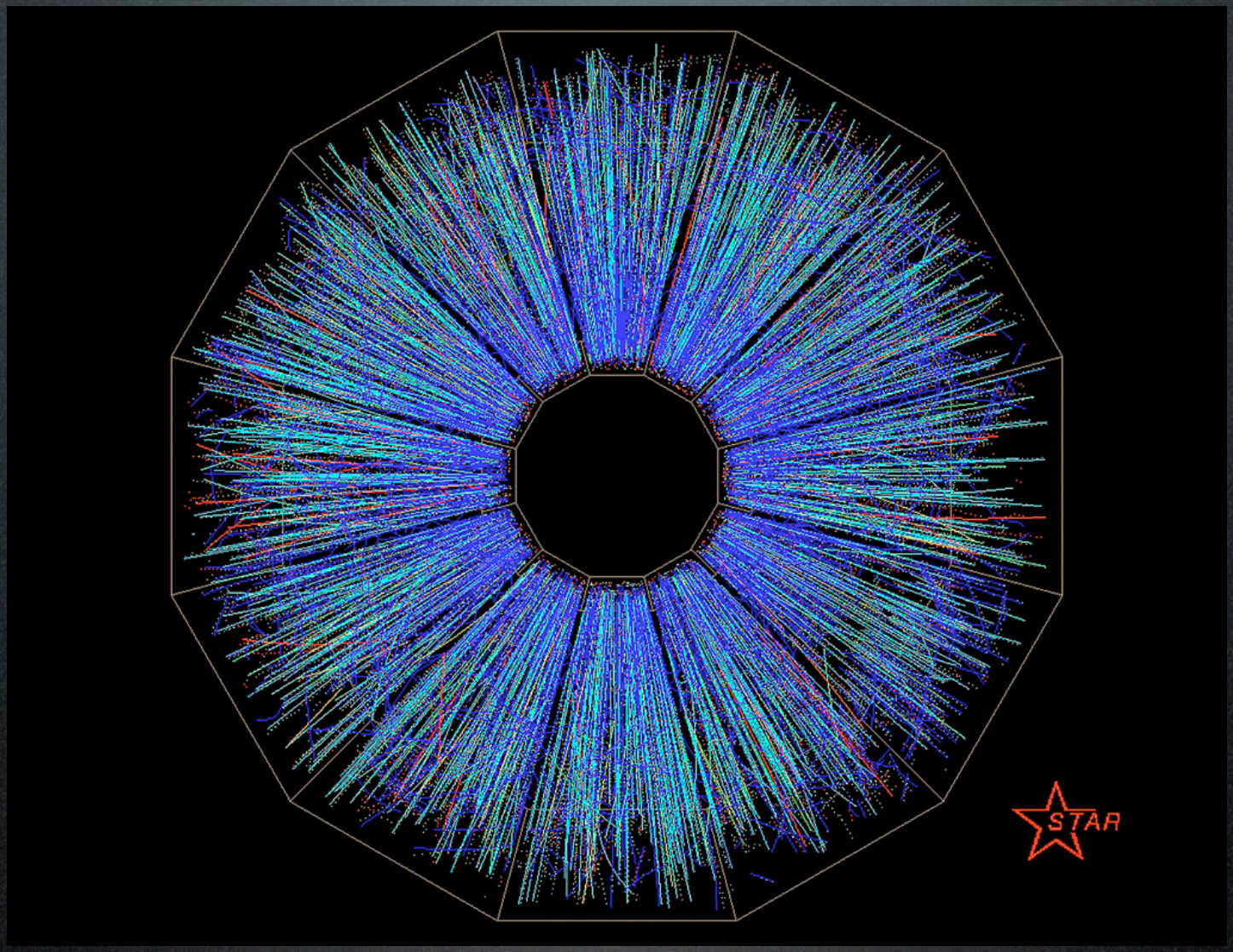


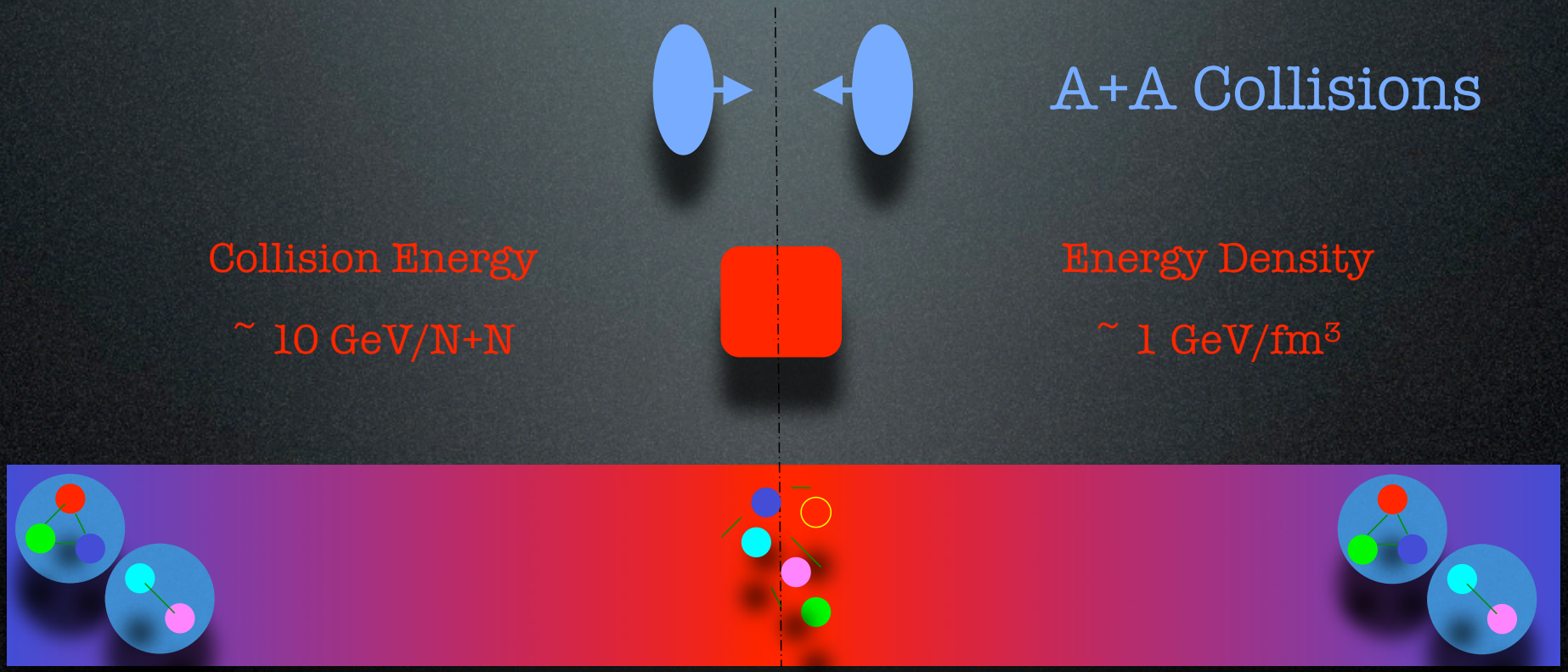
Solenoidal Tracker At Rhic (STAR) with recent Results

HIM 2011-04 @ KPS

Outline

- Relativistic Heavy Ion Collision
- STAR Experiment at RHIC(ollider) in BNL
- Recent Highlights
- A Large Ion Collider Exp. @ LHC

