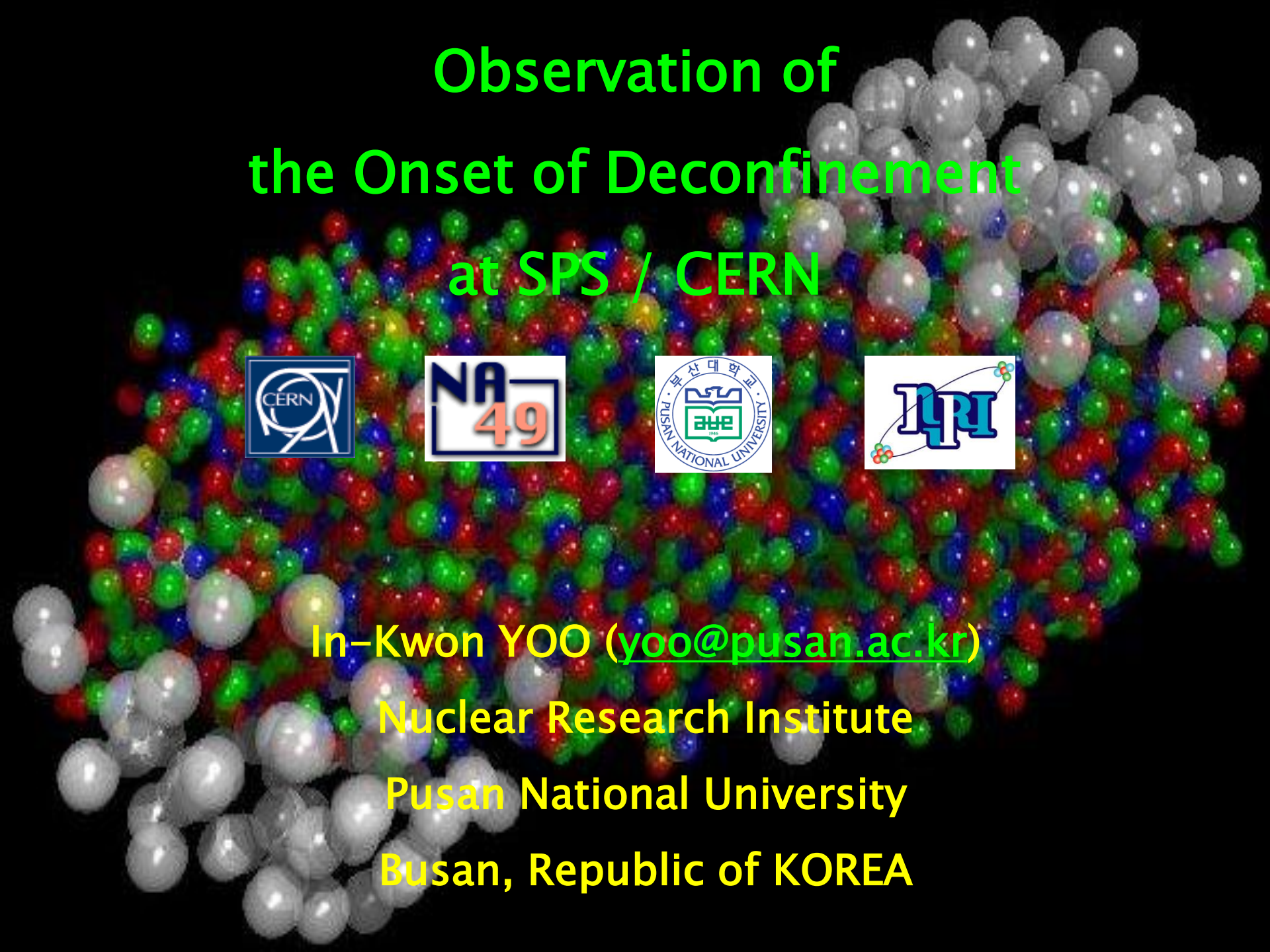
Observation of the Onset of Deconfinement at SPS / CERN



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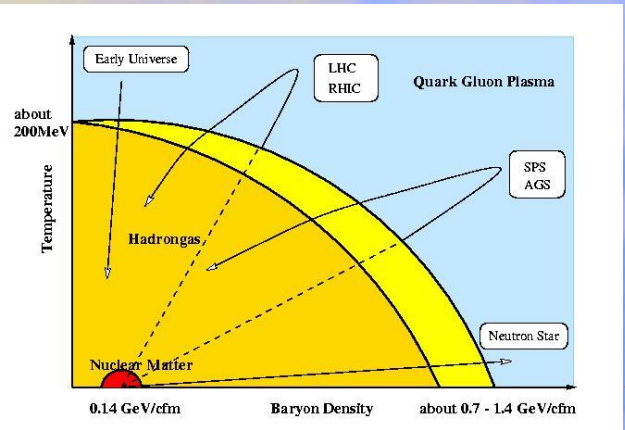
Busan, Republic of KOREA

Outline

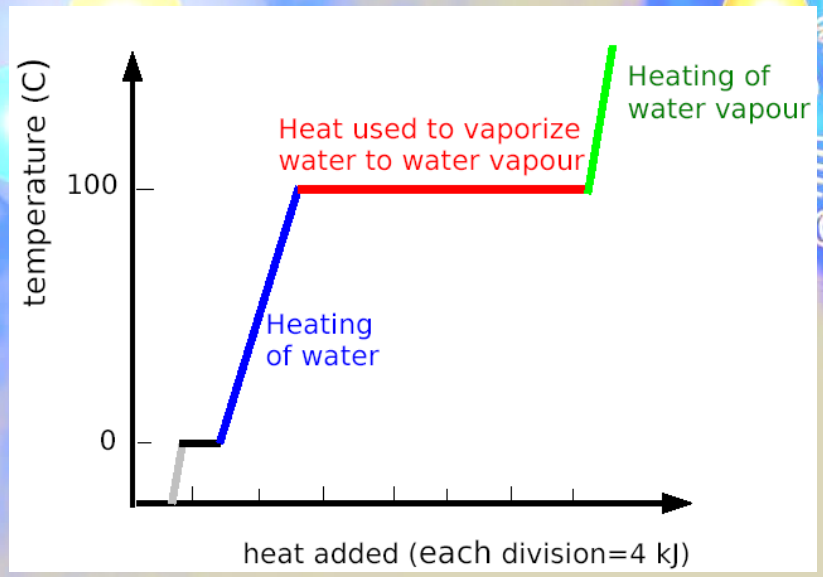
- Physics Motivation
- Experimental Survey
- Physics Results and Interpretations
- Outlook

Looking for the QGP



Anomalies at the Phase Transition ?

