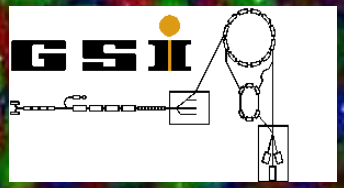
Current Heavy Ion Physics Experiments and Results Survey



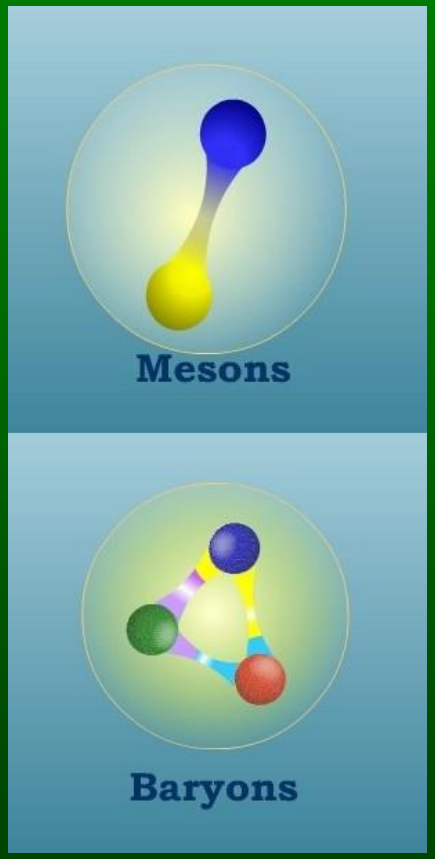
In-Kwon YOO (yoo@pusan.ac.kr)

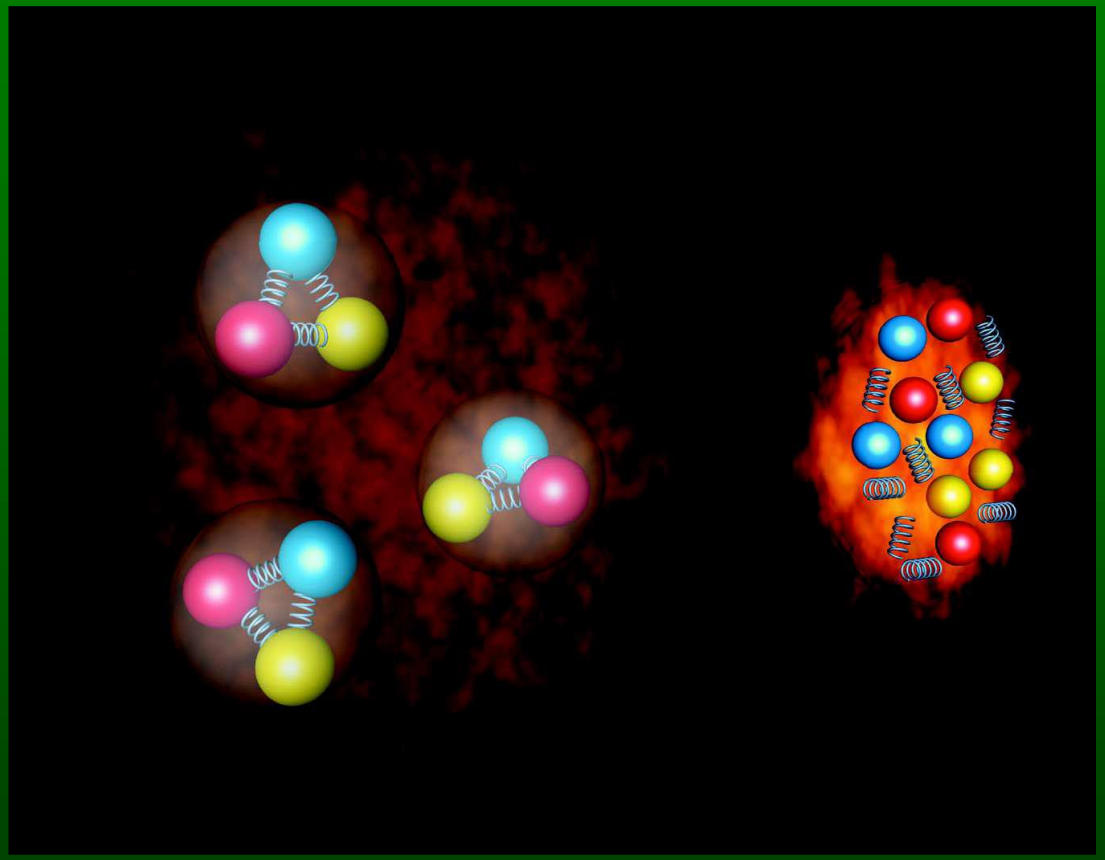
Heavy Ion Physics Experiment Lab.

Pusan National University

Busan, Republic of KOREA

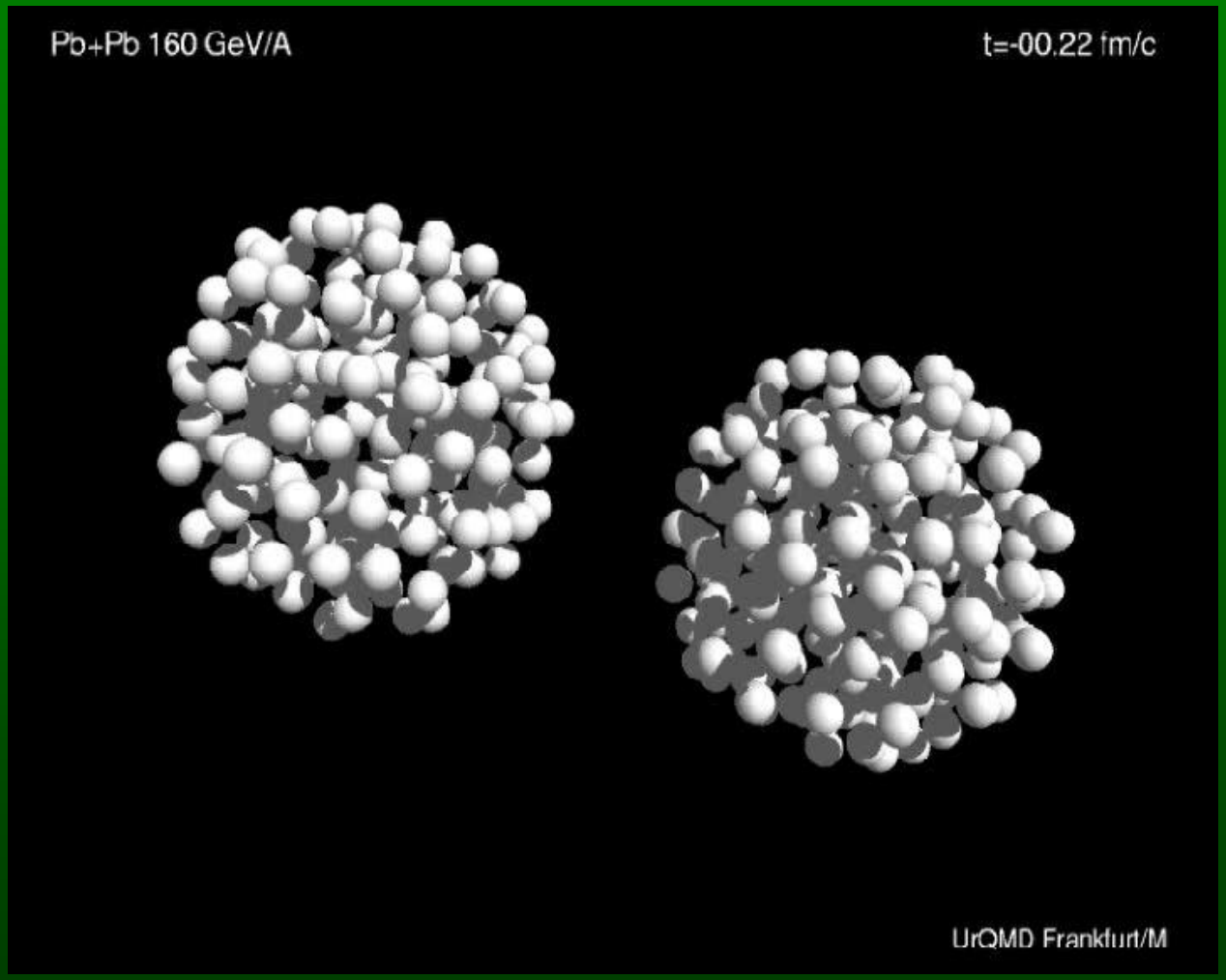
What are we looking for ?