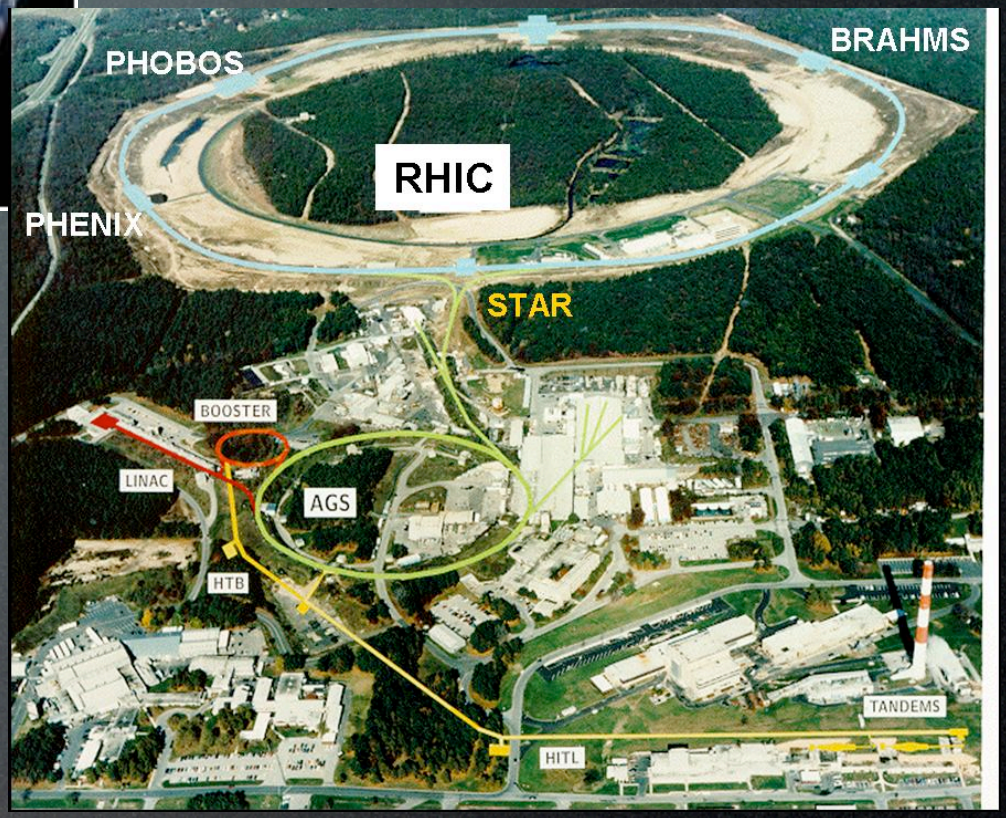
Relativistic Heavy Ion Collisions



Heavy Ion Accelerators

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	Running
RHIC (BNL, USA)	200A	Running
LHC (CERN, Switzerland)	5500A	Plan to run from ~2007

Brookhaven National Lab. (BNL)



★ Circumference: 3.83 km

★ First collision: 2000

★ 100A GeV Au+Au($2X10^{26}/cm^2/s$)

★ 250 GeV p + p ($2X10^{32}/cm^2/s$)

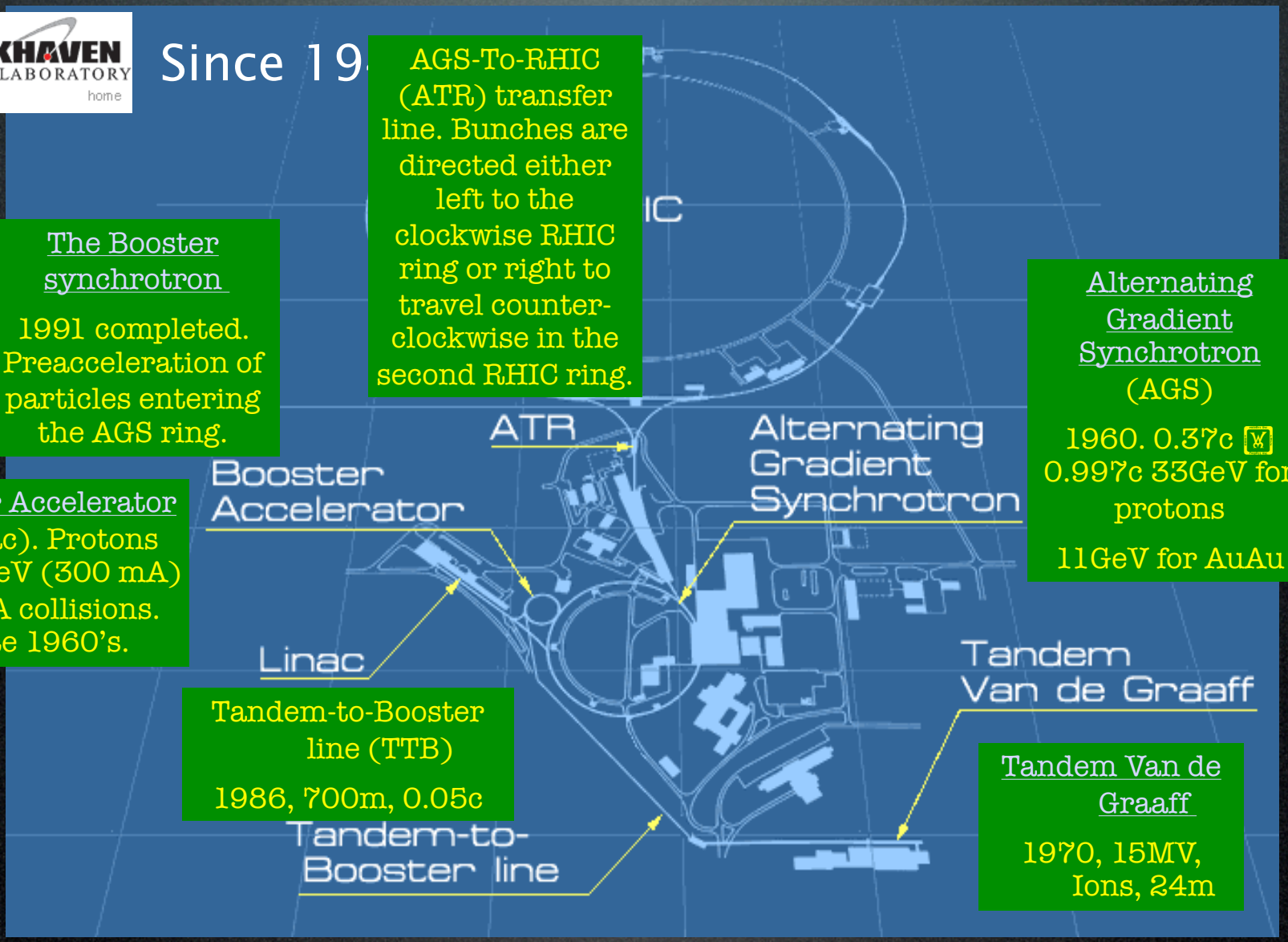
★ AuAu @ 19.6, 62, 130, 200 AGeV/u

★ CuCu @ 200 AGeV/u

★ dAu @ 200 AGeV/u

★ polarized pp @ 200 AGeV

Relativistic Heavy Ion Collider



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.

The Booster synchrotron

1991 completed. Preacceleration of particles entering the AGS ring.

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

Tandem-to-Booster line (TTB)

1986, 700m, 0.05c

Alternating Gradient Synchrotron (AGS)