Hadronic Observables

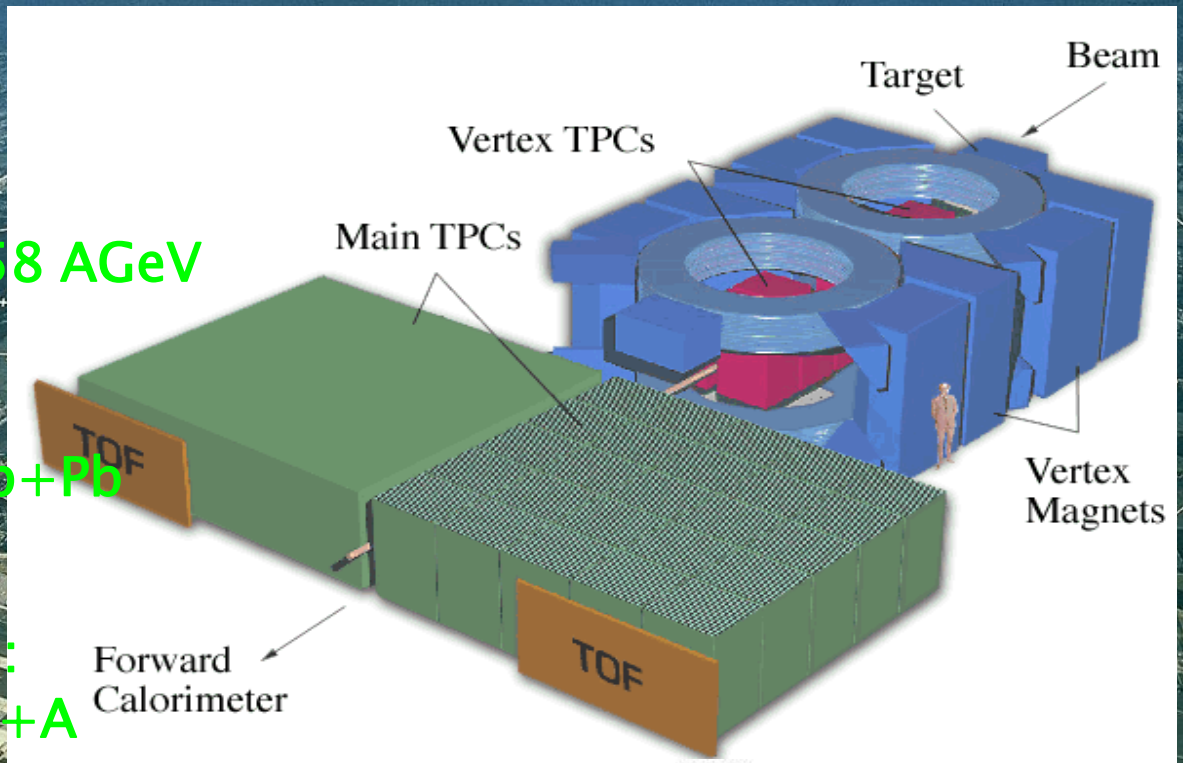


Collision Energy

NA49@SuperProtonSynchrotron.CERN

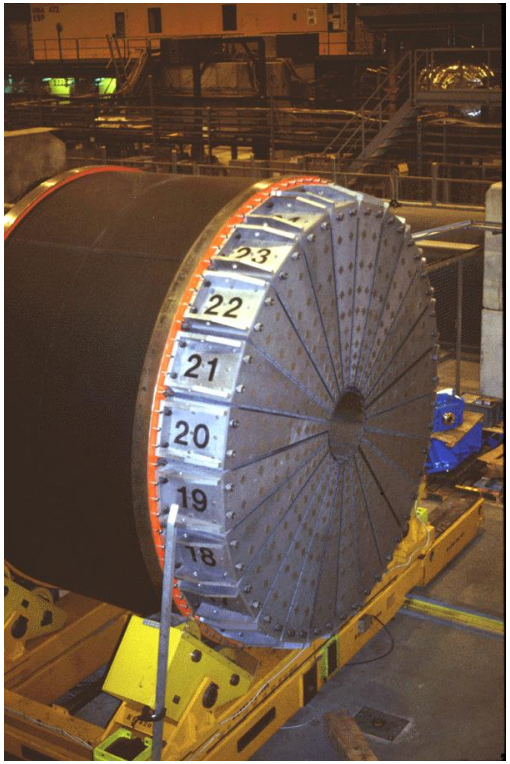
http://na49info.cern.ch

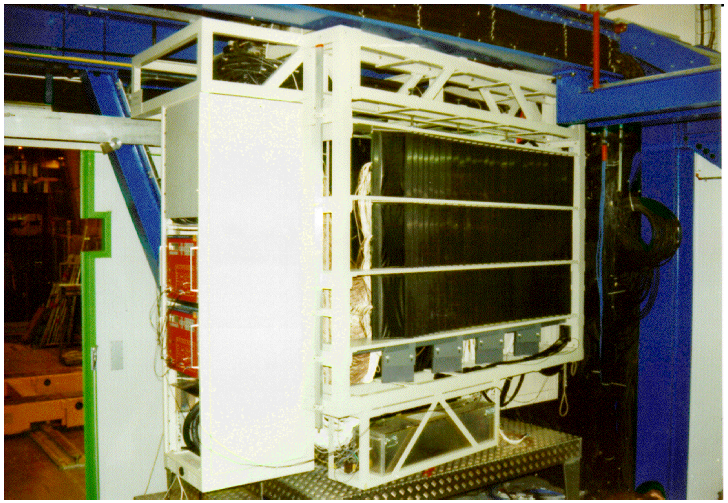
- Energy Scan :
  20, 30, 40, 80, 158 AGeV
- System Scan :
  pp, C+C, Si+Si, Pb+Pb
- Elementary Reactions :
  p+p, π+p, d+p, p+A