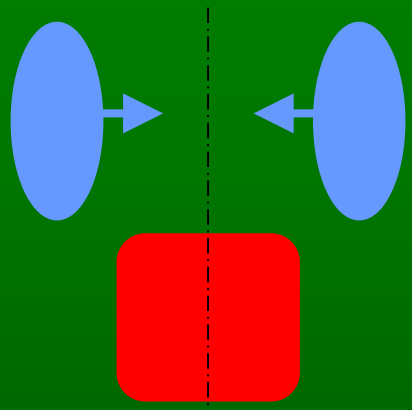


Ultra-Relativistic Heavy Ion Collisions

Ultra-Relativistic Quantum Molecular Dynamic Model



Basic Idea



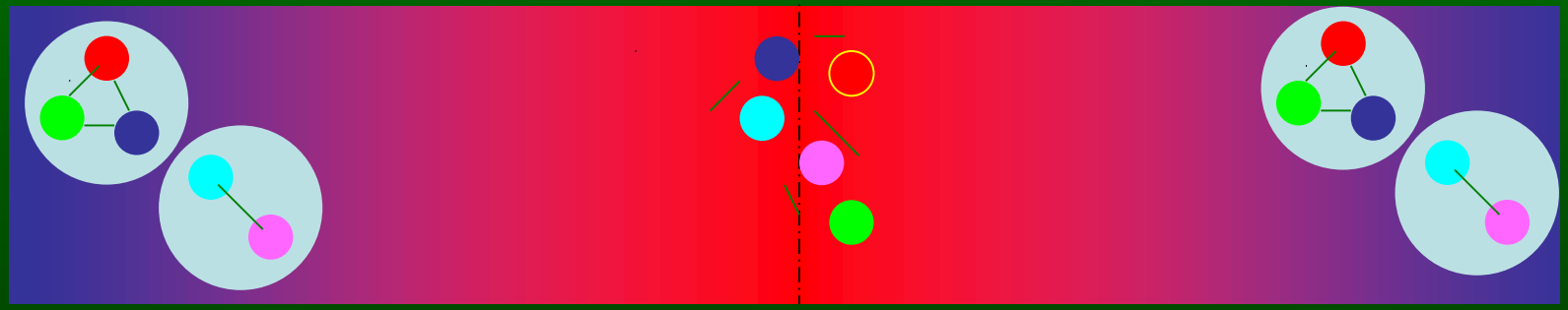
A+A Collision

Collision Energy

~ 10 GeV/N+N

Energy Density

~ 1 GeV/fm^3



Low

Hadrons

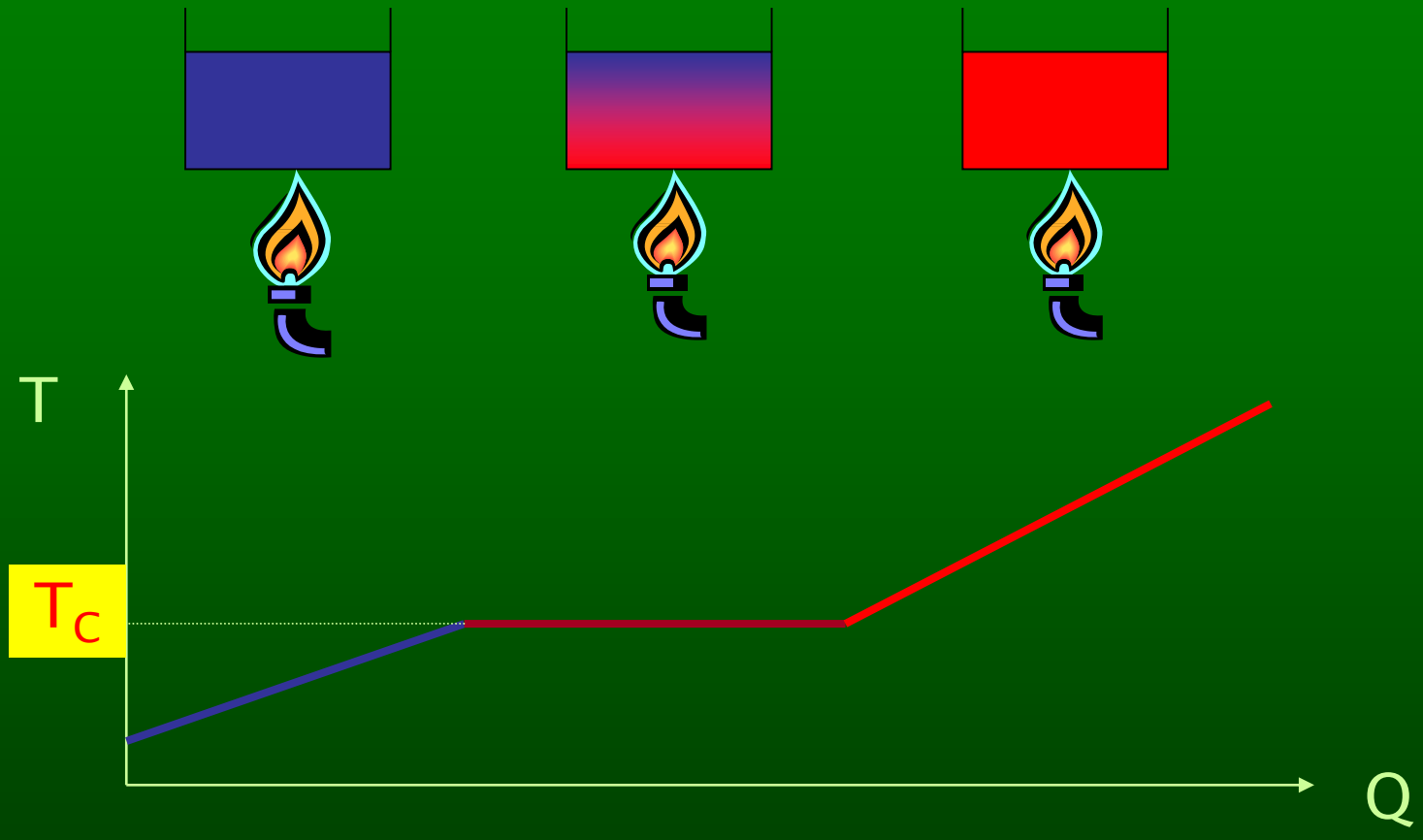
High DoF

Quark & Gluons

Low

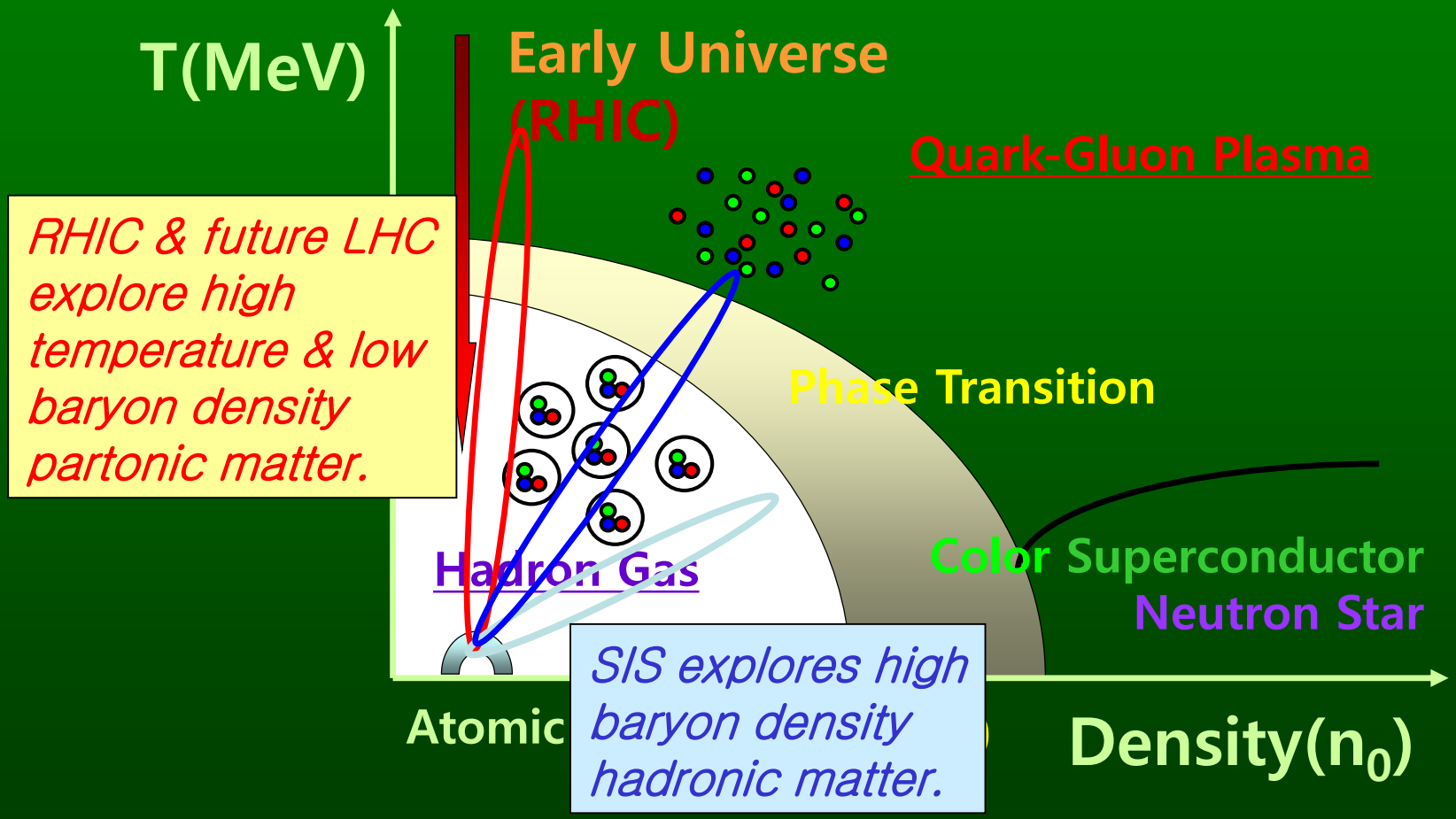
Hadrons

Phase Transition



Anomalies in the Energy Dependence of the relevant observables

Relativistic HI Collisions



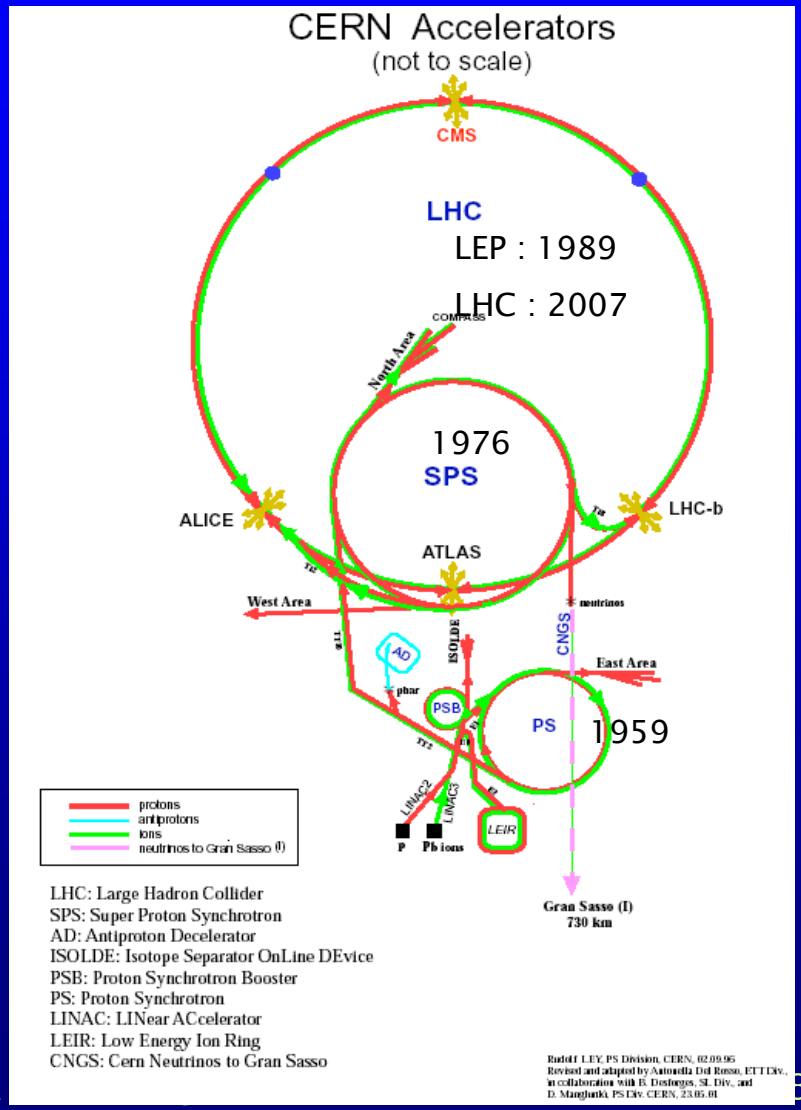
HI Accelerator

Accelerator	c.m. Energy (GeV)	Status
SIS 18 (GSI, Germany)	2A (A=mass number)	Running
AGS (BNL, USA)	5A	Finished
SIS 300 (GSI, Germany)	8A	Plan to run from ~2014
SPS (CERN, Switzerland)	20A	Finish soon
RHIC (BNL, USA)	200A	Running
LHC (CERN, Switzerland)	5500A	Plan to run from ~2007

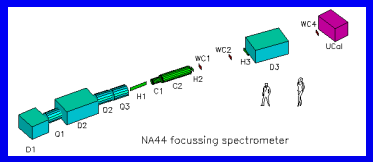
Conseil Europeen pour la Recherche Nucleaire

Organisation Européenne pour la Recherche Nucléaire
European Organization for Nuclear Research

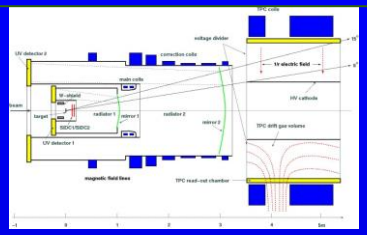
Since 1954



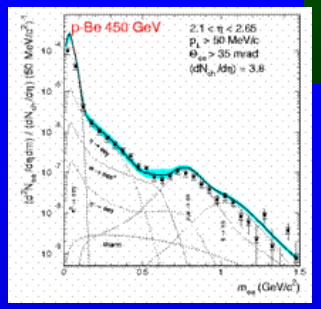
Experiments @ SPS.CERN



NA44 : The Focussing Spectrometer for one and two particles



NA45 (CERES) : Study of Electron Pair Production in Hadron and Nuclear Collisions