1960. 0.37c 0.997c 33GeV for protons

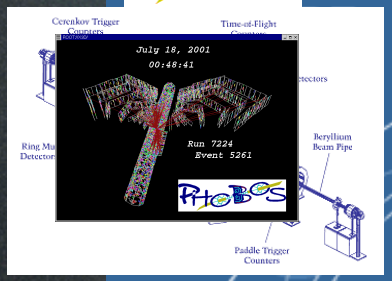
11GeV for AuAu

Tandem Van de Graaff

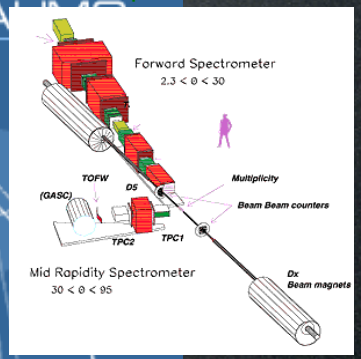
1970, 15MV, Ions, 24m

Detectors @ RHIC

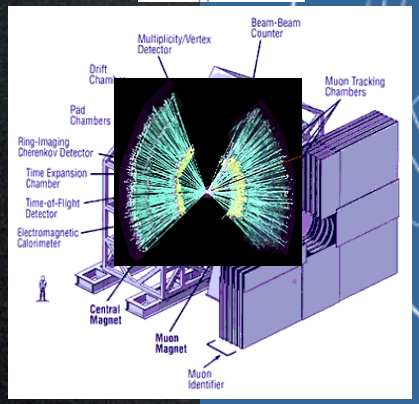
PHOBOS



the Broad Range Hadron Magnetic Spectrometer

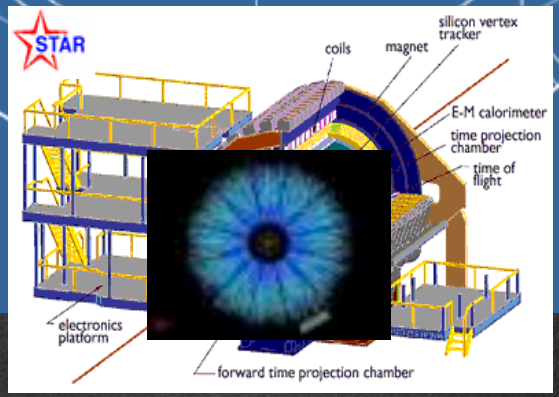


PHENIX

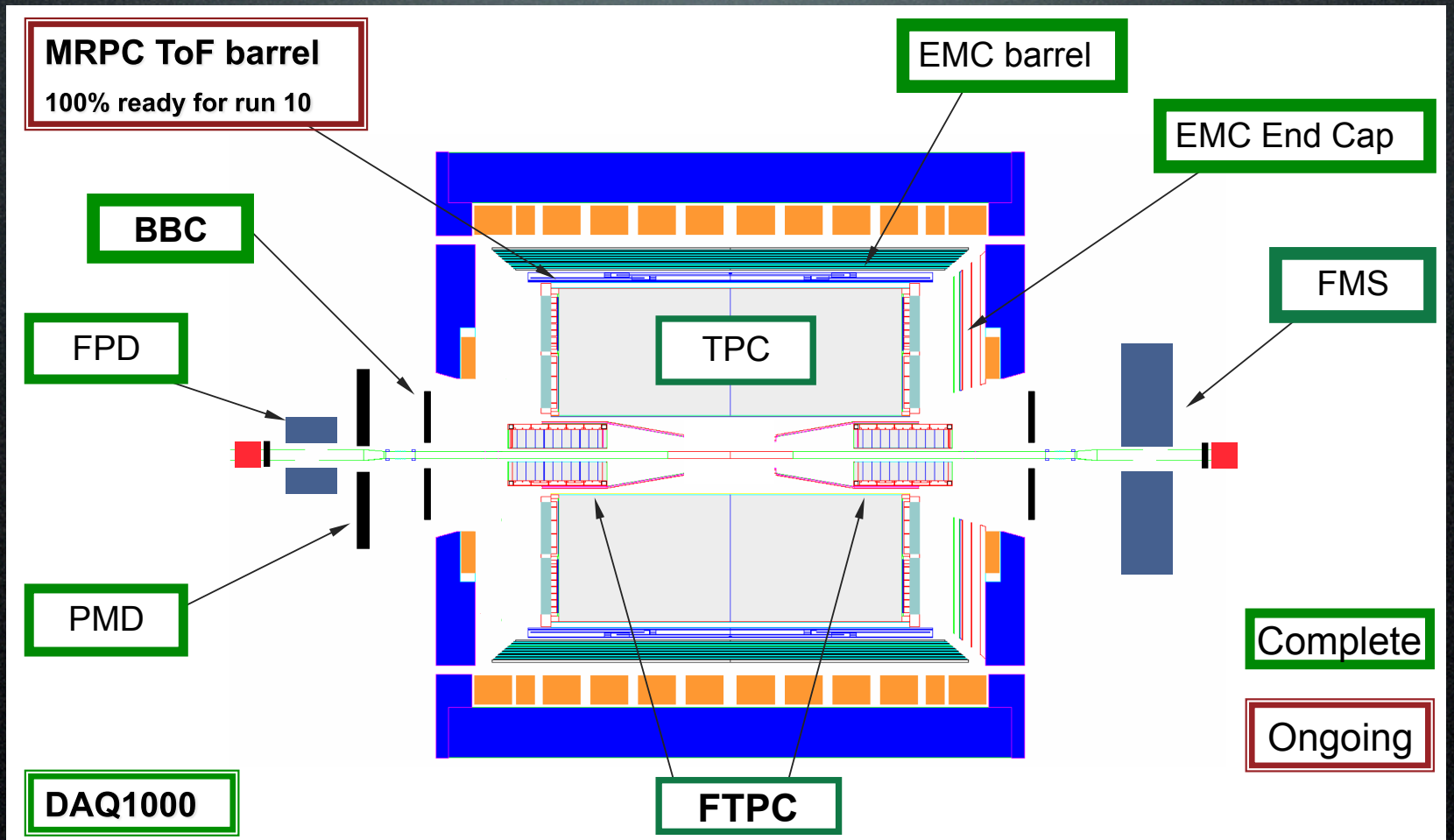


STAR

The Solenoidal Tracker at RHIC (STAR)