NA49 Detector System

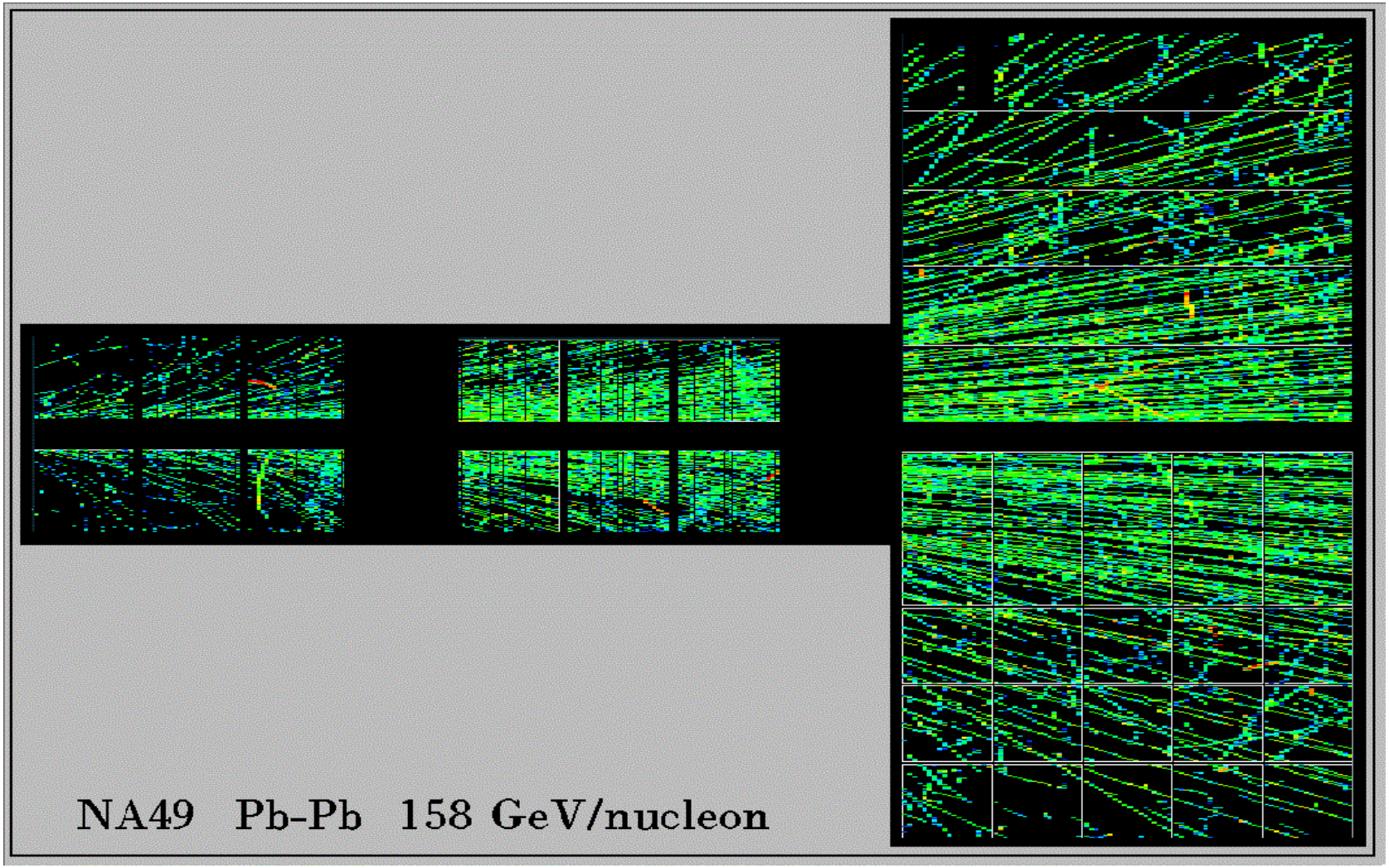
1m



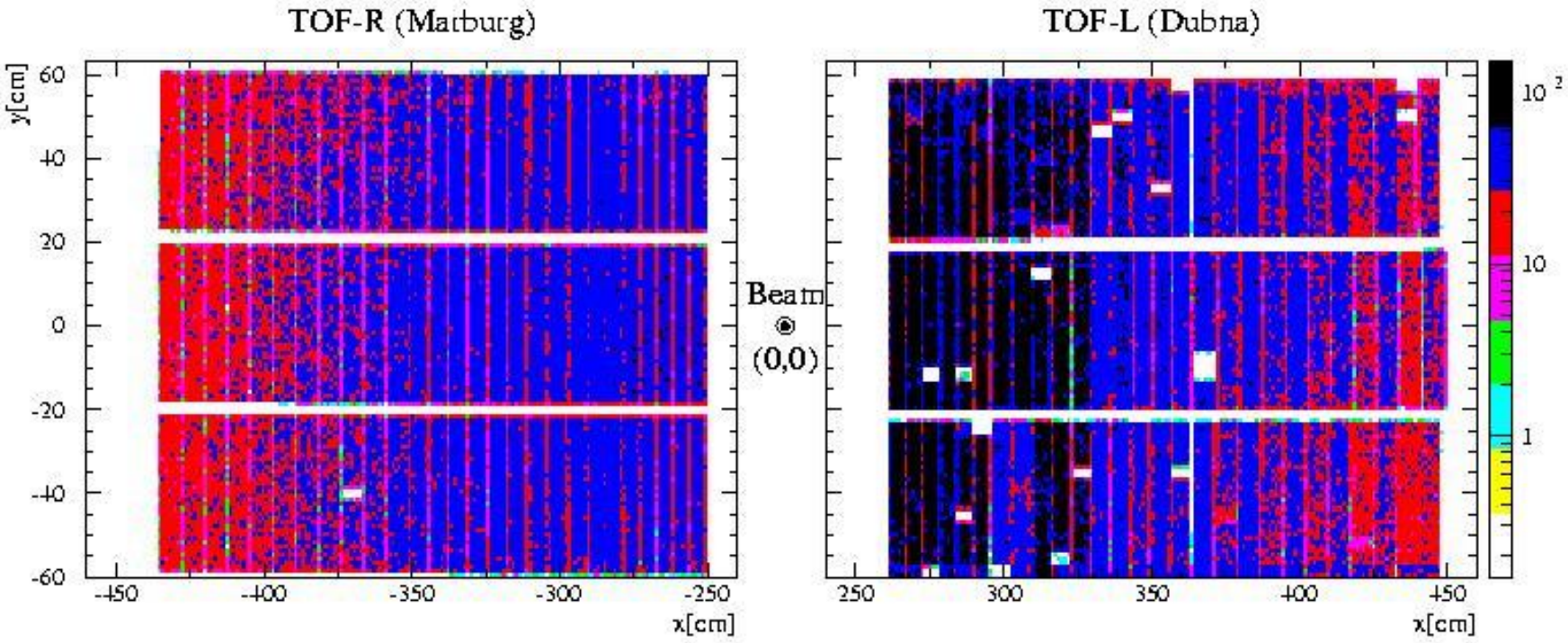


NIM A430
(1999) 210–244

TPC Tracks (topview)

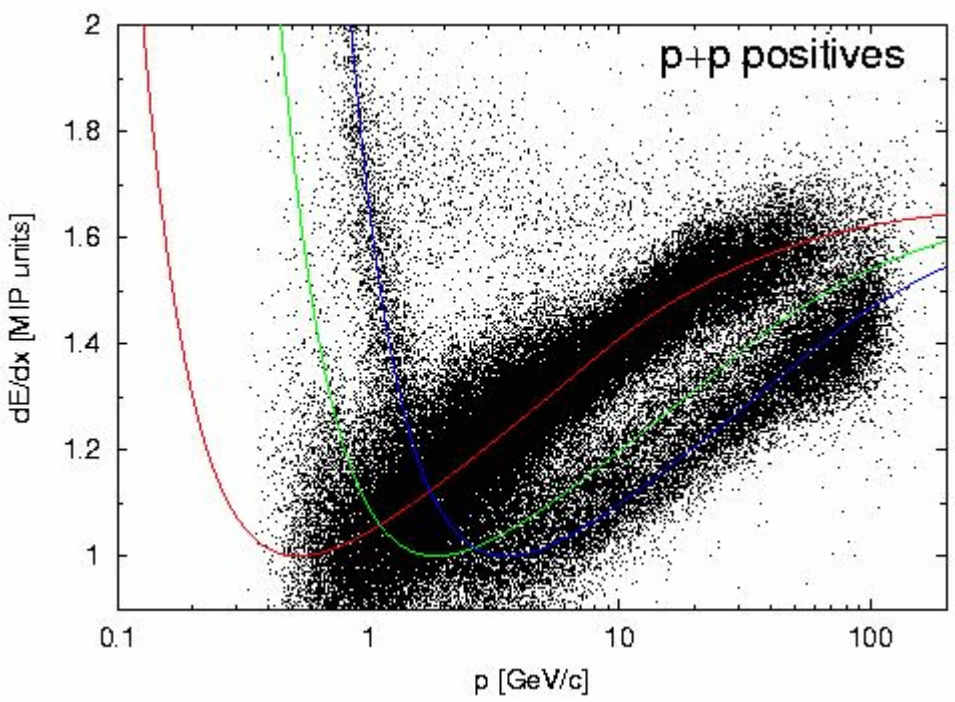


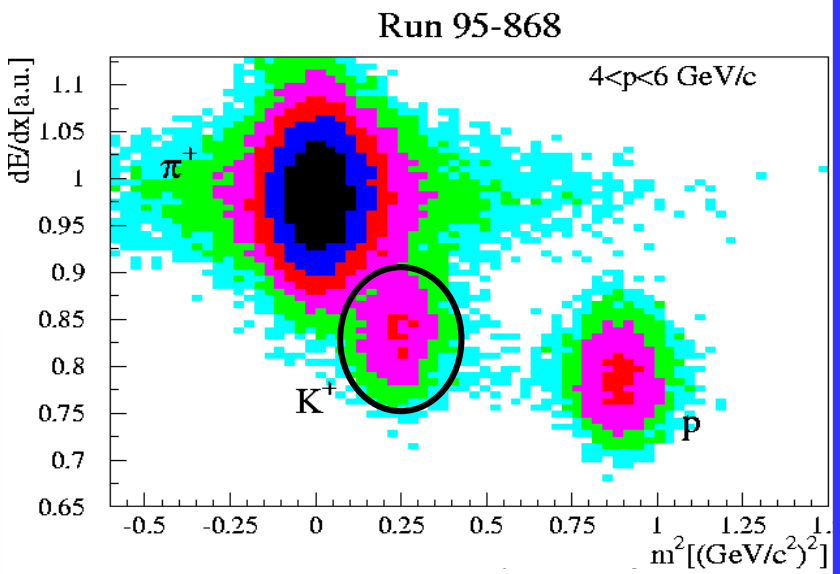
TOF Hits


TOF-R (Marburg)
TOF-L (Dubna)
y[cm]
60
40
20
0
-20
-40
-60
-450
-400
-350
-300
-250
x[cm]
Beam
(0,0)
250
300
350
400
450
x[cm]
10 ²
10
1

Particle Identifications

- Track Curvature → Momentum
- Specific dE/dx → Bethe-Bloch
- dE/dx PID



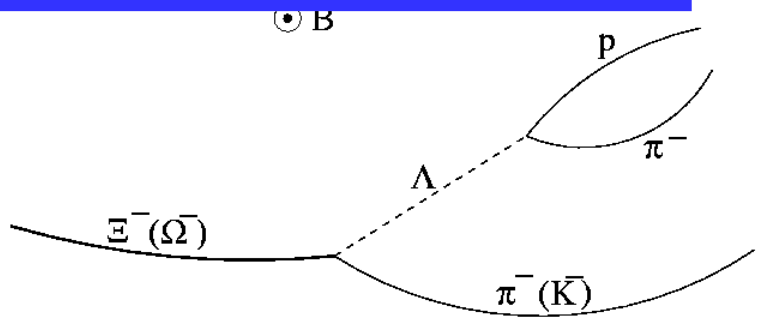


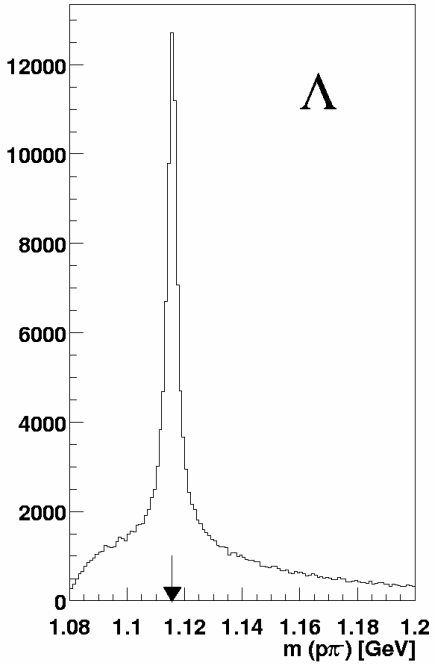
- Time-Of-Flight & Tracklength
  - → Velocity
  - → Mass
  - → TOF PID

