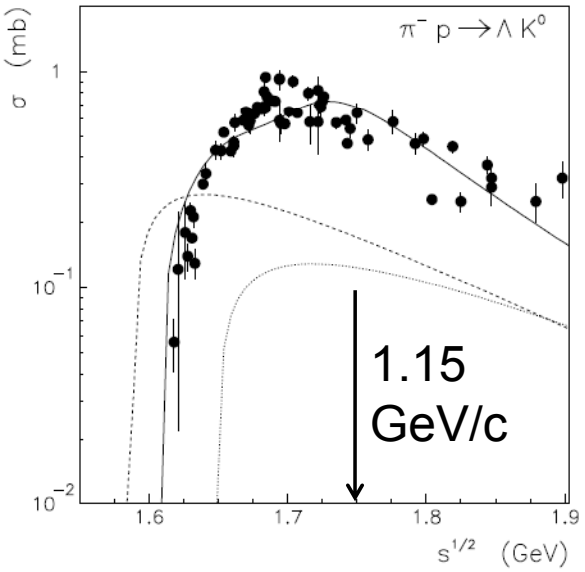
Normal nuclear matter density

ratio Pb/C target



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

inklusive cross sections



K. Tsushima et al., PRC62

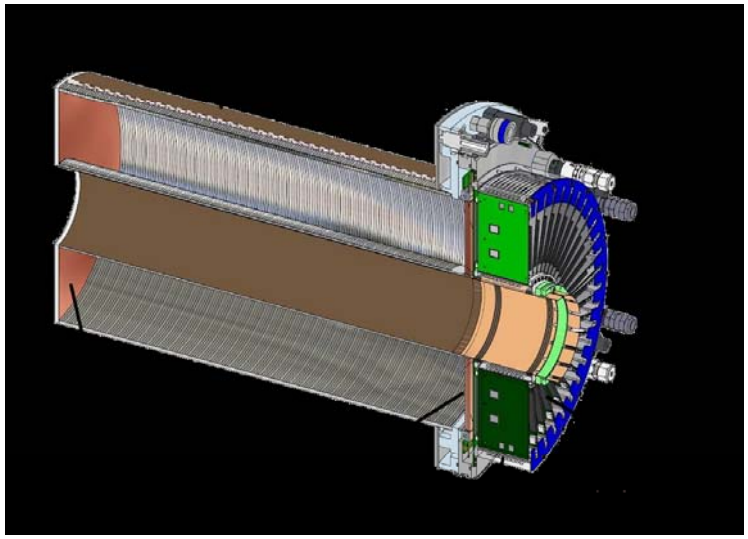
dashed: $\rho = \rho_0$

Comparison to HSD → repulsive Potential of ~ 20 MeV

Conclusions

- The FOPI experiment (today in Phase III) is active since ~ 1990 at the SIS of the GSI
  - Coverage of nearly the full solid angle
  - 2007 RPC Time-of-Flight barrel
- Study of Heavy Ion Collisions
  - High density and pressure (2 ρ_0)
  - Flow and Stopping
  - Production of strange particles (Kaons, Lambda, …)
  - Equation of State
- Proton+proton reactions
  - Search for the K^-pp nuclear cluster
  - $\Lambda(1405)$
- Pion induced reactions
  - In-medium effects at normal nuclear matter density

Outlook



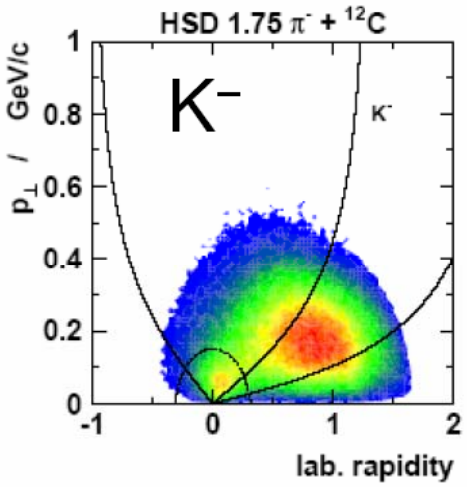
The prototype of the PANDA TPC with GEM readout is adopted to the FOPI setup

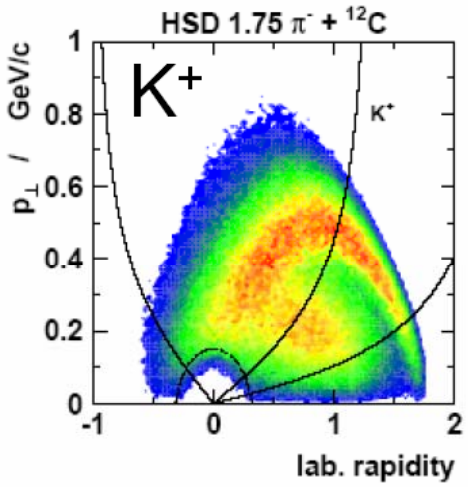
First in-beam test September/October

→ Improvement of forward PID

"Pion induced in-medium production and propagation of strangeness"

Beamtime first half 2011; last experiment (so far) of the FOPI core program





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FWF Der Wissenschaftsfonds.

HadronPhysics2 Study of Strongly Interacting Matter