Motivation

Experiment

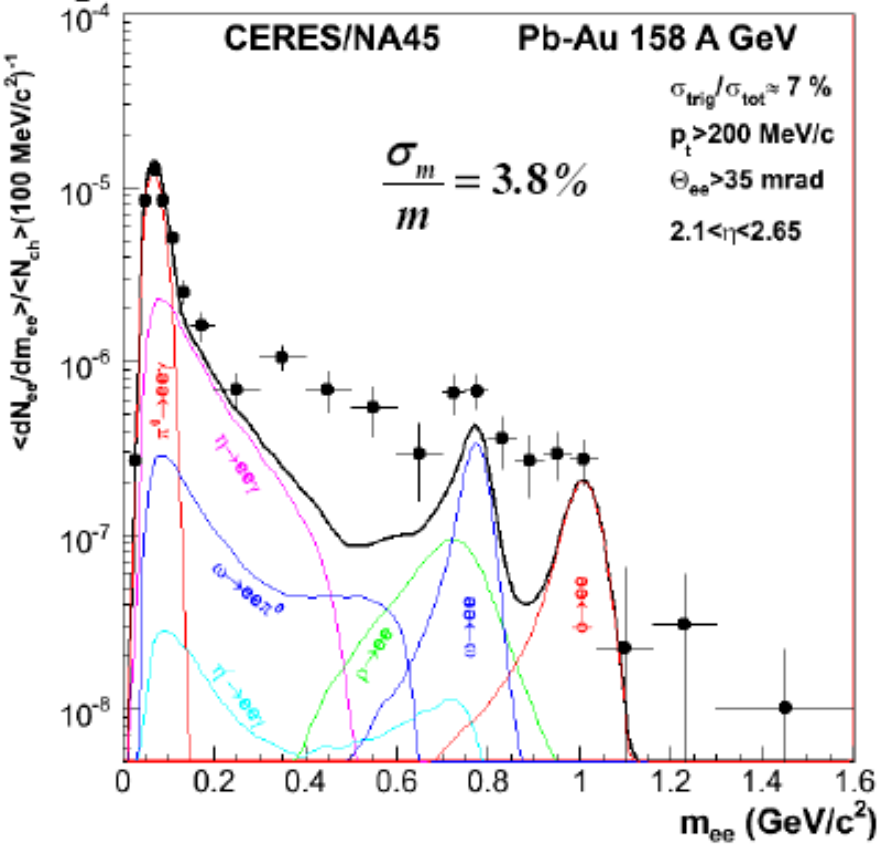
Results

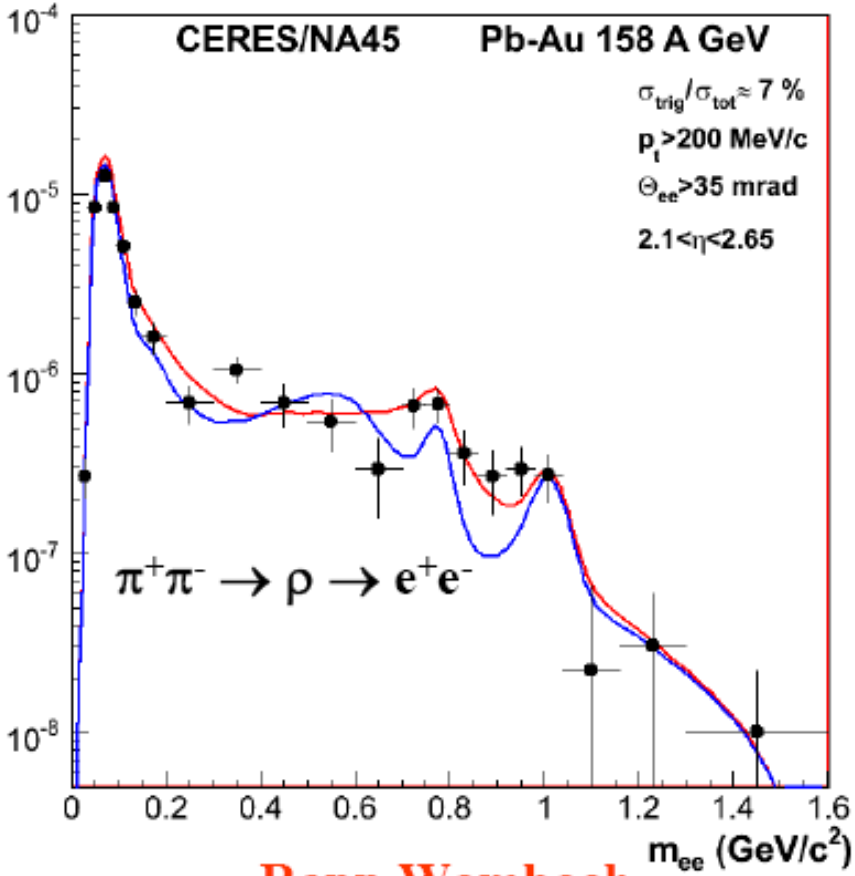
Outlook

CERES: Pb + Au 158 AGeV

D.Adamova et al., subm. to PRL

data in comparison to post freeze out hadronic cocktail



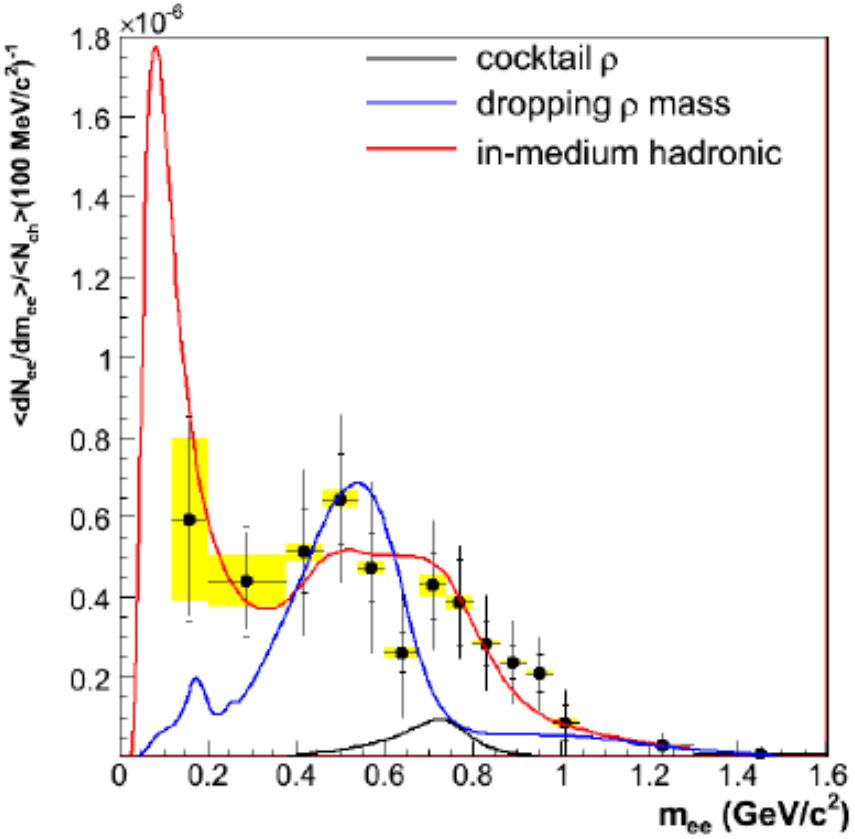


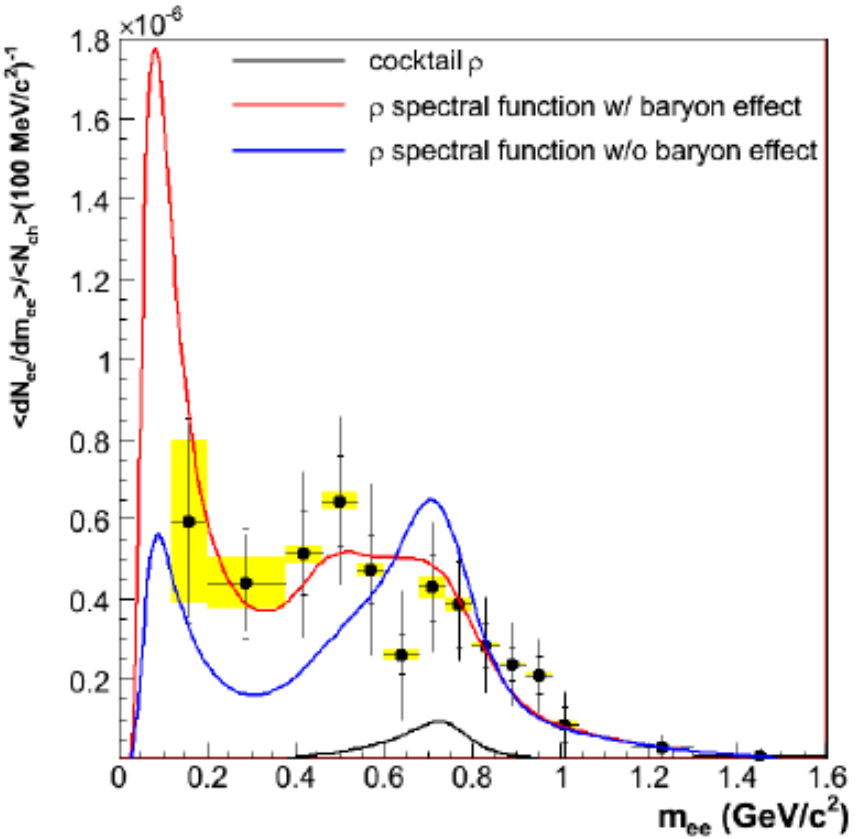
for $0.2 < m_{ee} < 1.1$ GeV/c^2
excess over hadronic decay contribution:
$2.45 \pm 0.30(stat) \pm 0.38(syst) \pm 0.74(decays)$