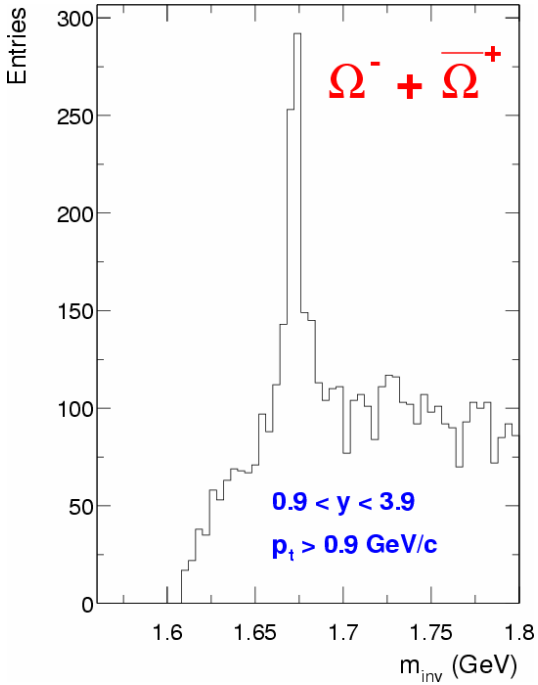
Resonance Reconstruction

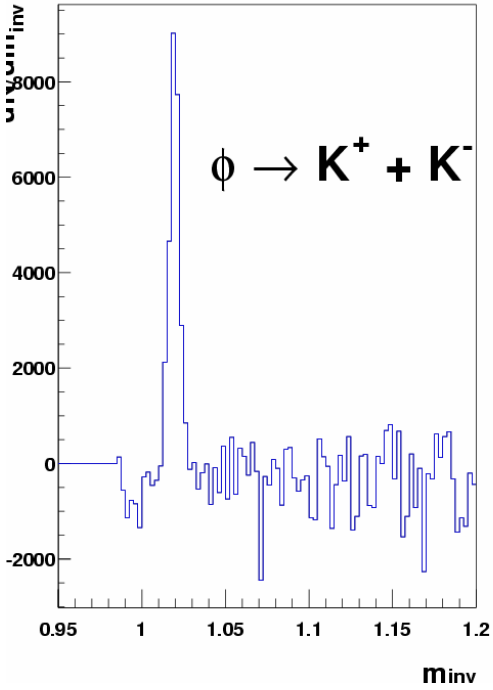
$$m_{inv} = [(E_1+E_2)^2-(\vec{p}_1+\vec{p}_2)^2]^{1/2}$$

- Identify secondary vertices
- Examples in Pb+Pb@158AGeV



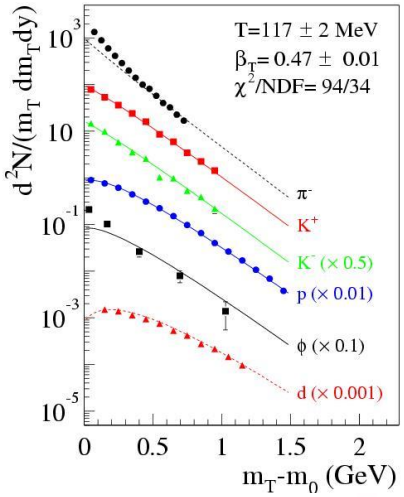




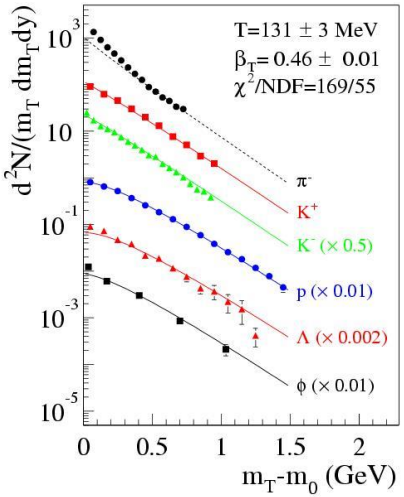


m_T Spectra [$d^2N/(m_T\, dydm_T) \sim \exp(m_T/T)$]