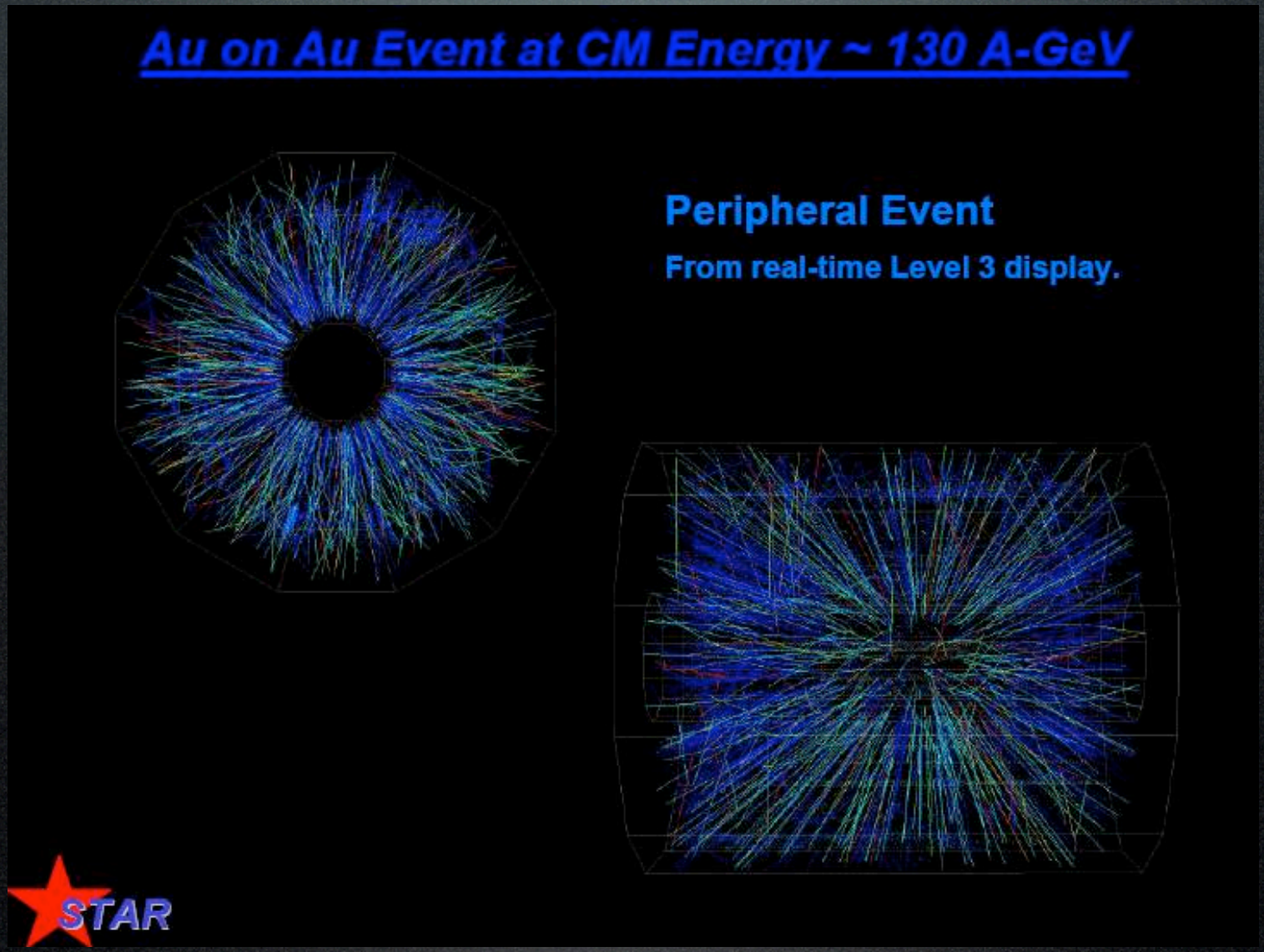
STAR Detector



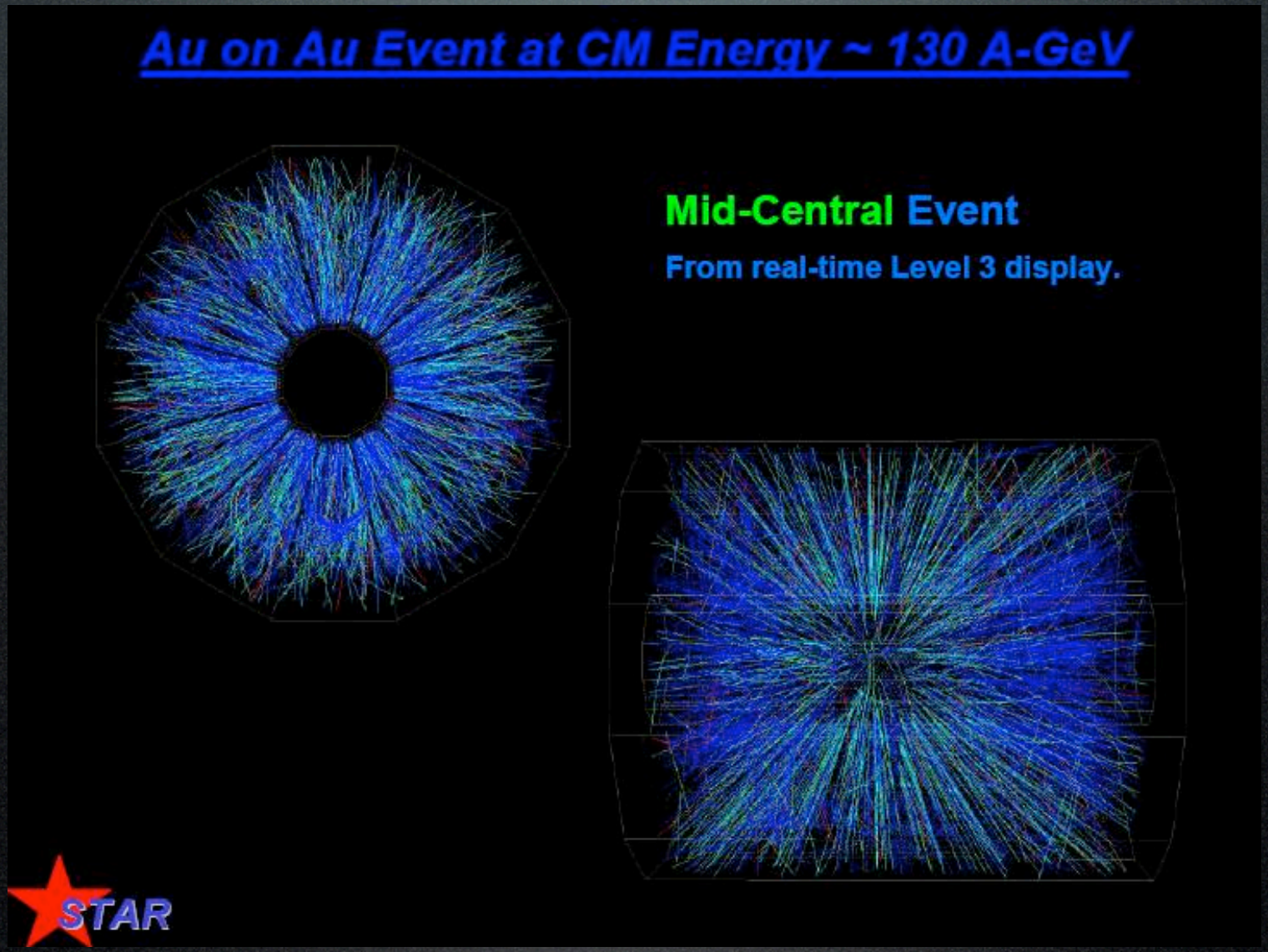
Full azimuthal particle identification!