Rapp Wambach
broadened ρ spect. function

Brown Rho
dropping ρ mass

CERES e^+e^- pair yield after subtraction of hadronic cocktail excluding ρ



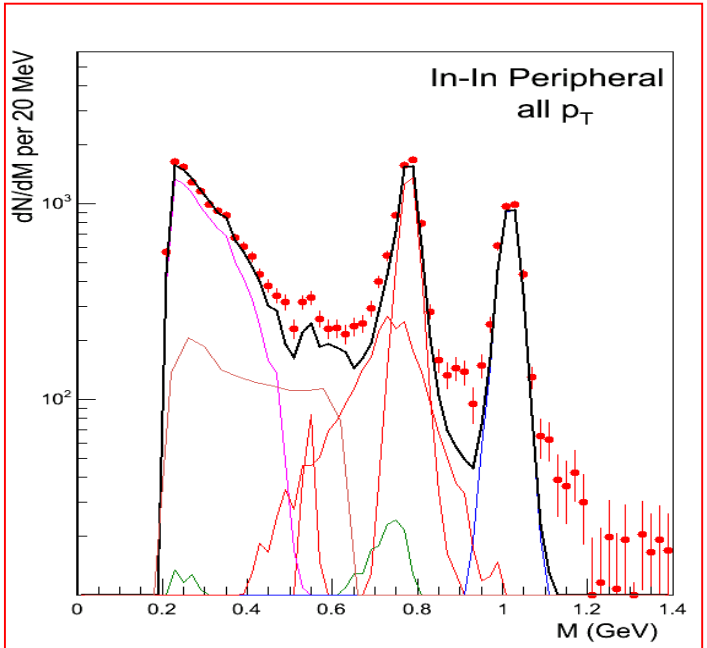


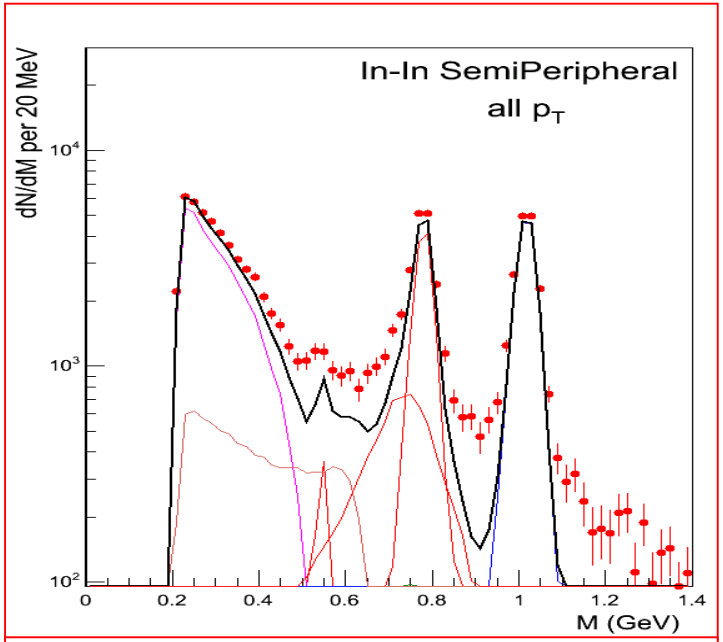
excess smeared out over wider mass range than expected for dropping ρ mass scenario

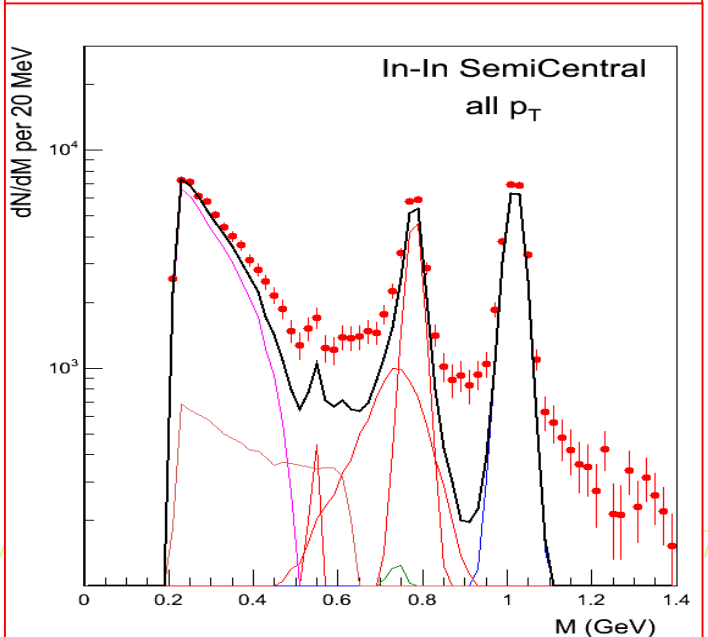
strength of di-lepton yield at low masses due to coupling to baryons

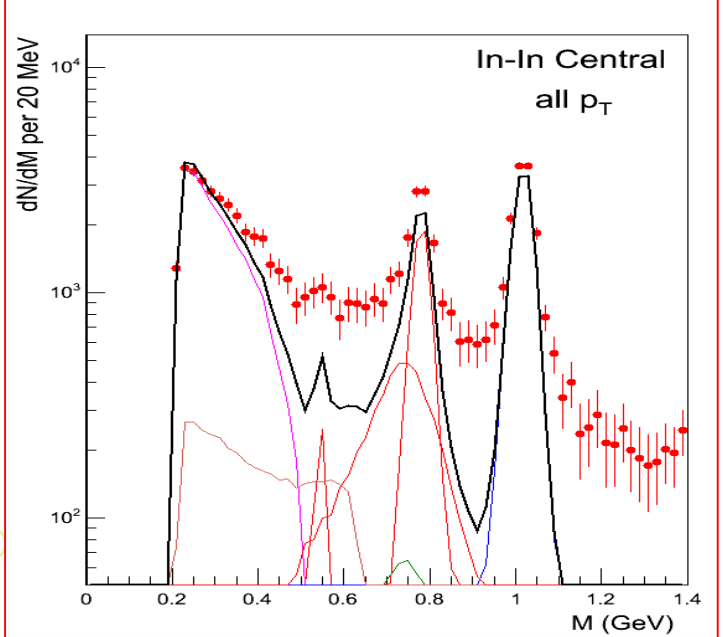
(similar to the observation by DLS, HADES)

NA60 very precise measurements in InIn







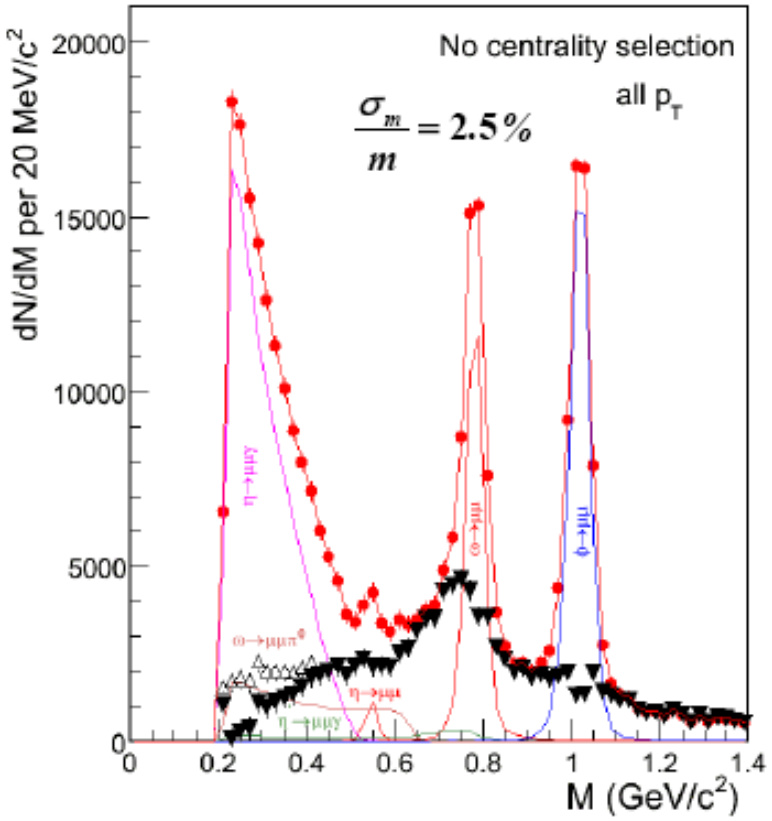


NA60 In+In 158 AGeV: ρ, ω, ϕ→μ⁺ μ⁻

s. talk by J. Seixas

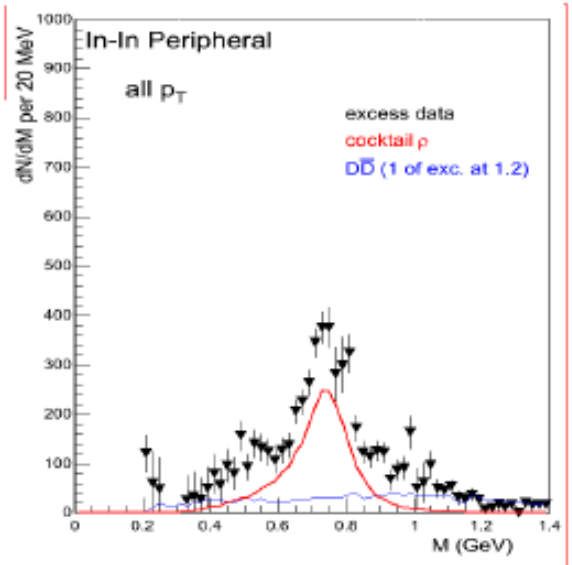
R. Arnaldi et al., PRL 96 (2006) 162302

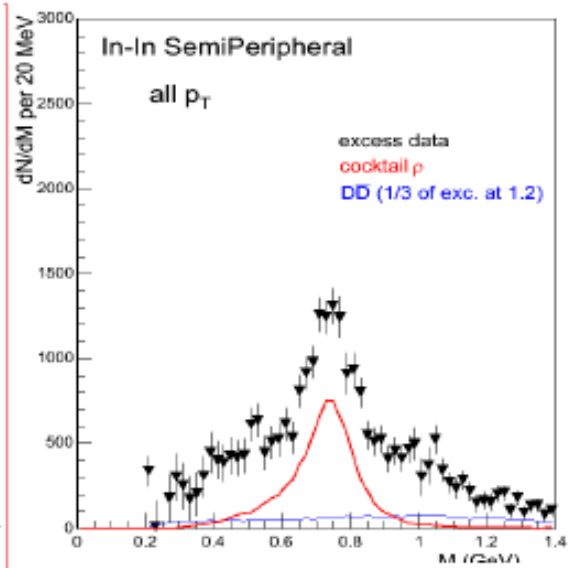
isolation of $\mu^+ \mu^-$ excess

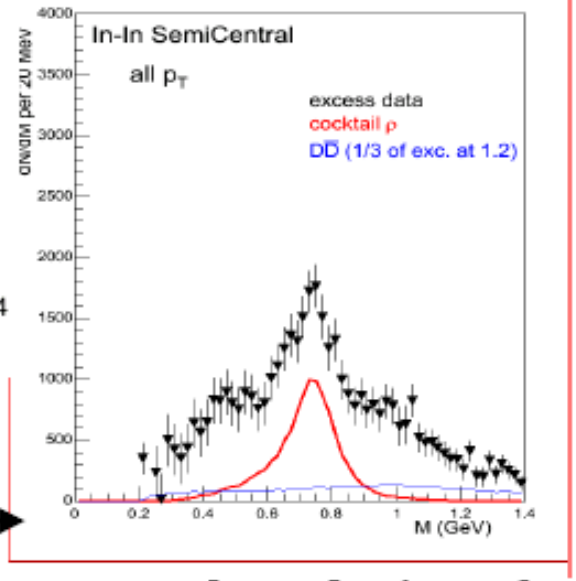


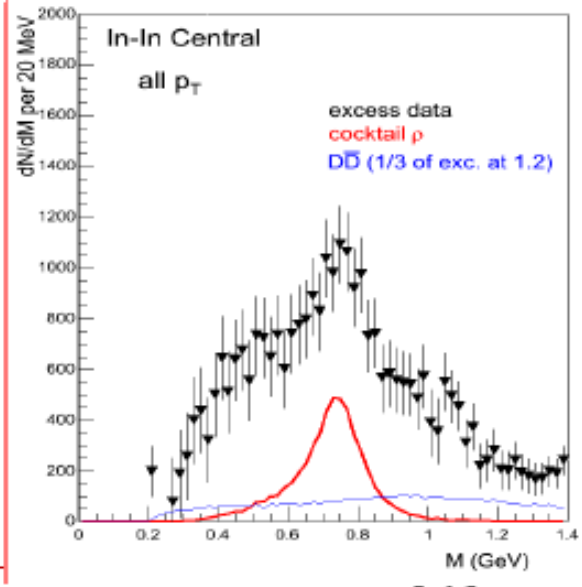
excess increases with centrality →

after subtraction of hadronic cocktail



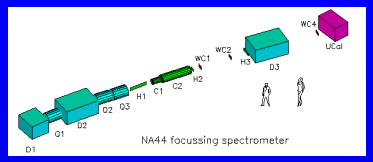






⇒ broadening of ρ meson; no mass shift

Experiments @ SPS.CERN



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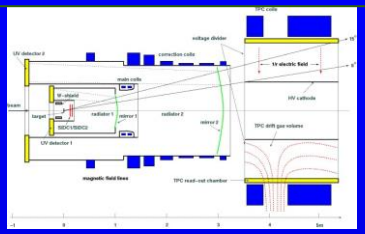