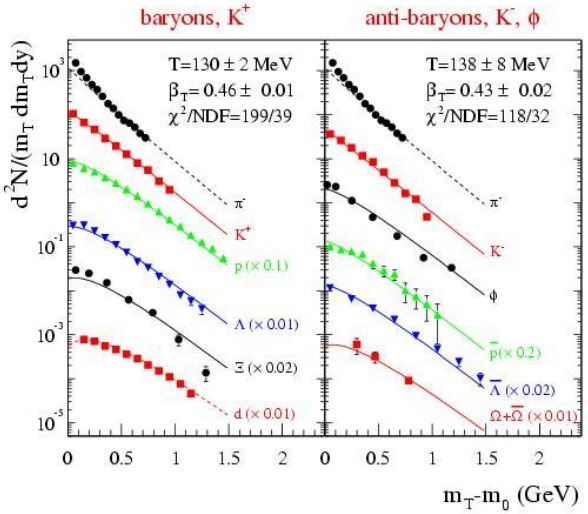
20GeV



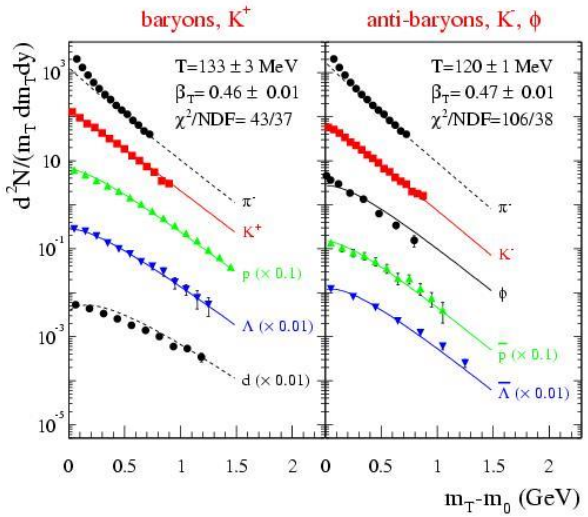
30GeV



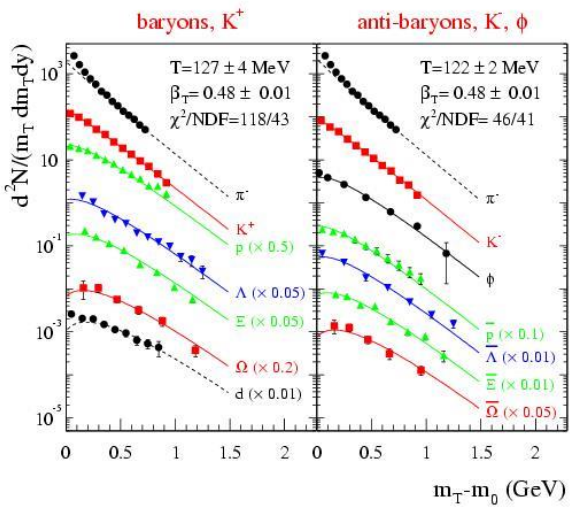
40GeV



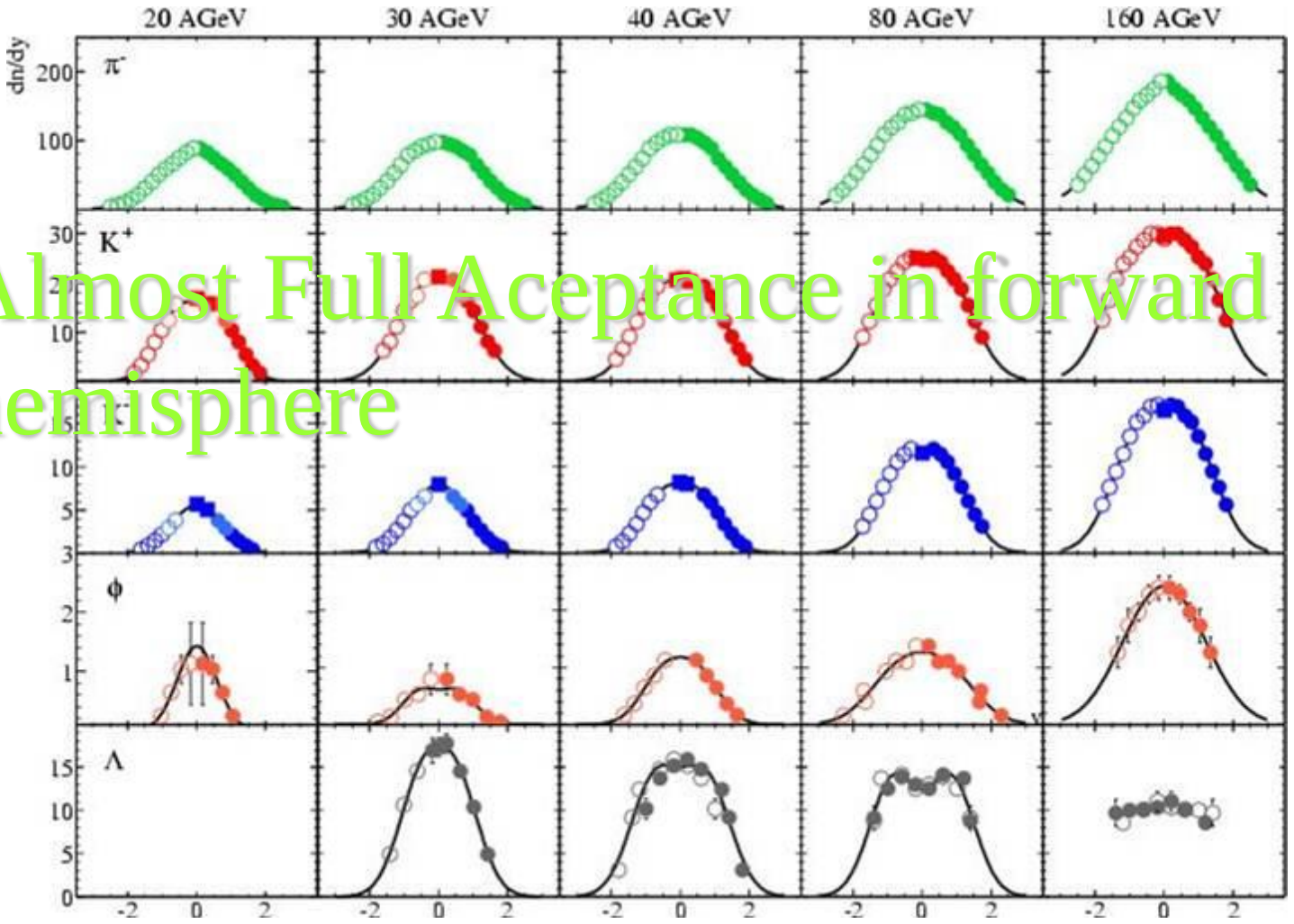
80GeV



158GeV



Rapidity Distribution



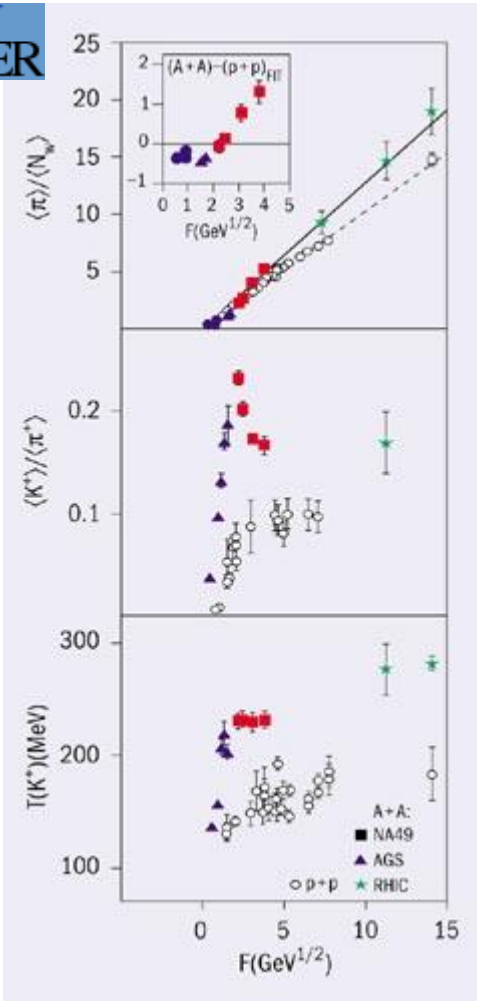
Almost Full Aceptance in forward hemisphere

Results Interpretation

- Energy Dependence (AGS – SPS – RHIC)
  - Transverse Mass Spectrum ➔ Temperature
  - Rapidity Distribution ➔ Multiplicity
  - Strangeness Production
- System Size Dependence (p+p, C+C, Si+Si, Pb+Pb)
  - Hadron Multiplicity
  - E-by-E Fluctuations
- Outlook of NA49

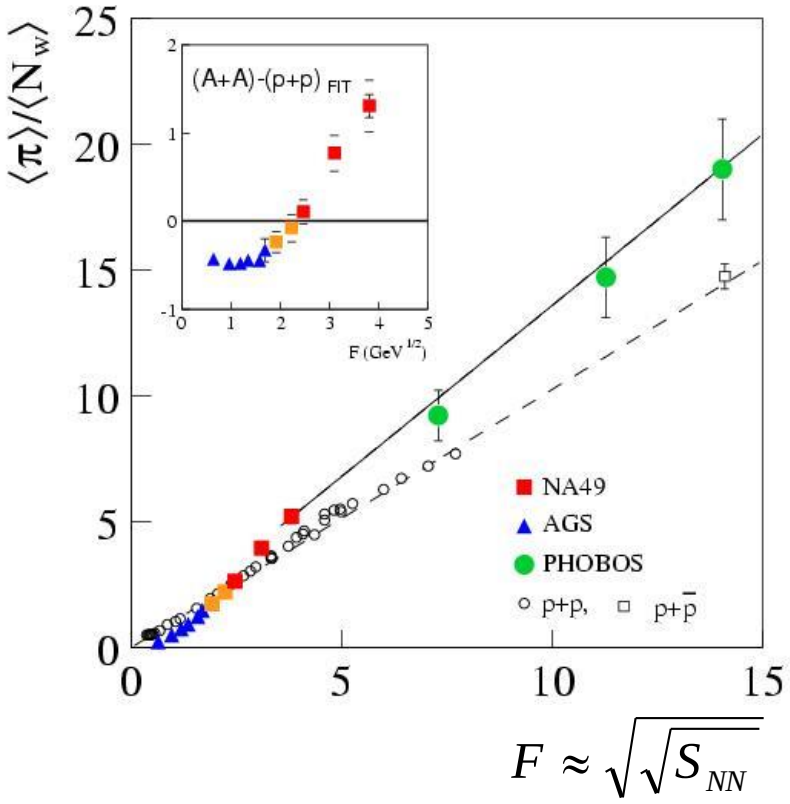
Signals of Deconfinement ?

CERN COURIER



- PION KINK
- THE STRANGE HORN
- THE STEP IN SLOPES

PION KINK



Onset at E_{lab} = 20–30 AGeV

The Pion Kink

M.Gazdzicki, Z.Phys. C66 (1995) 659

Deconfinement

↓

An Increase of Entropy, due to high number of effective degree of freedom in QGP

↓

$\langle\pi\rangle$ ~ Entropy

↓

An Increase of Pion Yield at the Onset of Deconfinement

The early stage of the collisions : Fireball

↓

- $E \sim s^{1/2}$; $V \sim s^{-1/2}$
- $\varepsilon = E/V \sim s$; $\varepsilon \sim gT^4$
- $T \sim g^{-1/4}\, s^{1/4}$
- $\langle\pi\rangle \sim S \sim gVT^3 \sim g^{1/4}s^{1/4} = g^{1/4}F$

↓

$$\langle\pi\rangle \sim g^{1/4}\, F$$

Statistical Model of the Early Stage (SMES) :

M. Gorenstein, Acta Phys. Polon. B30 (1999) 2705

The Statistical Model of the Early Stage (SMS)