*γ, e, π, **ρ**, K, **K***, p, **φ**, Λ, Δ, Ξ, Ω, D, Λ_C, **J/ψ**, **Υ** …*

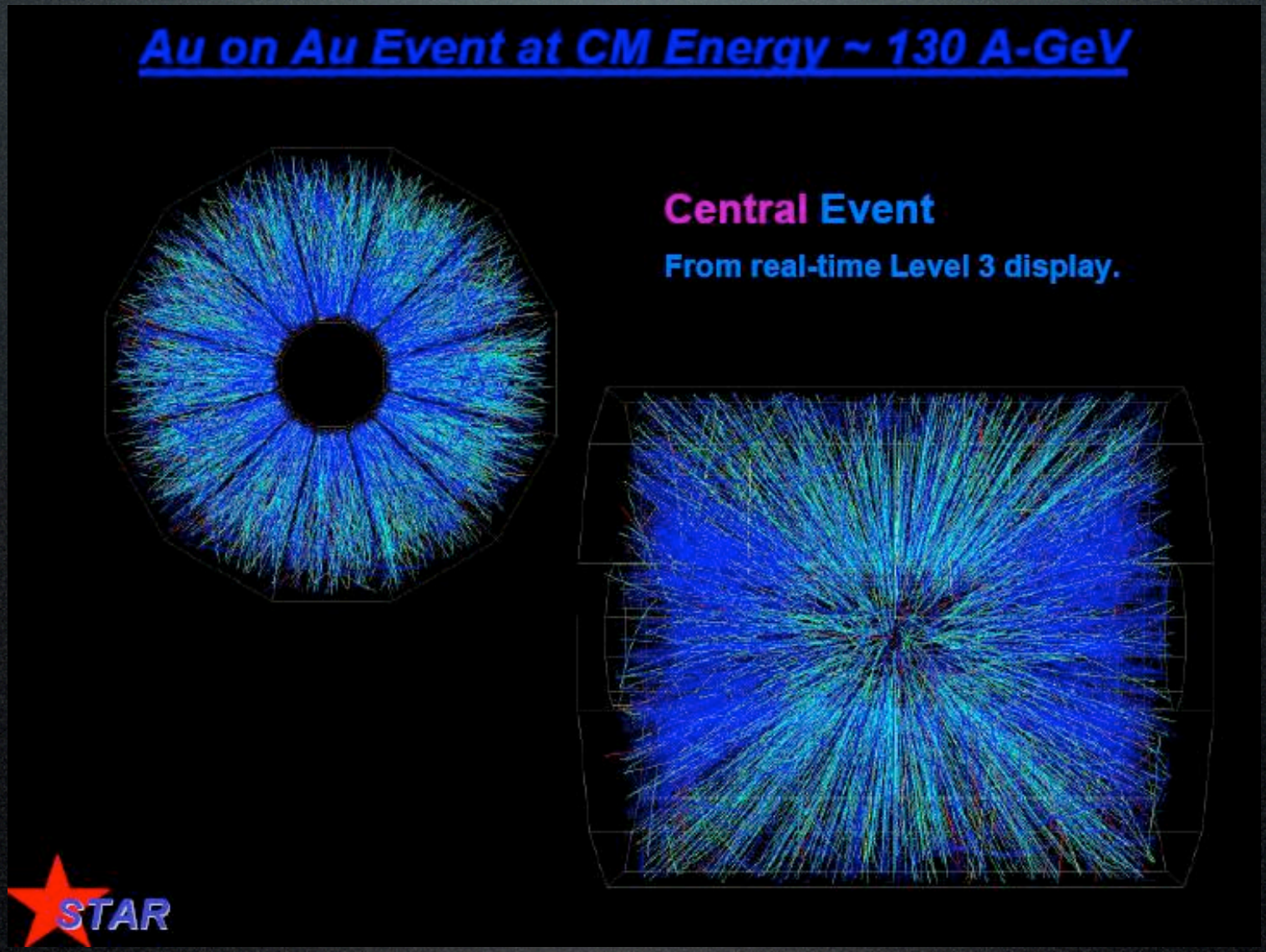
AuAu Collisions @ 130 AGeV



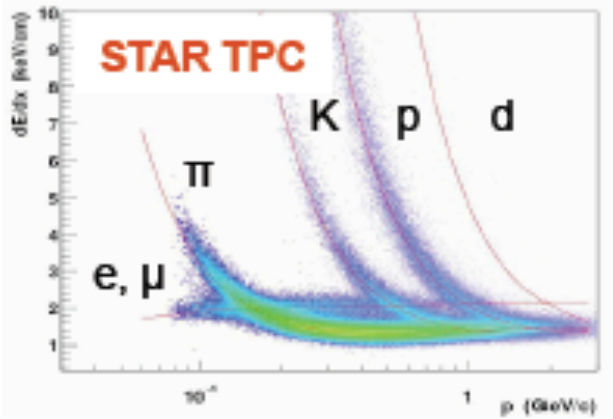
AuAu Collisions @ 130 AGeV

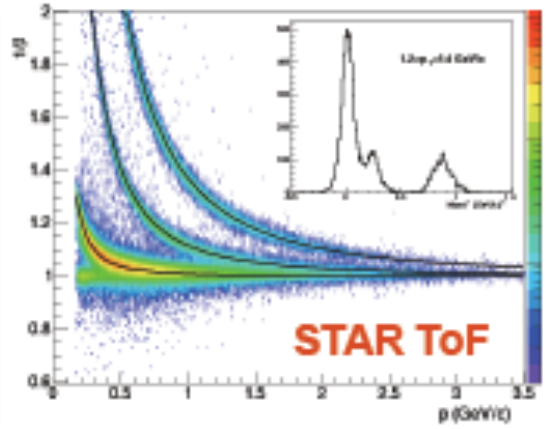


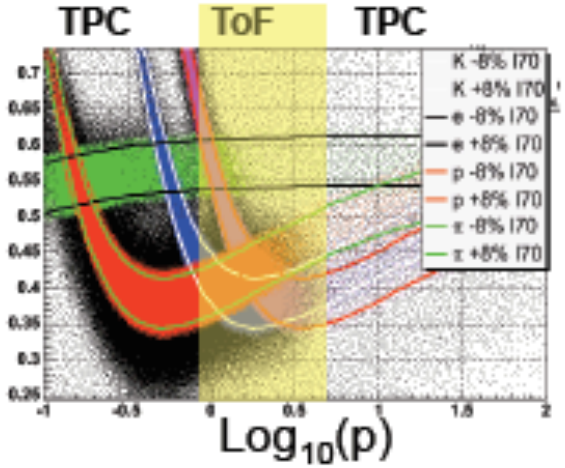
AuAu Collisions @ 130 AGeV

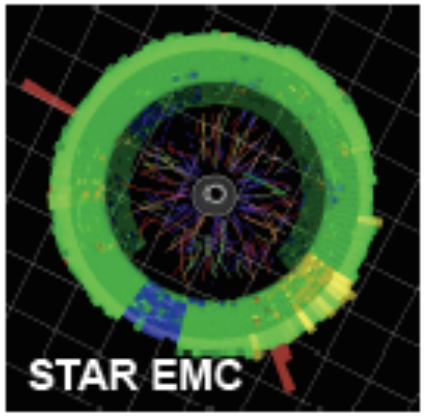


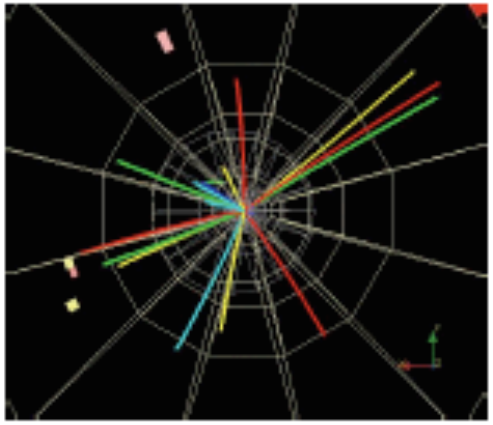
Particle ID @ STAR

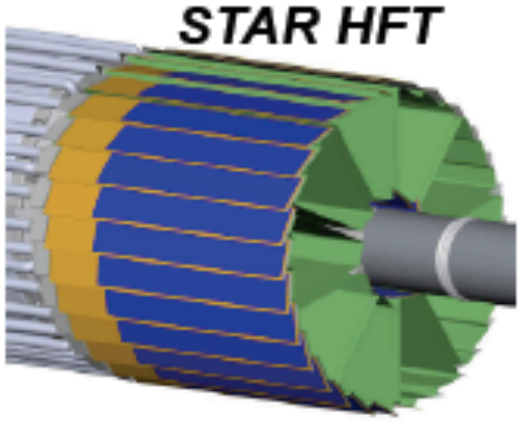






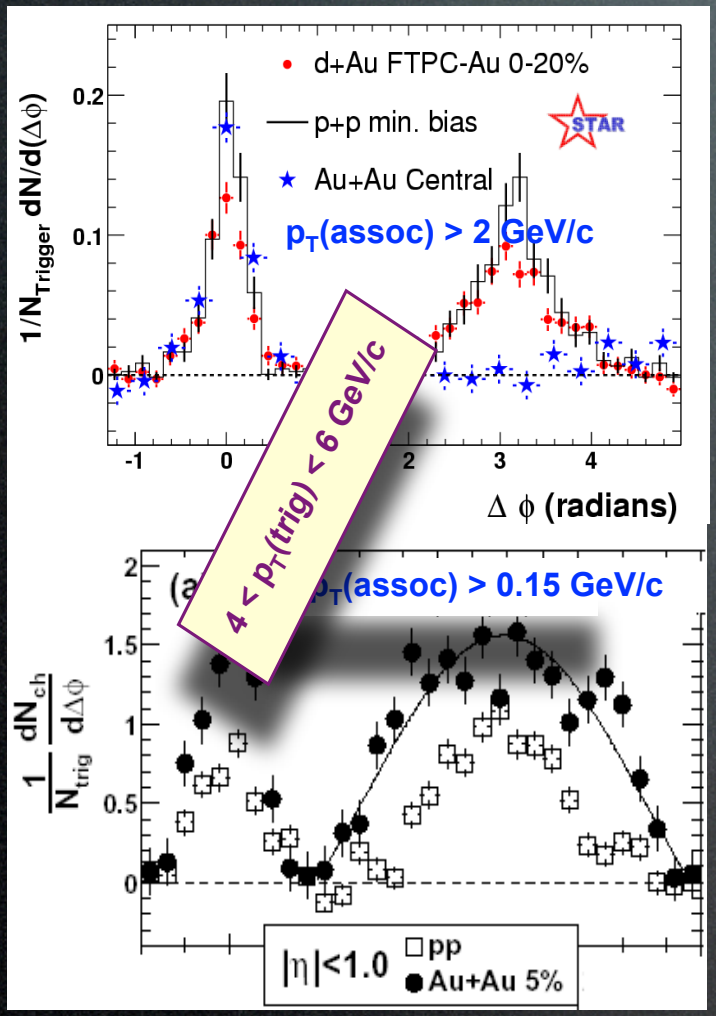