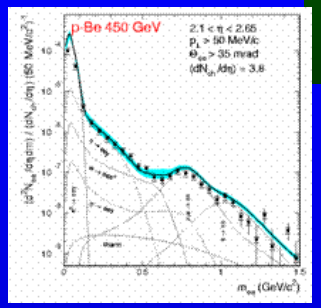

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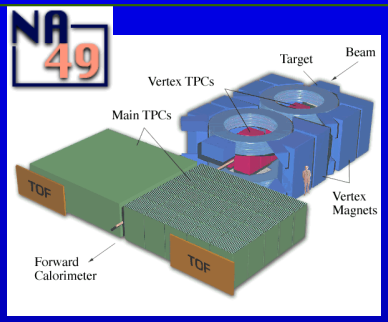
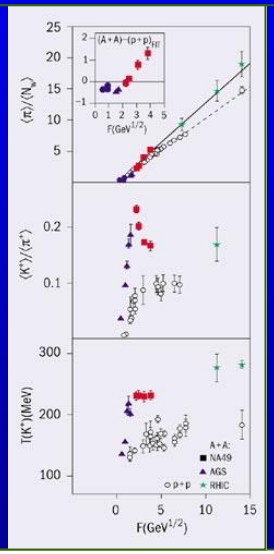
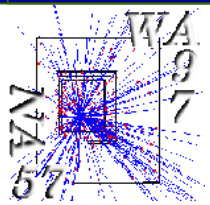
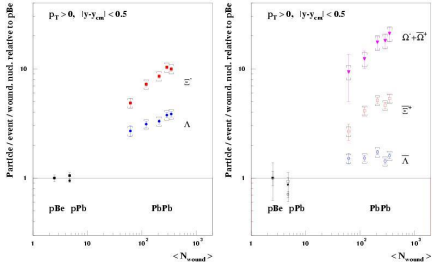


Large Acceptance Hadron Spectrometer





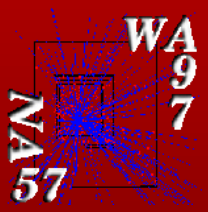
Study of Strange and Multistrange Particles

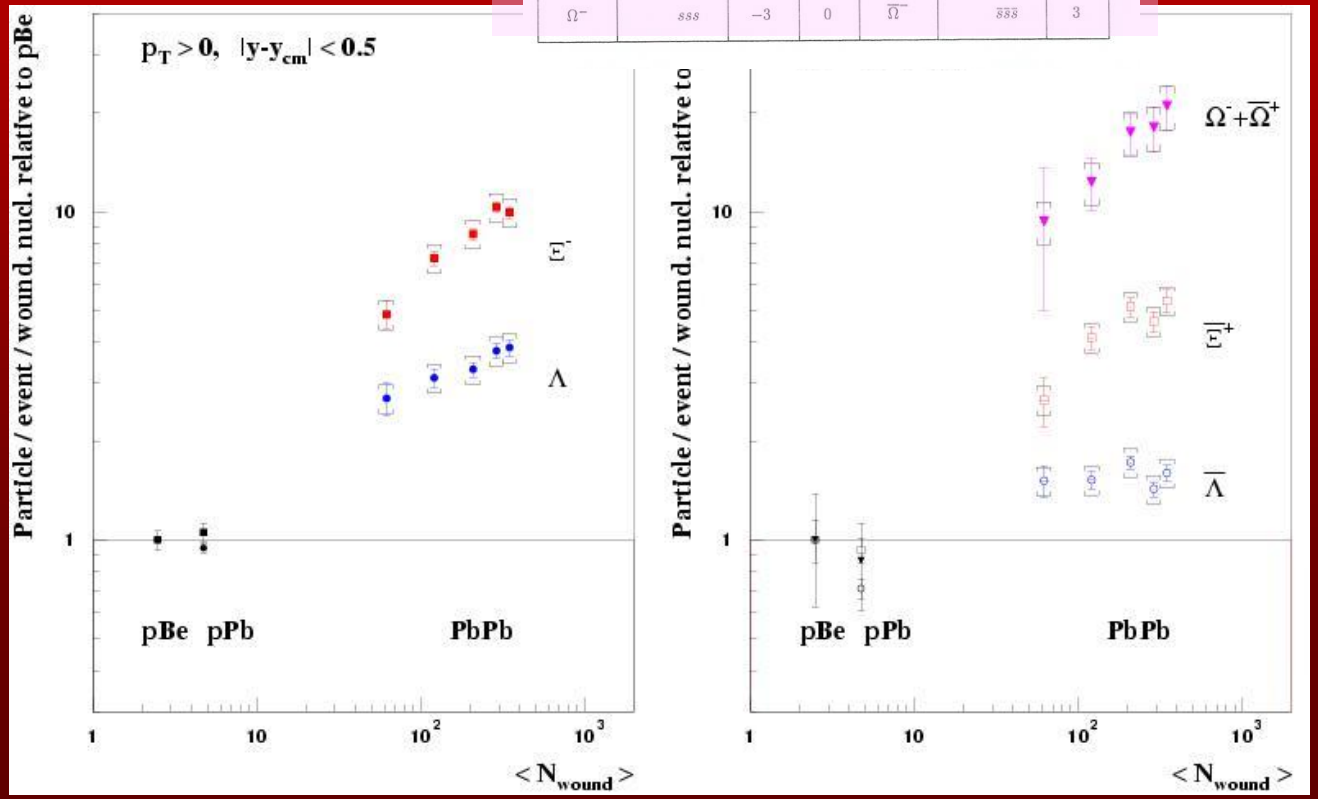


Strangeness Enhancement

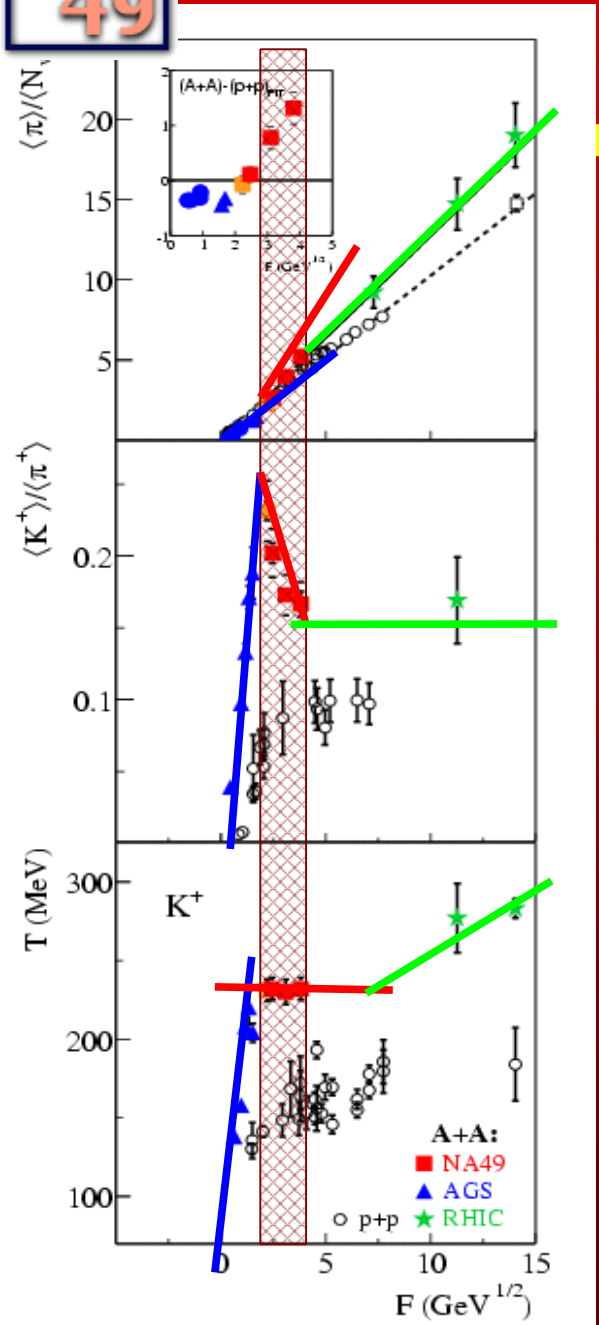
$K^+ = u\bar{s}$, $K^0 = d\bar{s}$, $\overline{K}^0 = \bar{d}s$, $K^- = \bar{u}s$ and $\phi = s\bar{s}$

Hyperon				Anti-hyperon		
	Quarks	S	I		Quarks	S
Λ	uds	−1	0	$\overline{\Lambda}$	$\bar{u}\bar{d}\bar{s}$	1
Σ^+	uus	−1	1	$\overline{\Sigma}^+$	$\bar{u}\bar{u}\bar{s}$	1
Σ^0	uds	−1	1	$\overline{\Sigma}^0$	$\bar{u}\bar{d}\bar{s}$	1
Σ^-	dds	−1	1	$\overline{\Sigma}^-$	$\bar{d}\bar{d}\bar{s}$	1
Ξ^0	uss	−2	$\frac{1}{2}$	$\overline{\Xi}^0$	$\bar{u}\bar{s}\bar{s}$	2
Ξ^-	dss	−2	$\frac{1}{2}$	$\overline{\Xi}^-$	$\bar{d}\bar{s}\bar{s}$	2
Ω^-	sss	−3	0	$\overline{\Omega}^-$	$\bar{s}\bar{s}\bar{s}$	3





Onset of Deconfinement ?