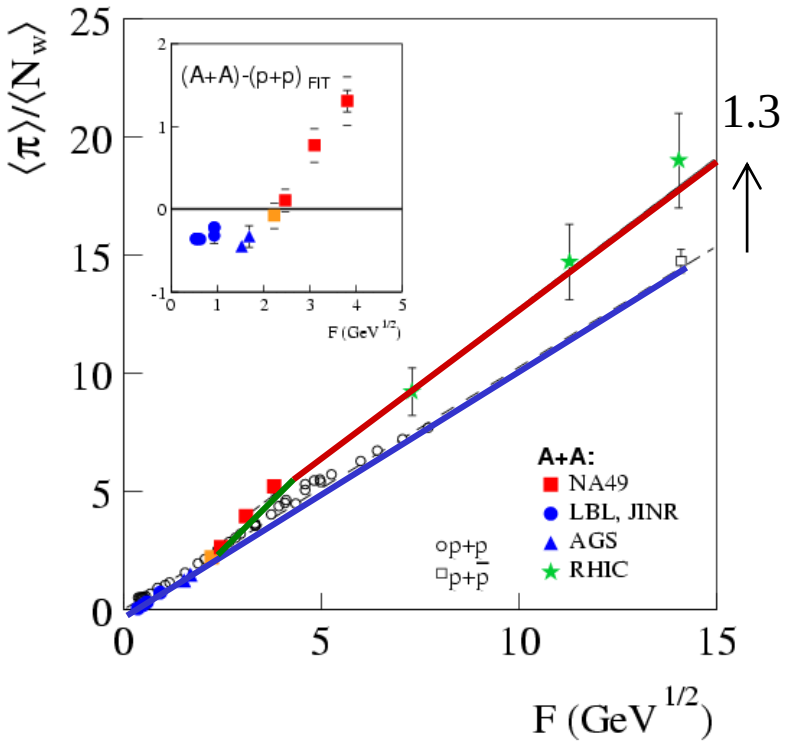
M.Gorenstein, Acta Phys. Polon. B30 (1999) 2705

g_H for hadron gas

$g_H < g_Q$

g_Q for QGP

$$g_Q / g_H \sim (1.3)^4 \sim 3$$



Strangeness Enhancement with the strange horn

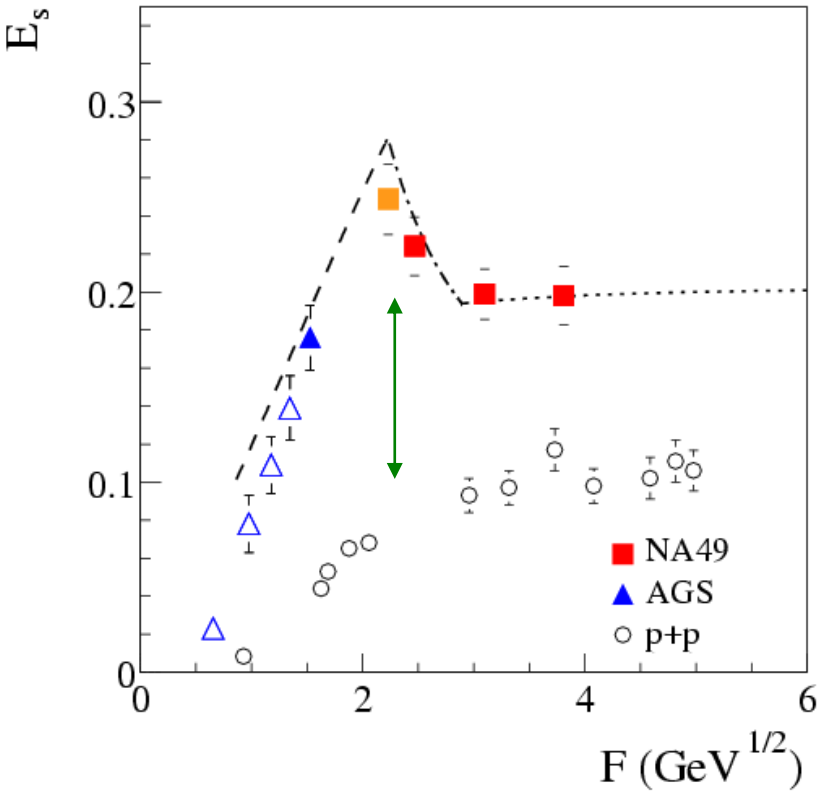
Strangeness Enhancement :

J. Rafelski, Phys. Rep. 88, 331 (1982)

Strange Horn :

M.Gazdzicki, D.Roehrich, Z.Phys. C71 (1996) 55

M.Gorenstein, Acta Phys. Polon. B30, 2705



Strange/Nonstrange Ratio

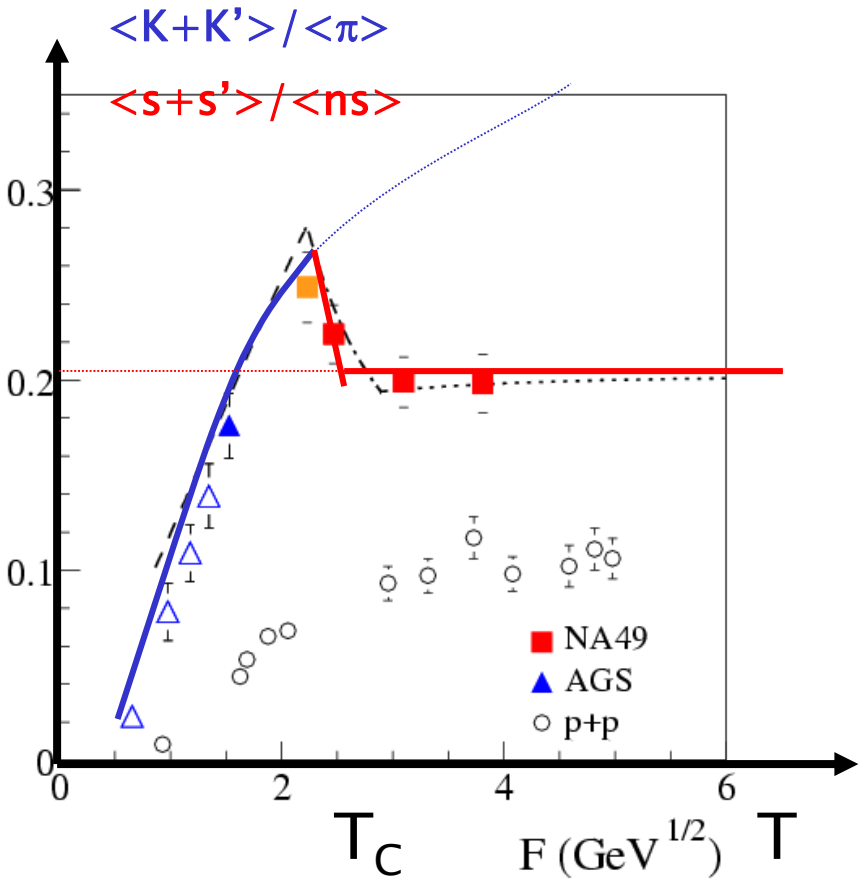
Hadron Gas $(K+K')/\pi$ at $T \sim T_C$

$\langle K+K' \rangle \sim T^{3/2} \exp(-m_K/T)$

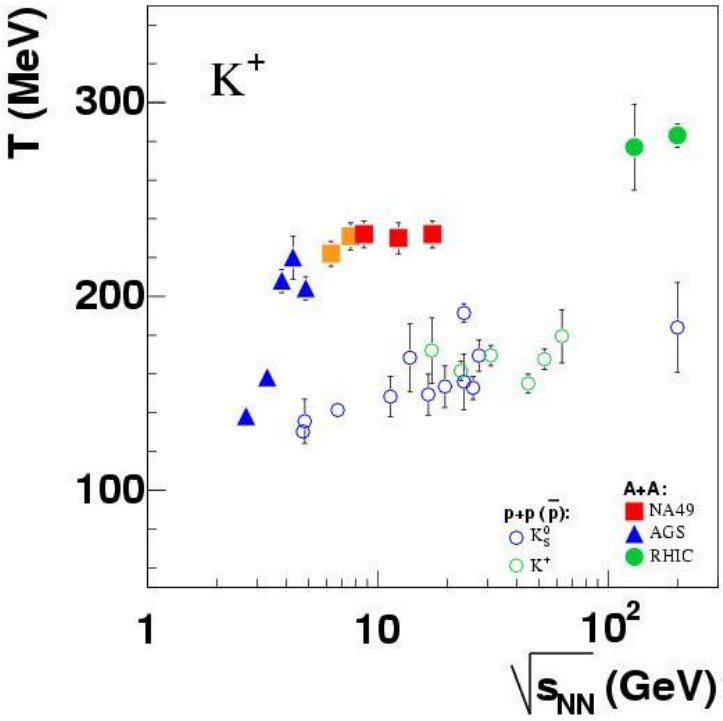
$\langle \pi \rangle \sim T^3$

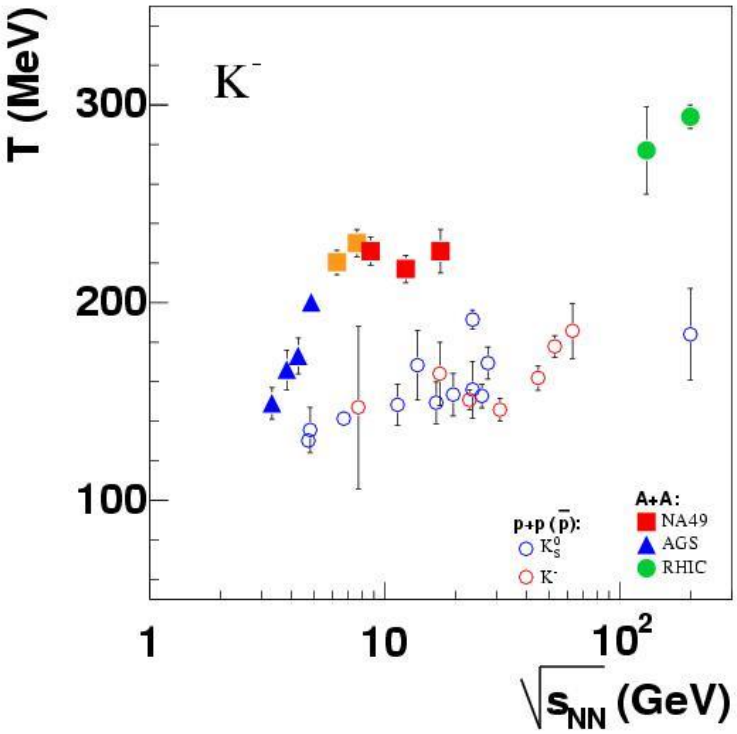
QGP at $T > T_C$ ($m_s < T$)