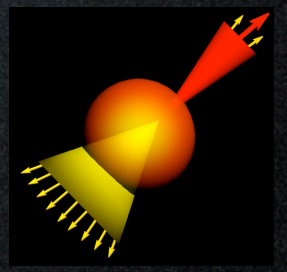


Neutral particles **Strange hyperons** **Jets** **Heavy Quark Hadrons**

Jet Quenching @ STAR

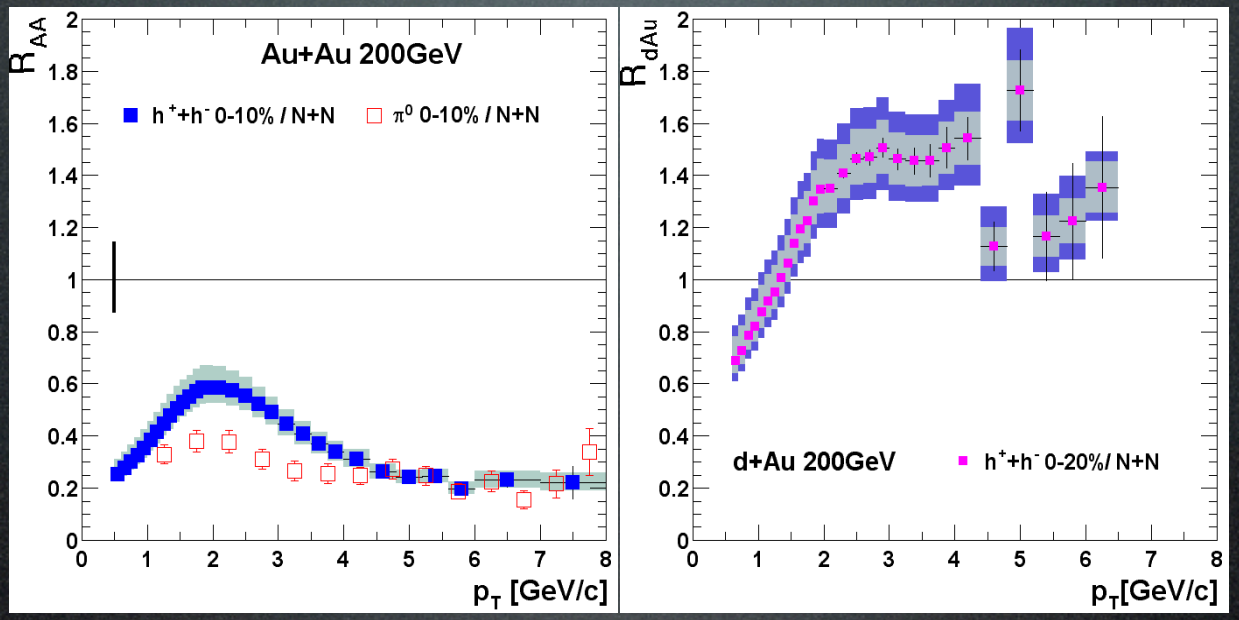


Hard associated particles → suppression

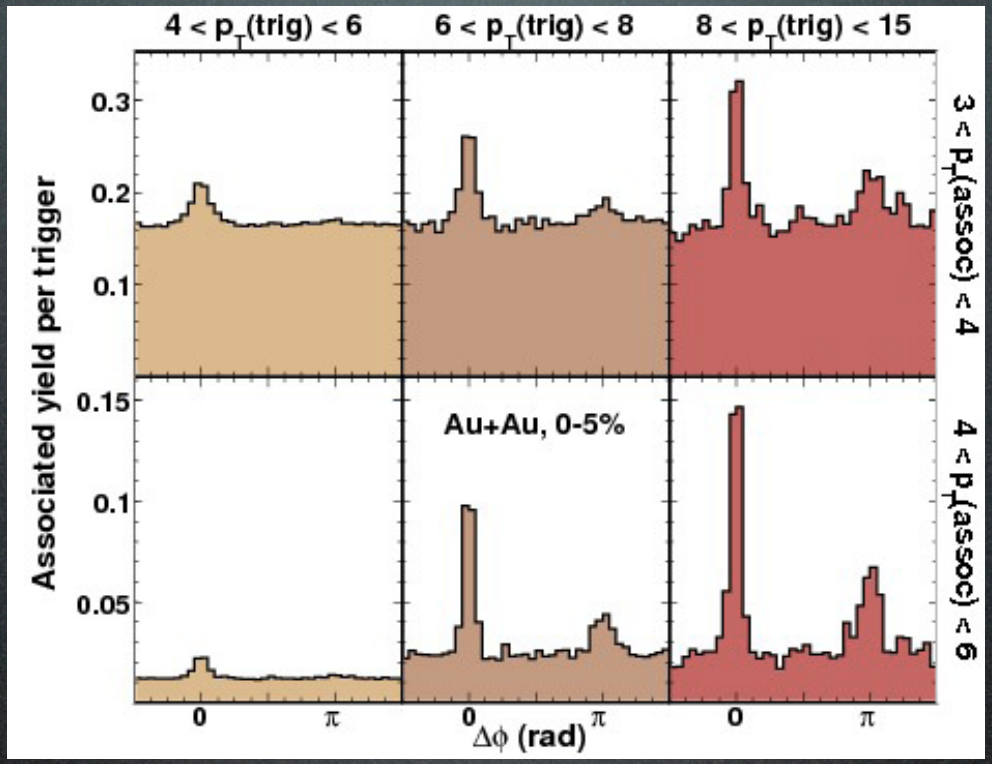


Soft associated particles → enhancement

Jet Quenching @ PHENIX

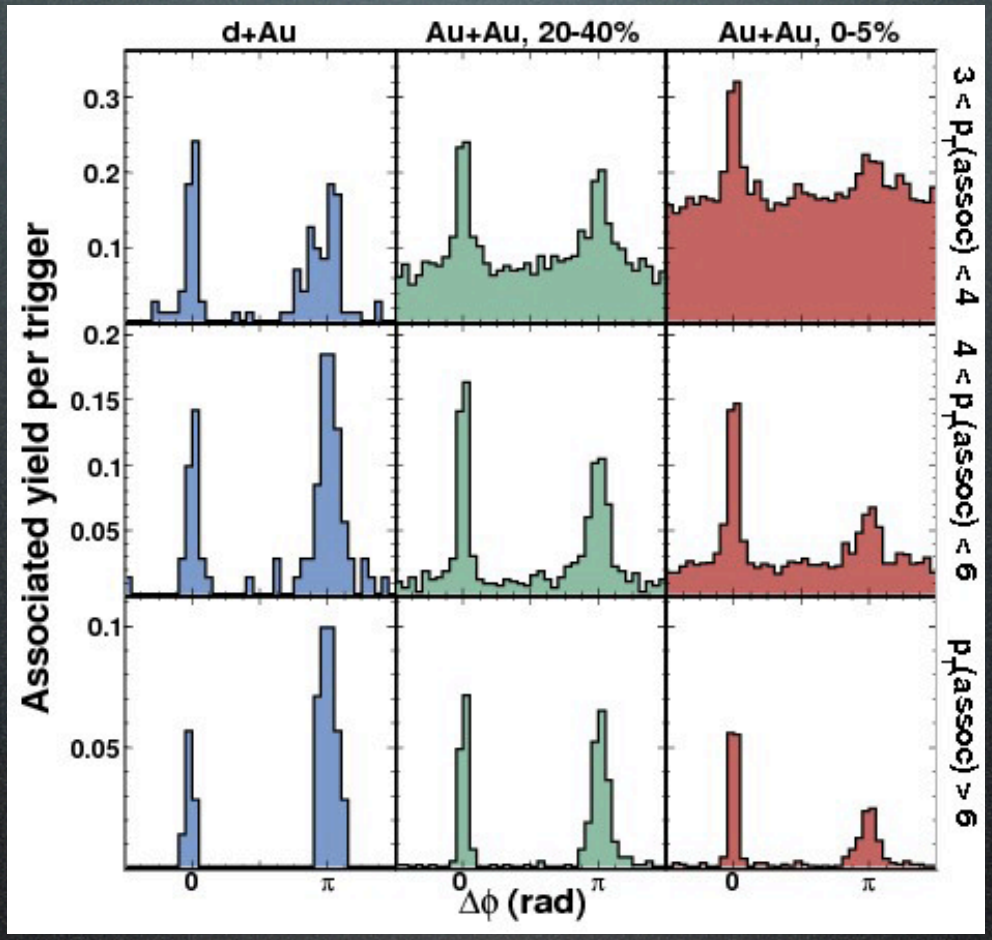


Monojet ? or Dijet?



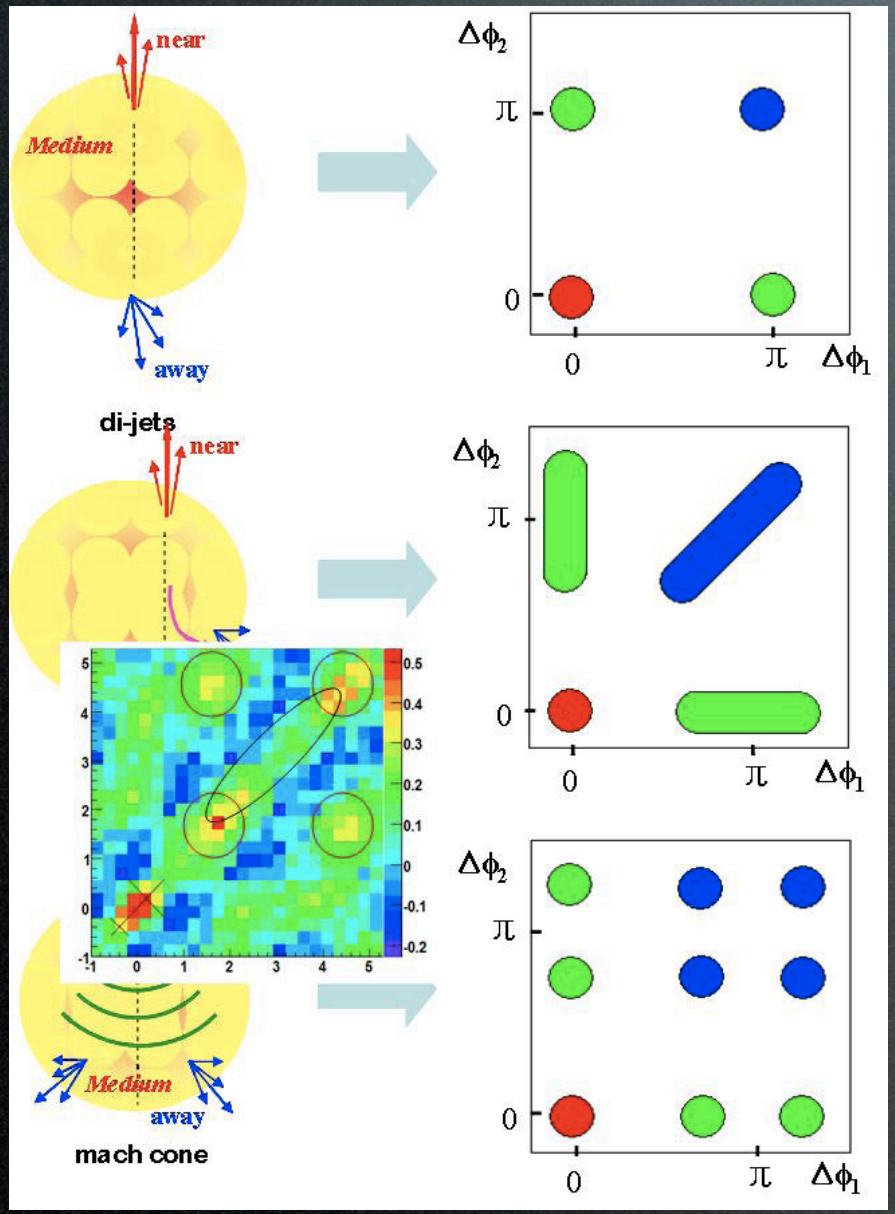
- With increasing the jet energy, back-to-back peaks in central AuAu collisions are reappearing