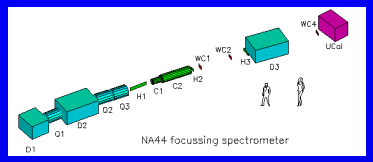


$\langle\pi\rangle$ ~ Entropy
Deconfinement :
An Increase of Pion Yield at the Onset

Strangeness Enhancement :
Hadron Gas – Mixed Phase – QGP

Anomaly in transverse Expansion

Experiments @ SPS.CERN



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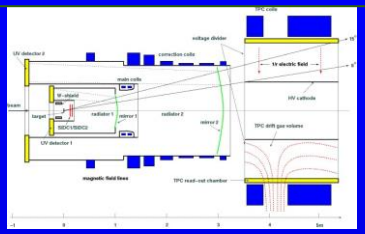

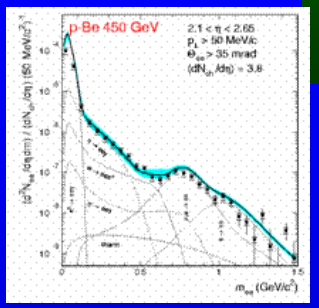

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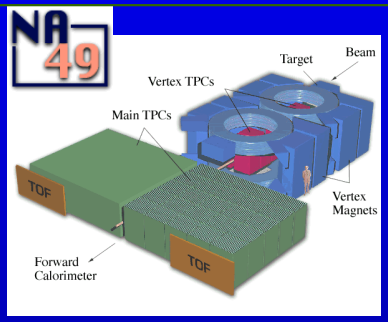

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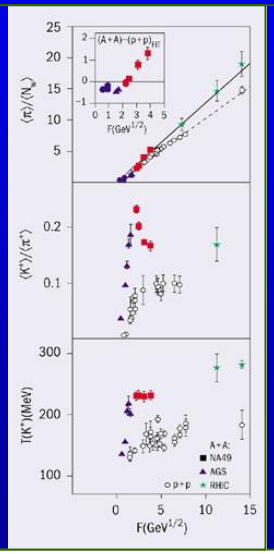
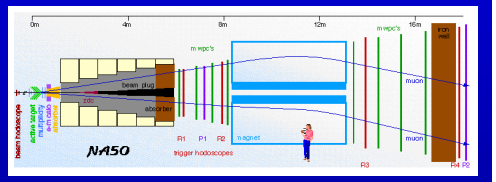
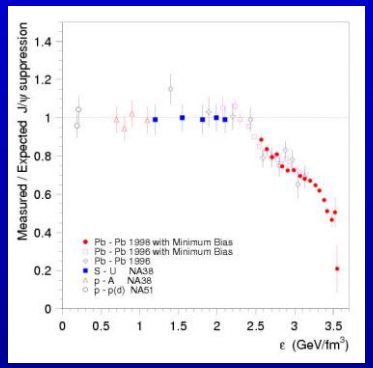
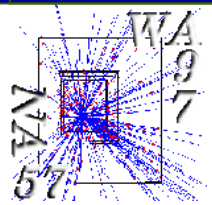




NA50 : Study of Muon Pairs and Vector Mesons





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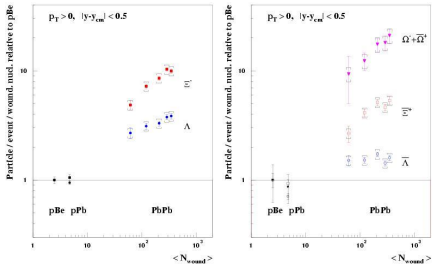


J/Ψ in QGP

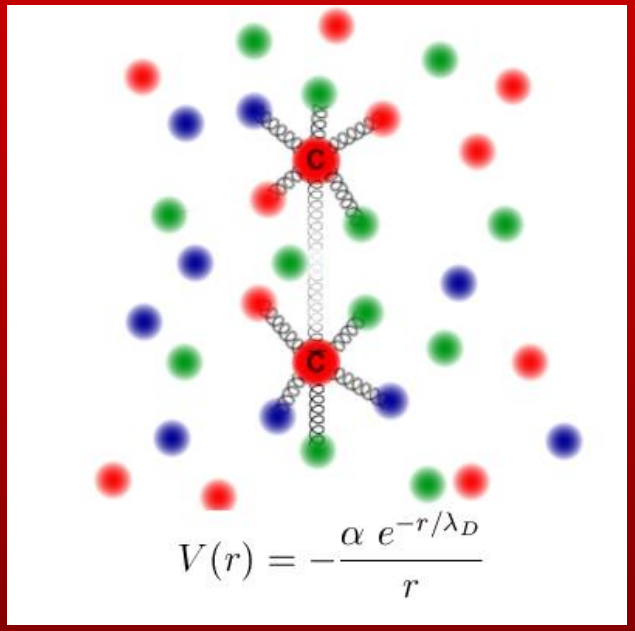
Matsui & Satz :

Ref) Phys. Lett. B178 (1986) 416.

In the QGP the screening radius could become smaller than the J/ψ radius, effectively screening the quarks from each other

	T=0	T=200
$R_{Bohr}\ (J/\psi) = \frac{1}{\alpha\,\mu}$	0.41 fm	1.07 fm
$\lambda_D\ (pQCD) = \sqrt{\frac{2}{9\pi\alpha}}\frac{1}{T}$	∞	0.59 fm

Ref) Introduction to High-Energy Heavy-Ion Collisions, C.Y. Wong 1994

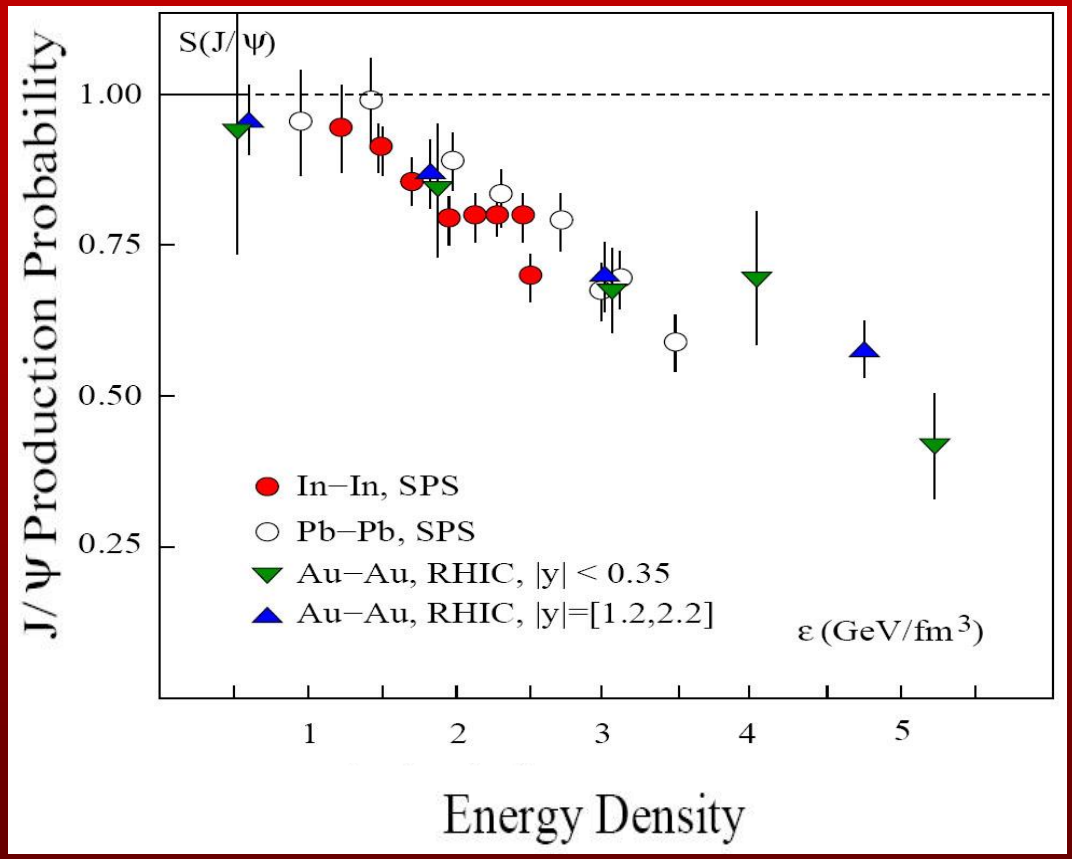


The charm and anti-charm become unbound, and may combine with light quarks to emerge as "open charm" mesons.

J/Ψ in QGP (J/Ψ Suppression)

- Charmonium dissociation temperatures

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$
T_d/T_c	2.10	1.16	1.12



Brookhaven National Lab.

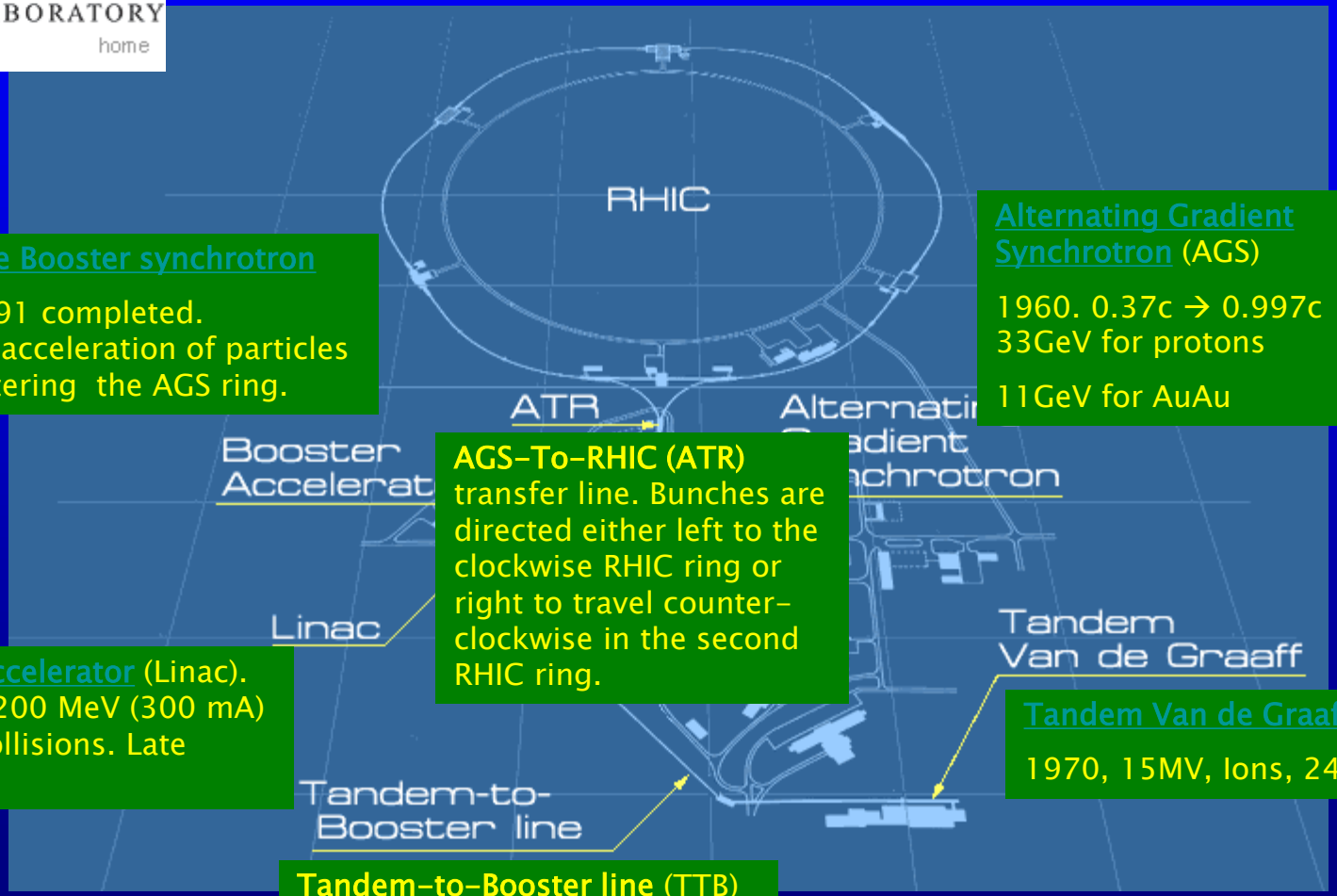
- Brookhaven National Lab. in New York

✓Circumference: 3.83 km
✓First collision: 2000
✓100A GeV Au+Au($2X10^{26}/cm^2/s$)
✓250 GeV $\vec{p} + \vec{p}$ ($2X10^{32}/cm^2/s$)

Brookhaven National Lab.