$\langle s+s' \rangle \sim T^3$



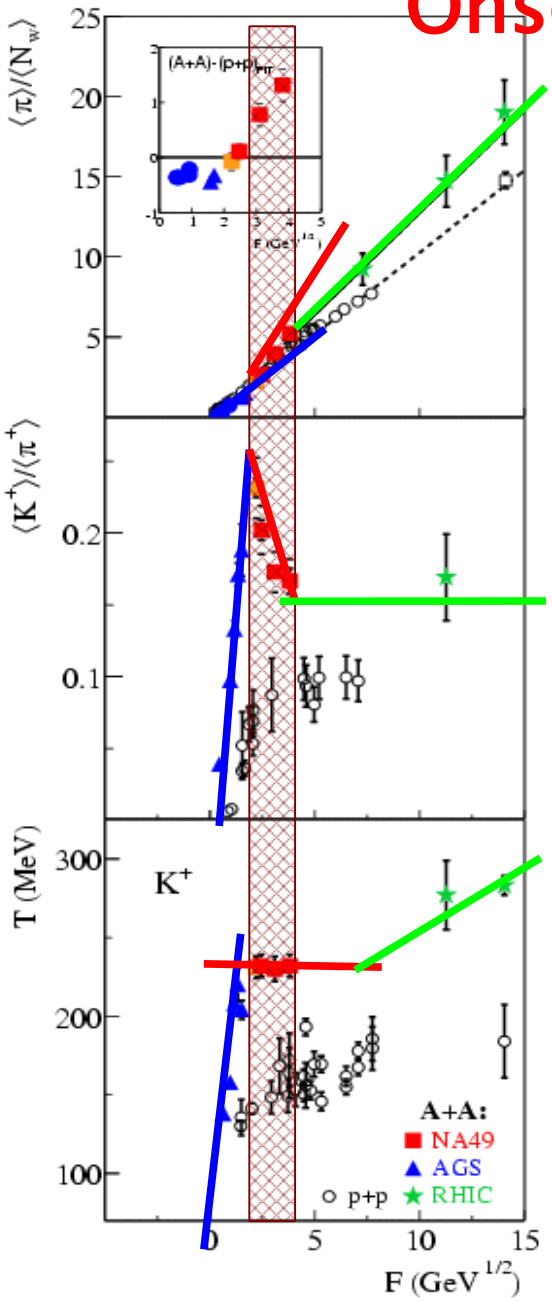
Slope vs. Energy





The Step at E_{lab} = 20 – 30 AGeV!

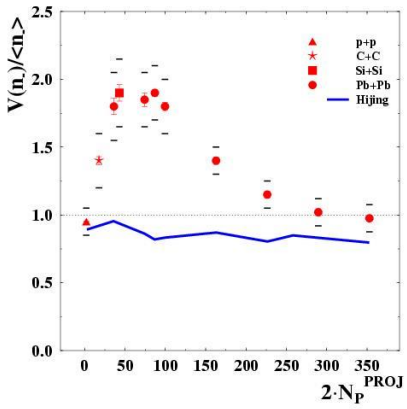
Onset of Deconfinement ? !



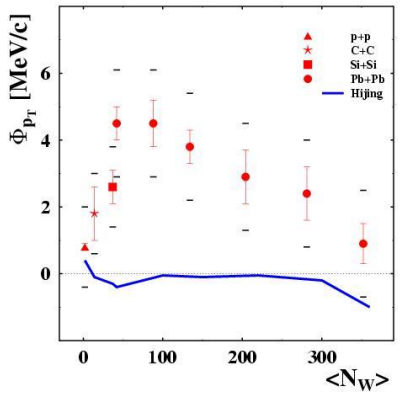
- Several anomalies in hadron production are observed at the low SPS energies
- The onset of the observed anomalies is located at about 30 AGeV
- The anomalies cannot be reproduced by the models without phase transition
- Measured rapid changes are consistent with the model assuming 1st order PT

System Size dependence of Fluc.