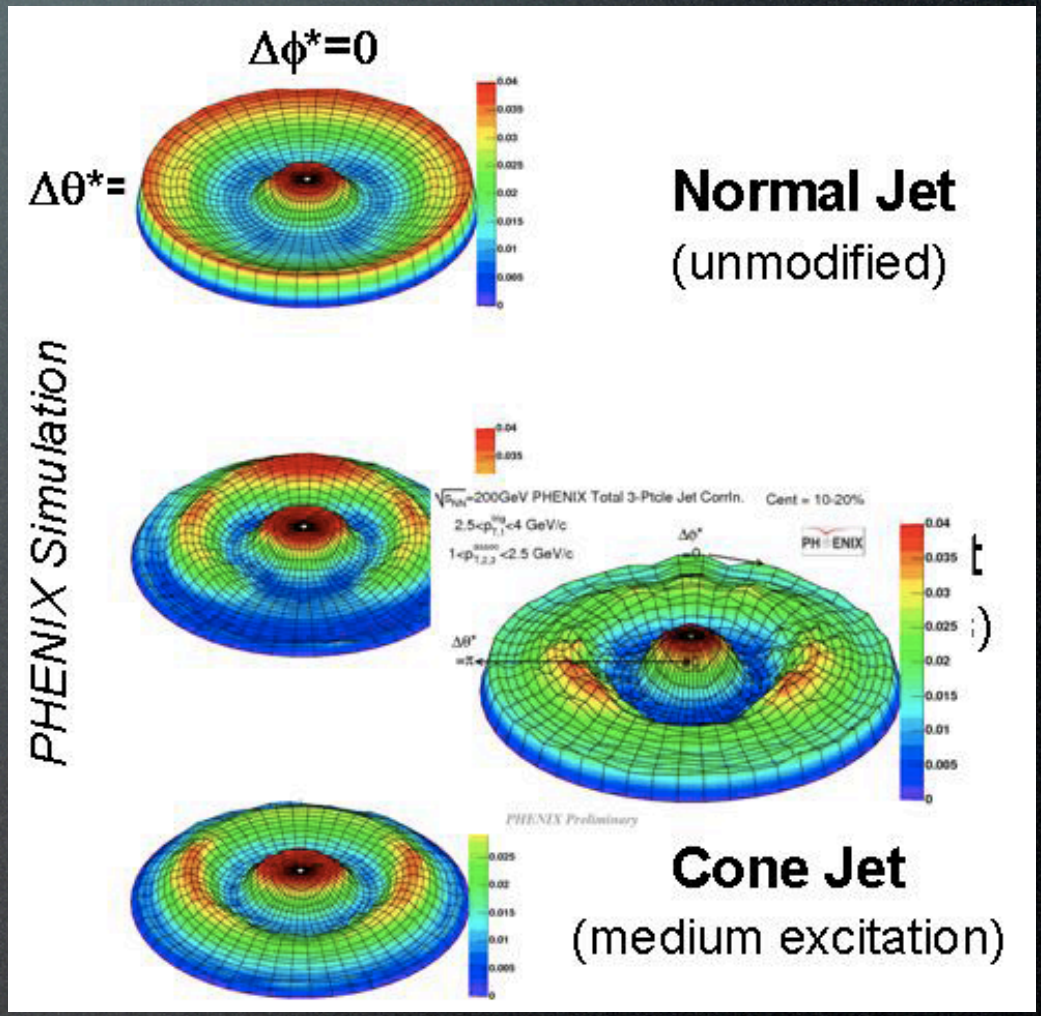
System-size dependence



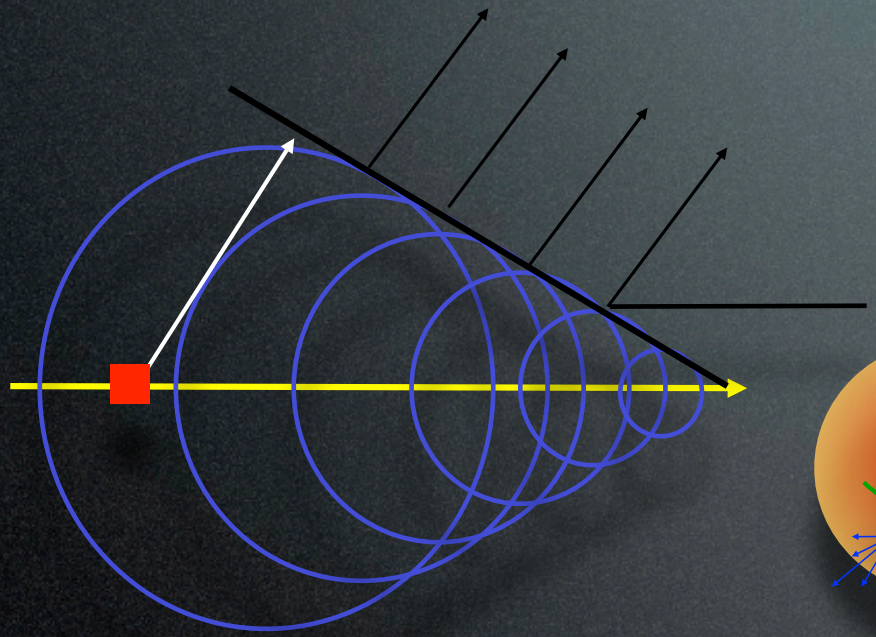
- With increasing system-size, back-to-back peaks are suppressed.