BROOKHAVEN NATIONAL LABORATORY home

Since 1947



The Booster synchrotron

1991 completed. Preacceleration of particles entering the AGS ring.

Alternating Gradient Synchrotron (AGS)

1960. 0.37c → 0.997c
33GeV for protons

11GeV for AuAu

AGS-To-RHIC (ATR) transfer line. Bunches are directed either left to the clockwise RHIC ring or right to travel counter-clockwise in the second RHIC ring.

Linear Accelerator (Linac). Protons 200 MeV (300 mA) for pA collisions. Late 1960's.

Tandem Van de Graaff

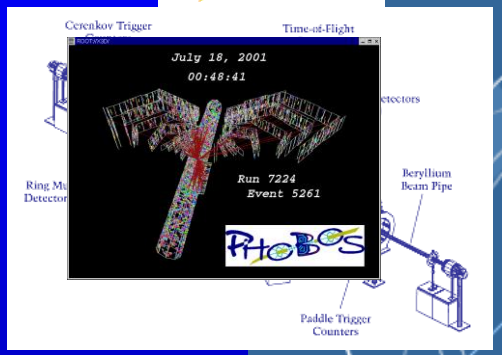
1970, 15MV, Ions, 24m

Tandem-to-Booster line (TTB)

1986, 700m, 0.05c

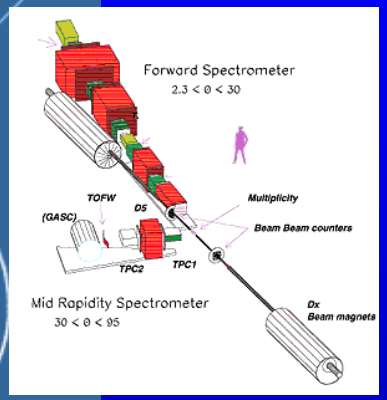
Experiments @ RHIC.BNL

PHOBOS

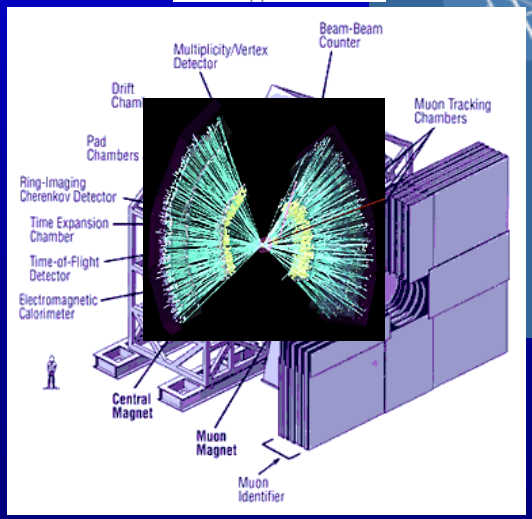


BRAHMS

the Broad Range Hadron Magnetic Spectrometer



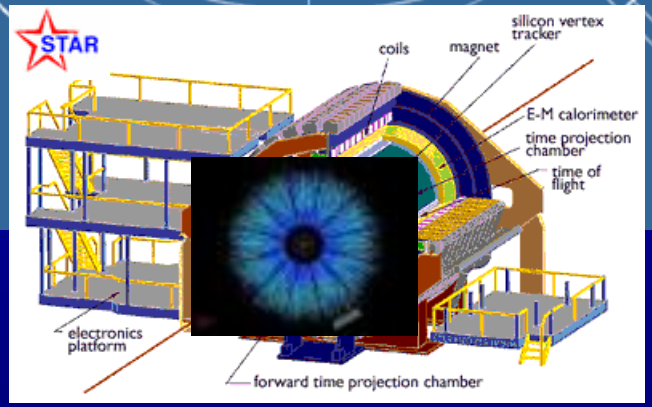
PHENIX



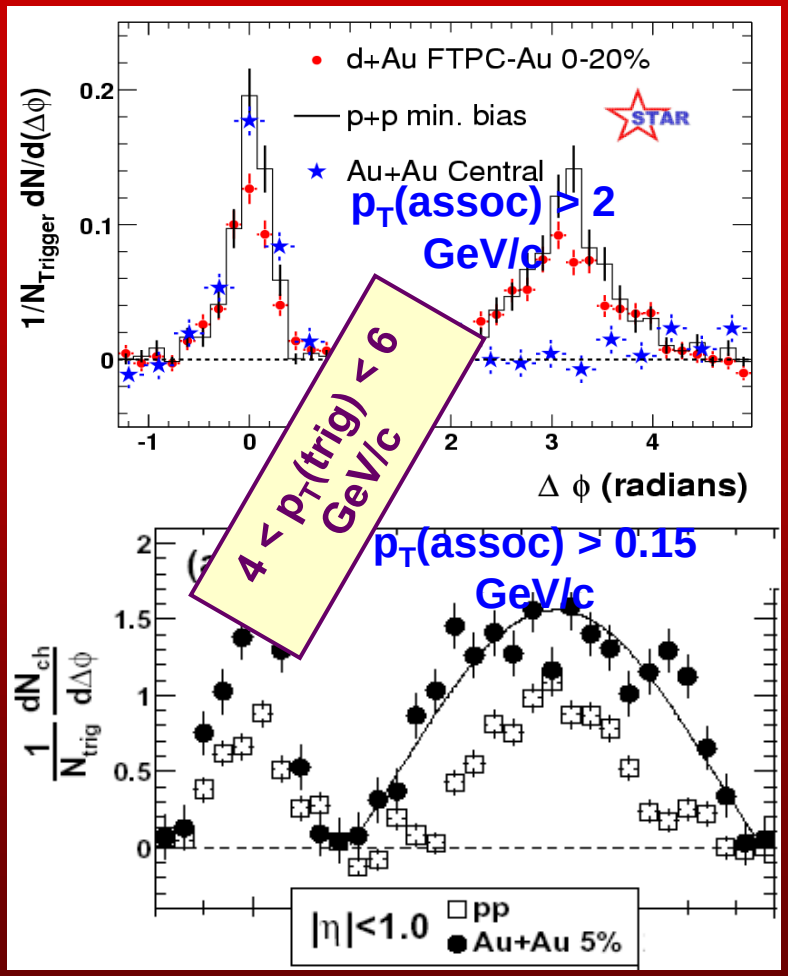
PHENIX

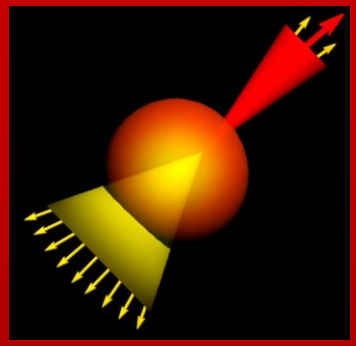
STAR

The Solenoidal Tracker at RHIC (STAR)