@158 AGeV

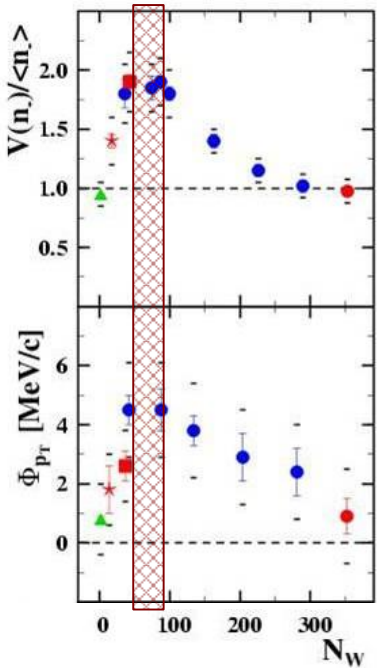


E-by-E Multiplicity Fluctuation



E-by-E p_T Fluctuation

System Size dependence @158 AGeV

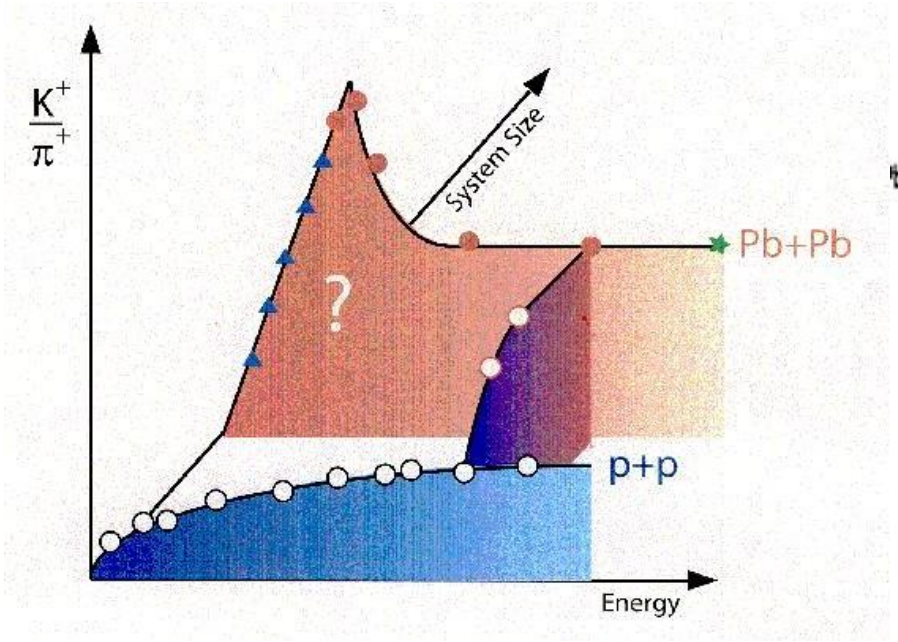


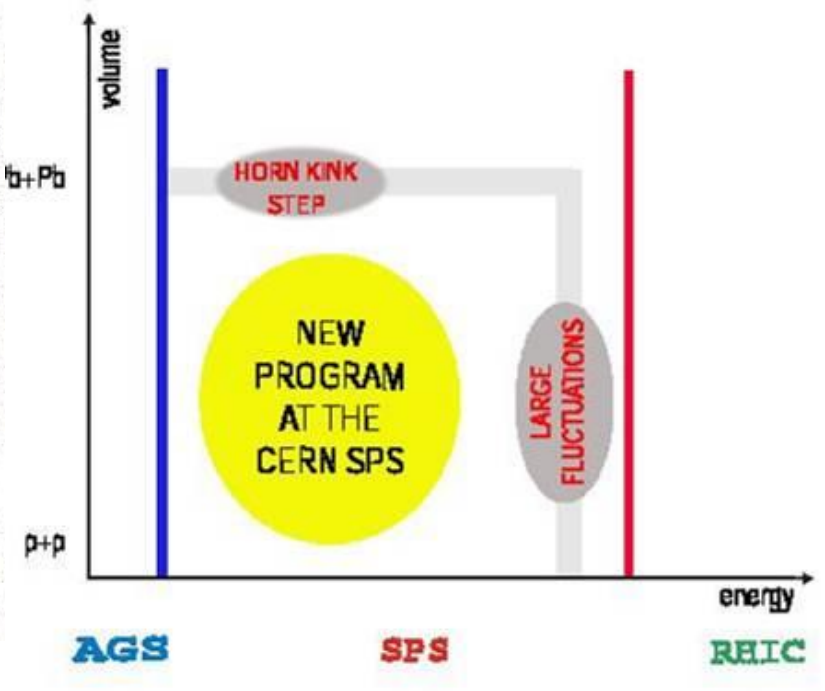
- Role of Volume in Strong interaction

Anomalies at $N_W \approx 70$

Is the maximum in fluctuations observed for small systems related to PT ?

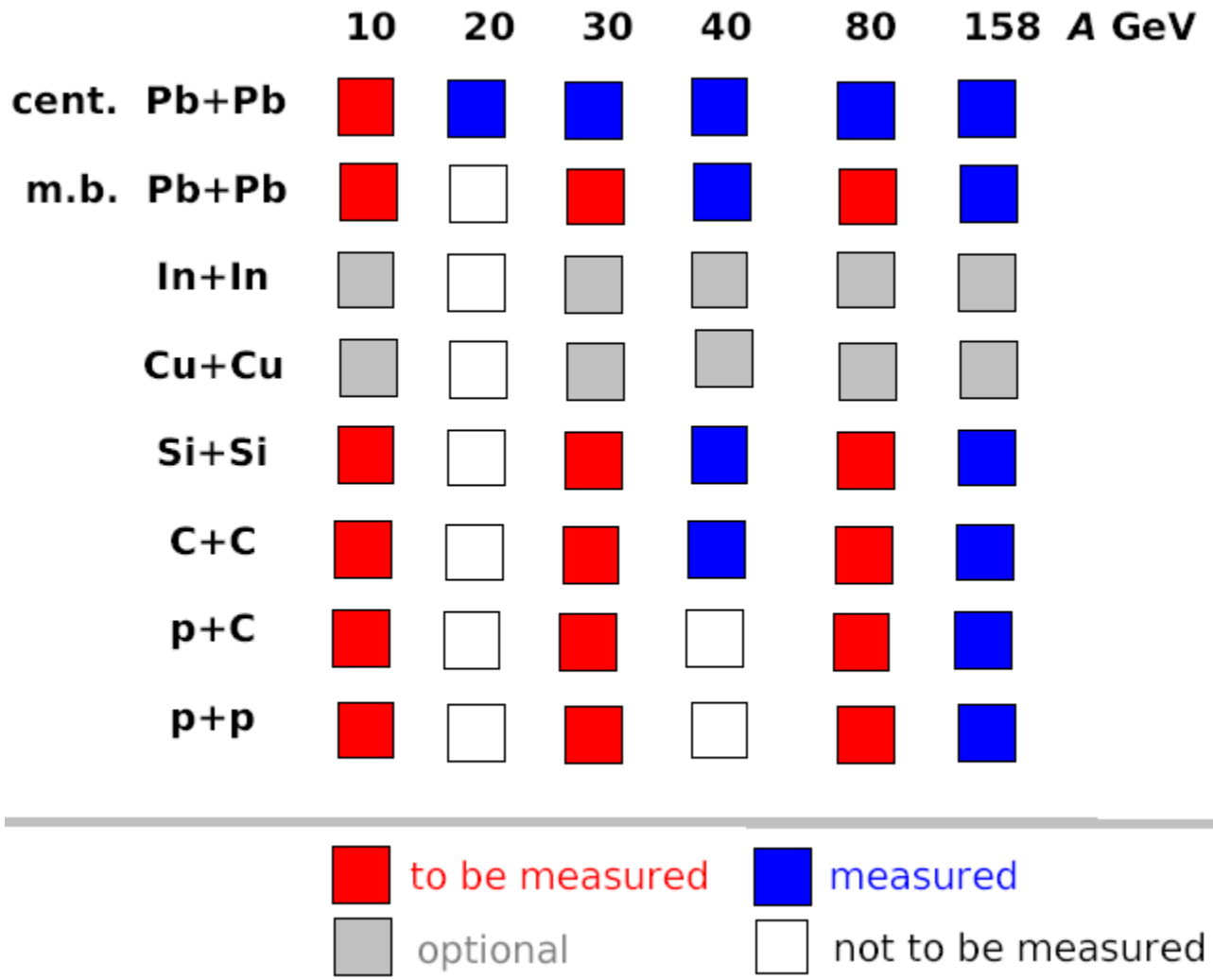
Summary and Outlook



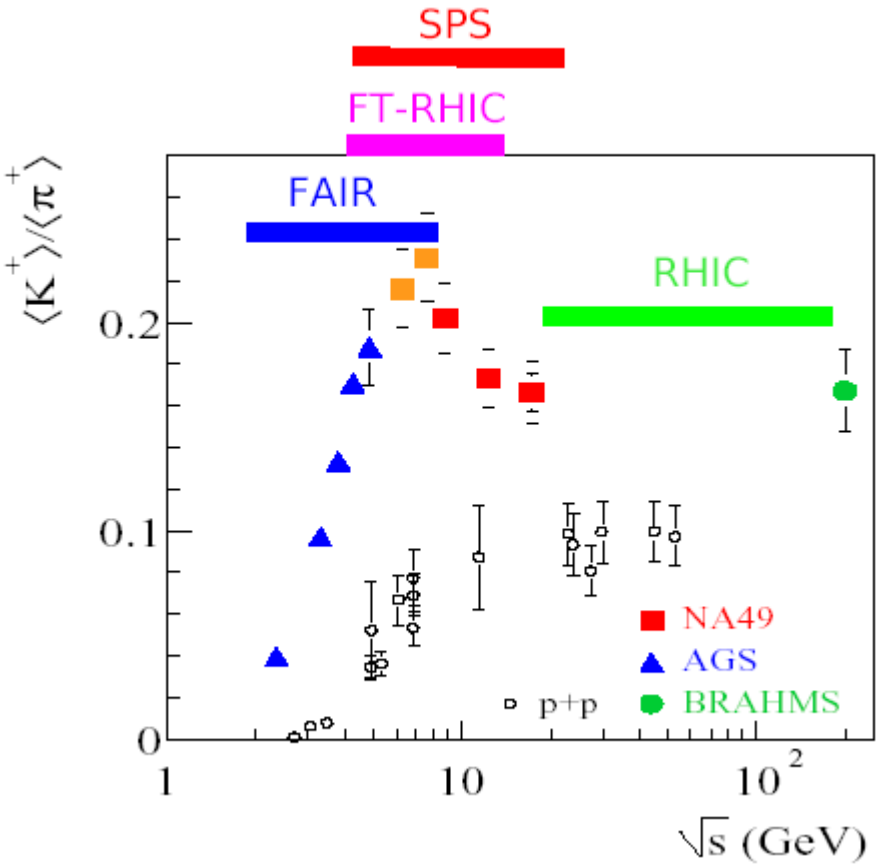


(Collision Energy) – (System Size) scan ≈ T–μ scan

Light ION program at the SPS



Possible future experimental landscape



FT-RHIC – Fixed Target program at RHIC

under discussion is use of BRAHMS detector and a jet target which should allow to study identified hadron spectra in A+A collisions in the energy range 10-100*A* GeV

+the program can run parallel to the collider runs

+almost continuous energy spectrum

- low priority as a parasitic program
- narrow acceptance, only inclusive spectra of identified charged hadrons

FAIR – Facility for Antiproton and Ion Research in Darmstadt

the proposed project should allow to study nuclear collisions in the energy range 2-35*A* GeV starting from 2012

+very high intensity beams, low cross section observables

+study of the properties of dense hadronic medium

-transition energy range is not covered, the critical point is not reachable

Light ION program at the SPS

Light Ion program at the CERN SPS

NA49 Collaboration

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