Jet Quenching



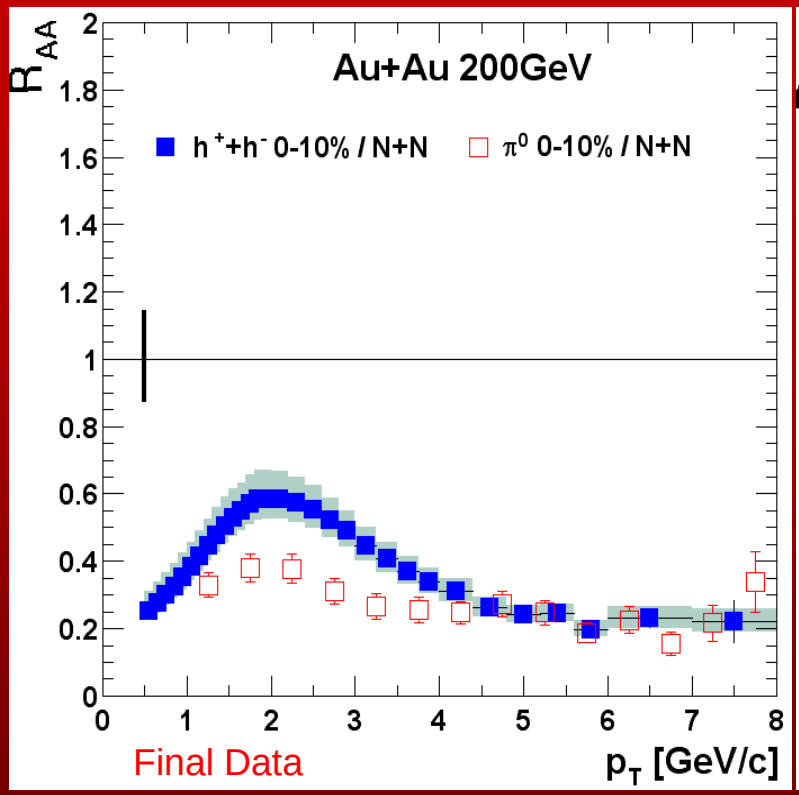


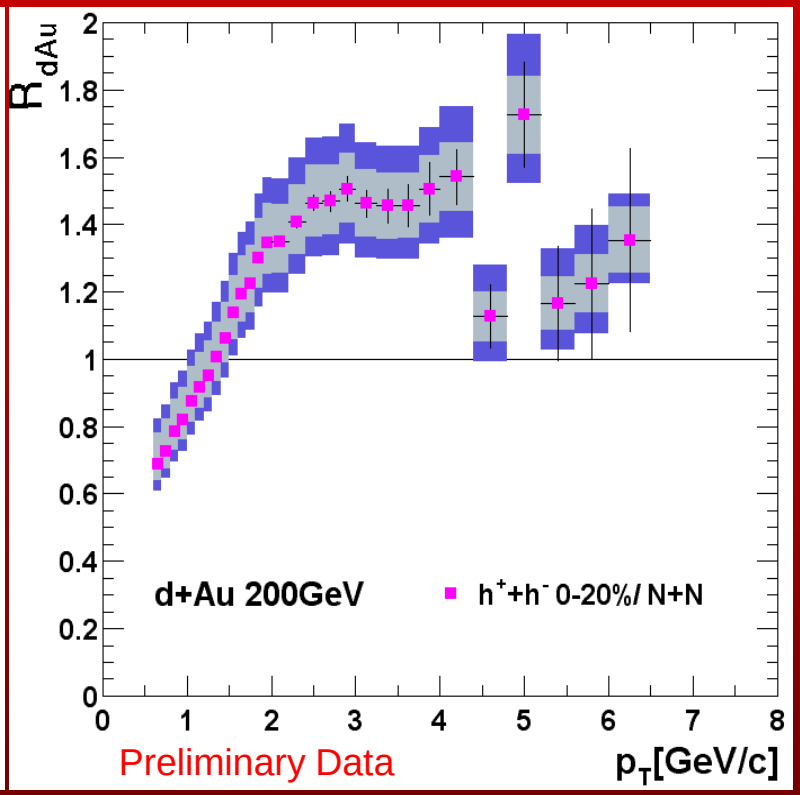
Hard associated particles → suppression

Soft associated particles → enhancement

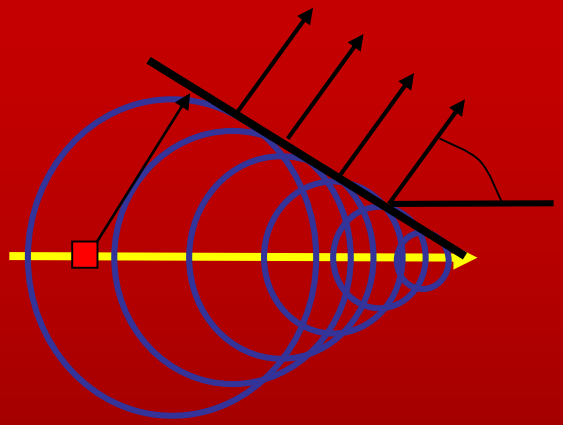
Motivation
Experiment
Results
Outlook

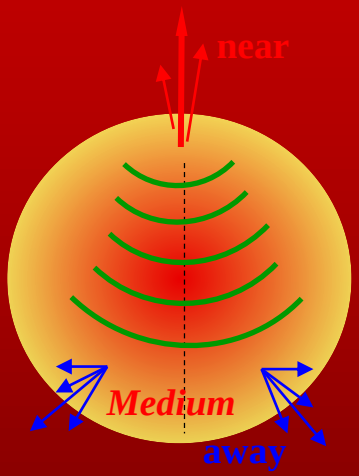
Jet Quenching



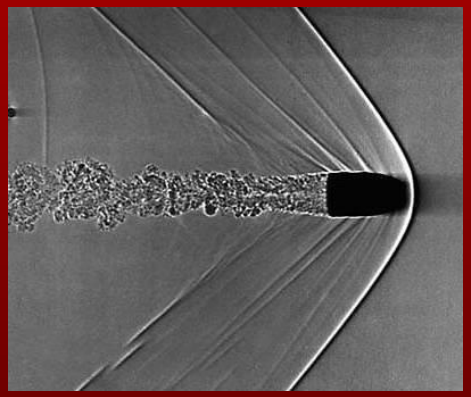


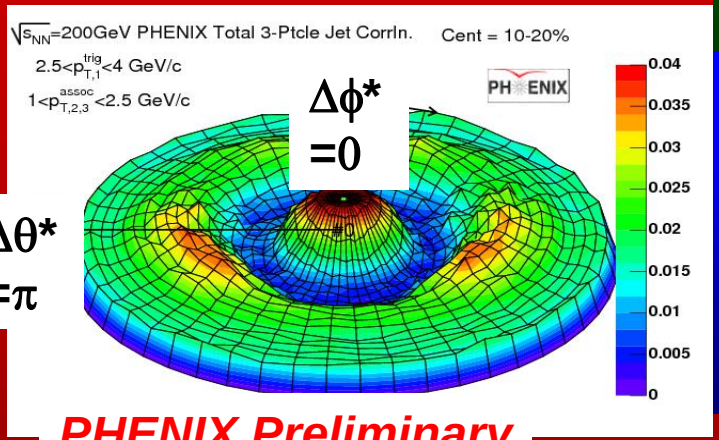
Mach-like Shock wave



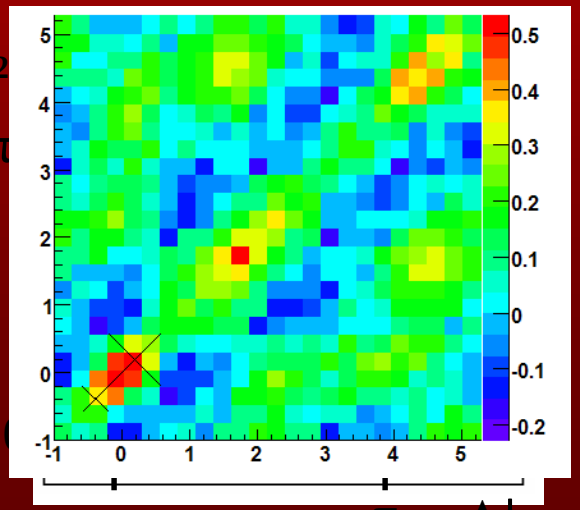


mach cone

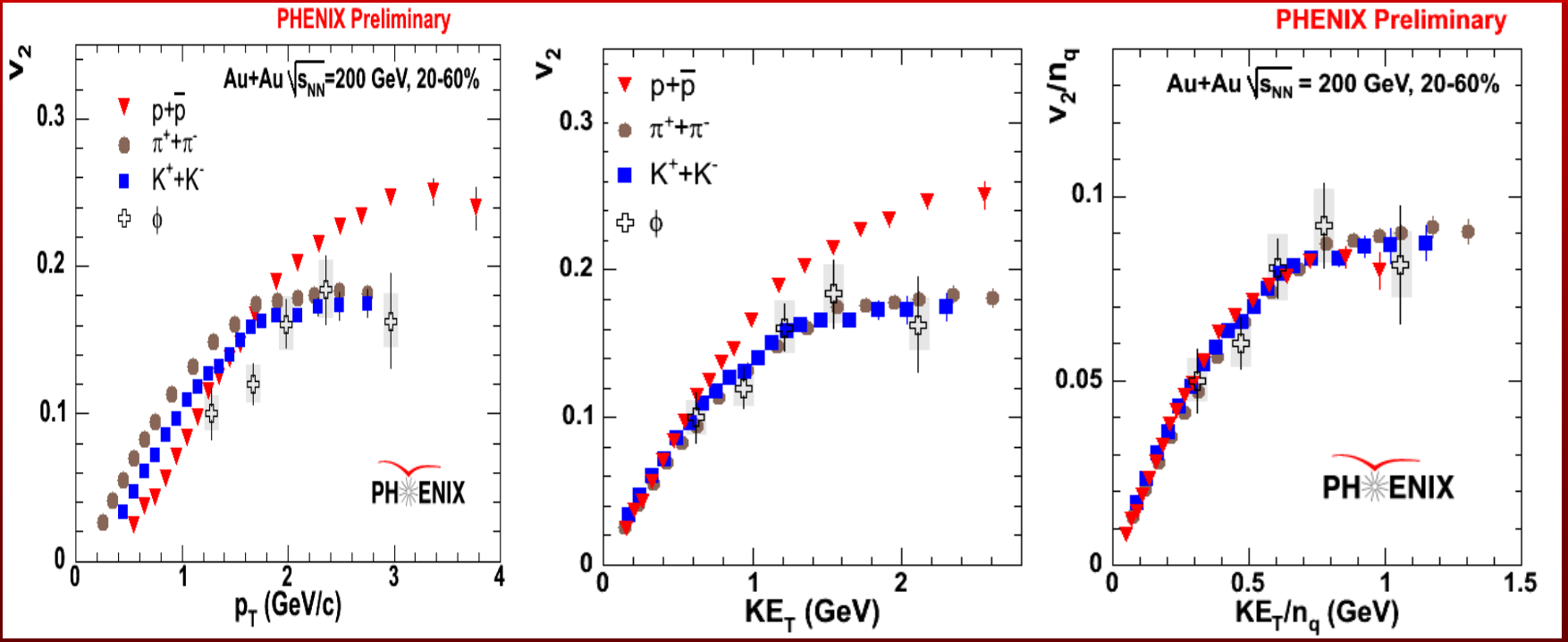




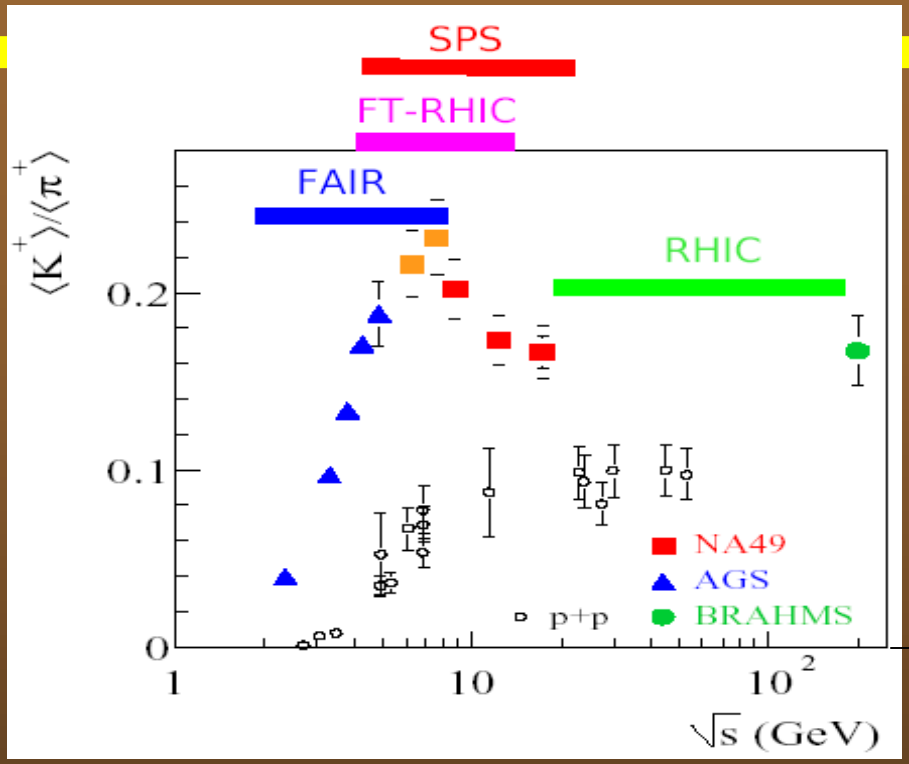
PHENIX Preliminary



Elliptic Flow (v2)



Heavy Ion Exp. Landscape



SPS ERA

LHC ERA

1990 2000 2010 2020 2030

AGS ERA

RHIC ERA

K O R I A ?

FAIR ERA

Motivation

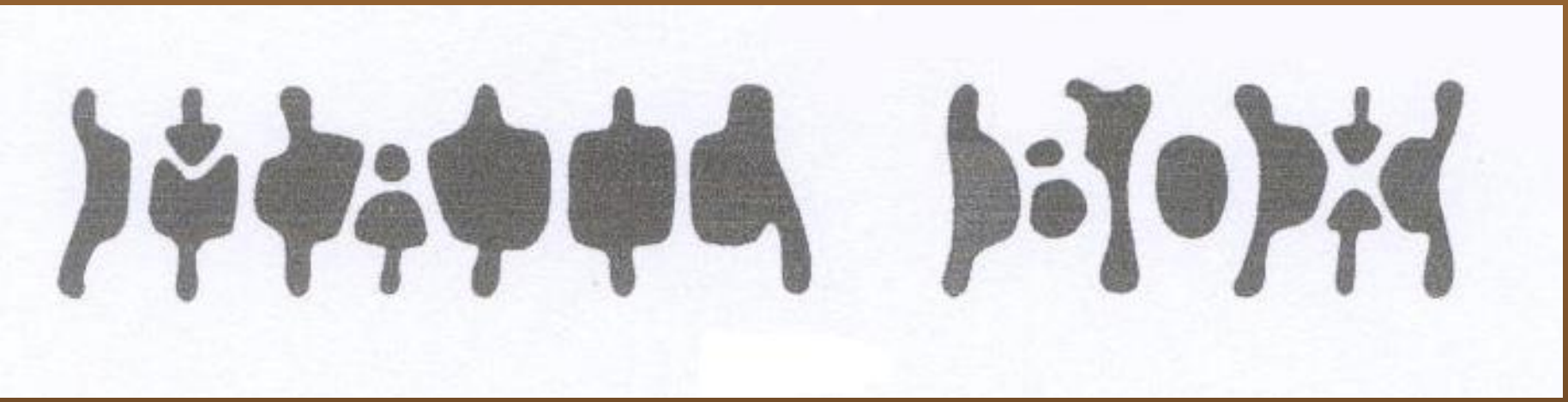
Experiment

Results

Outlook

Have We discovered QGP ?

Have We discovered Something ?



Physicists never say No!

Thanks for your attention