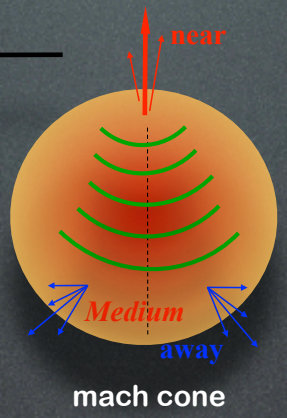
3 particle correlations

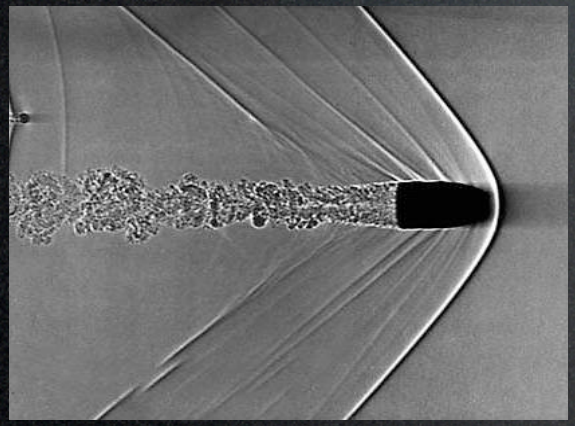




Mach-like Shock Wave

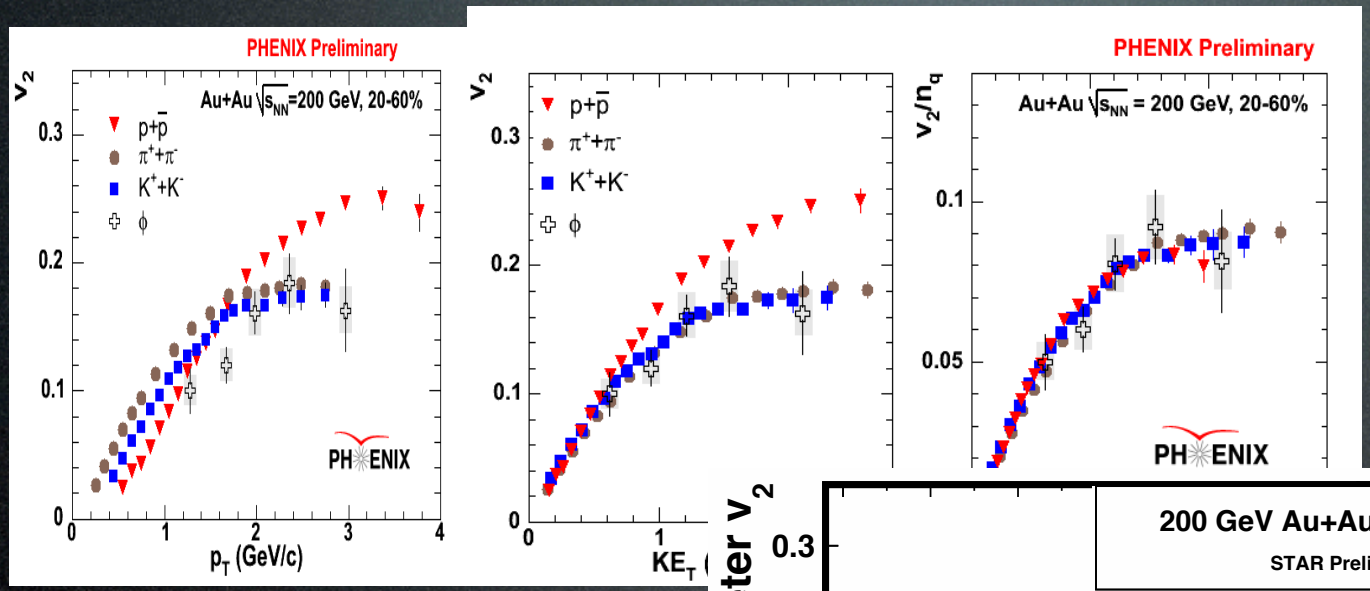


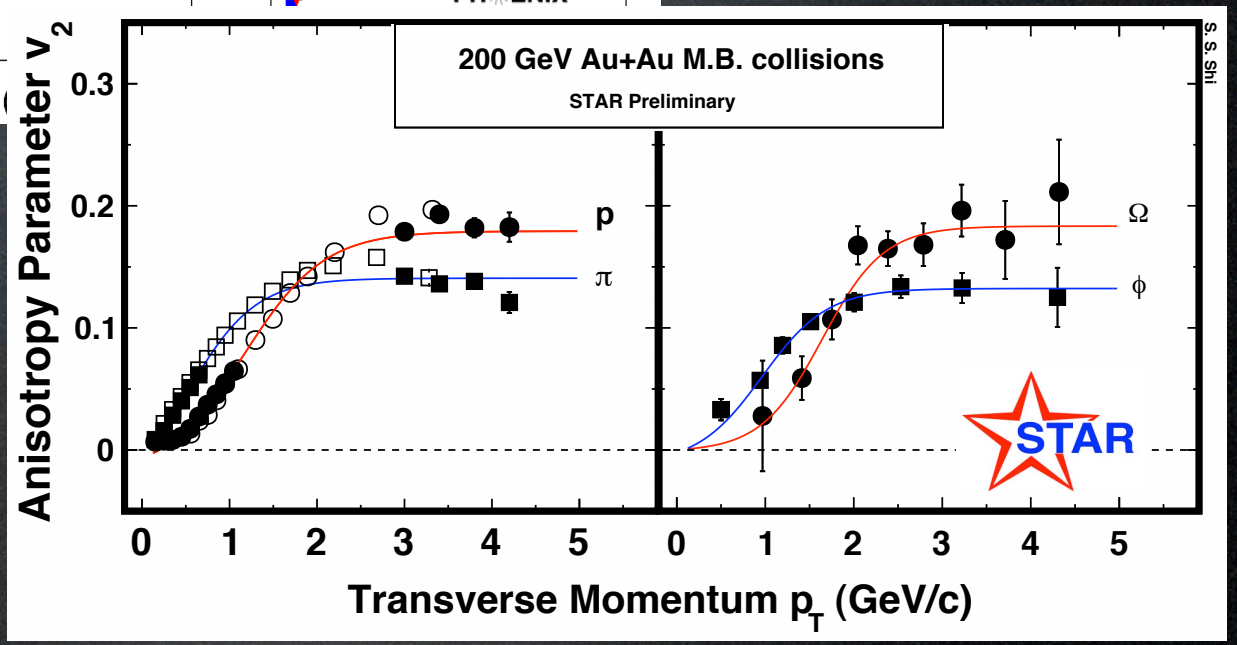




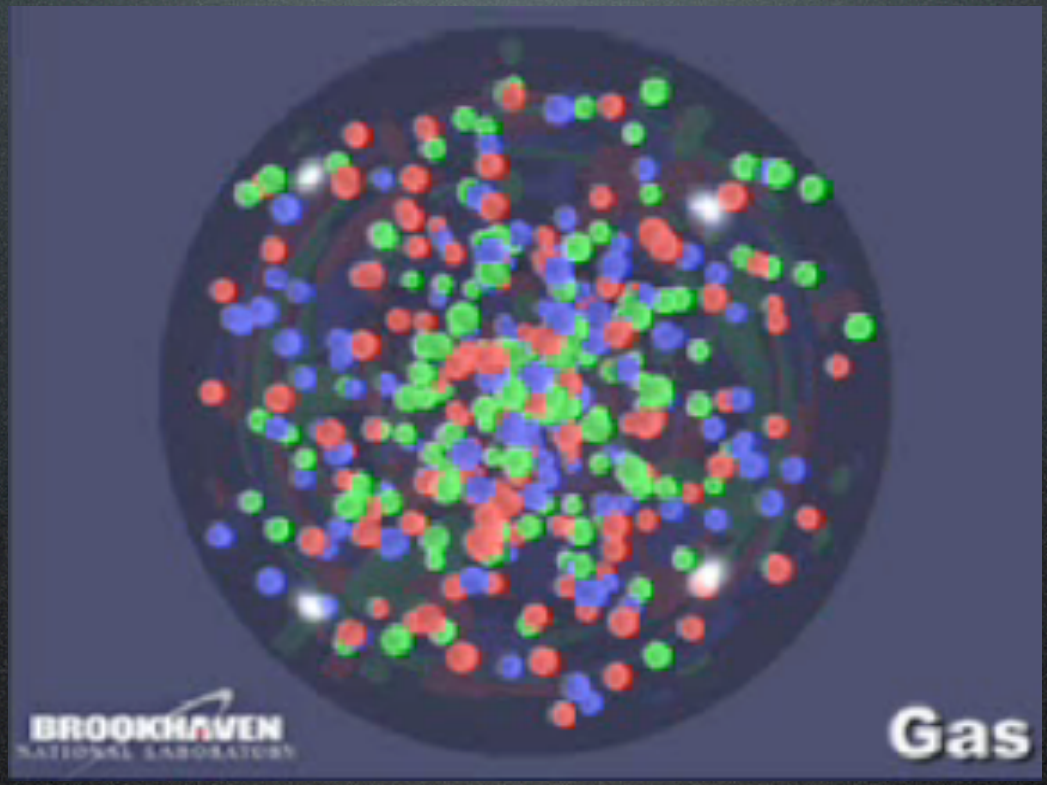
A fast thermalization through dispersing energy into collective modes of shock waves.

Coalescence @ RHIC



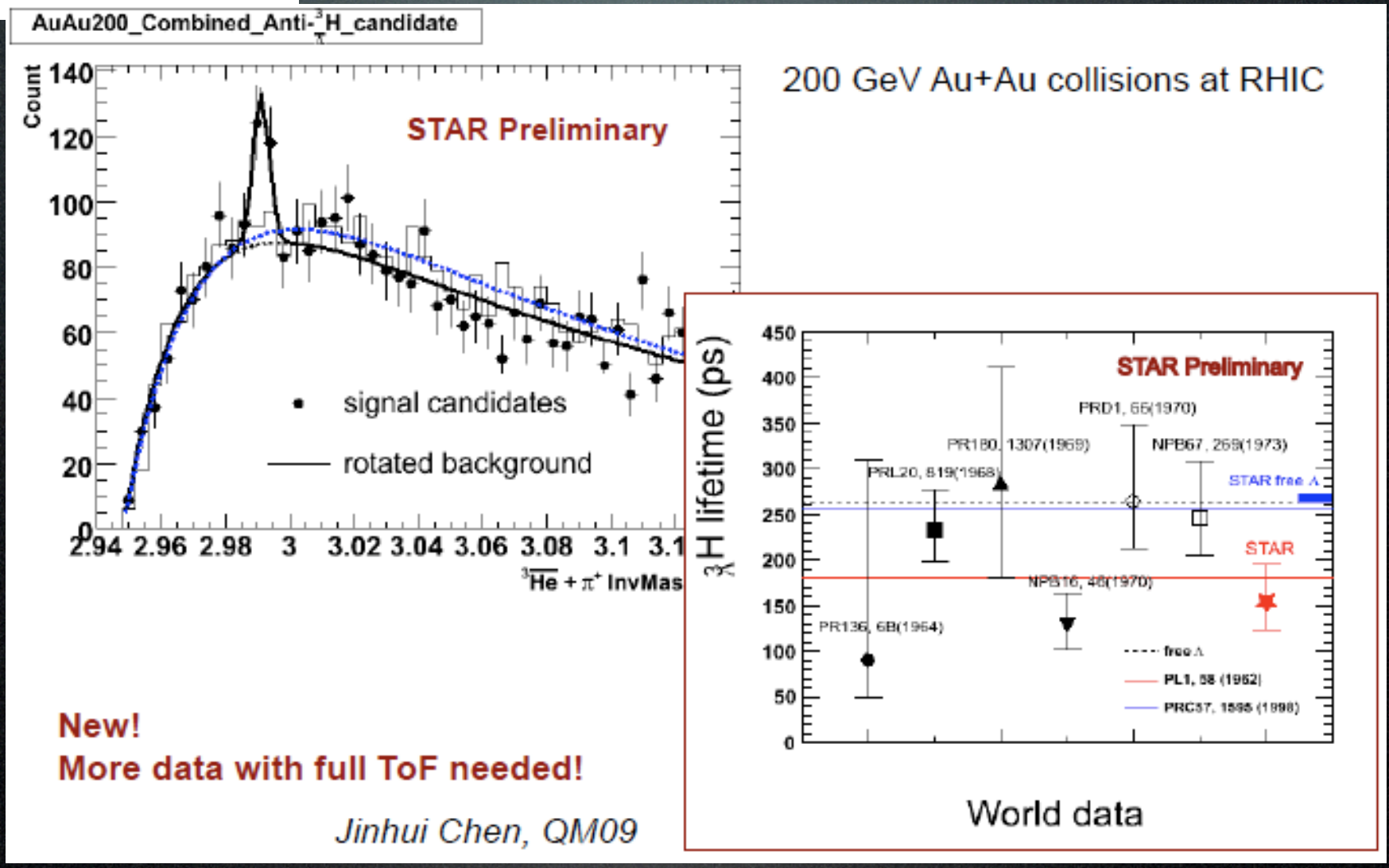


Liquid-like Early Universe

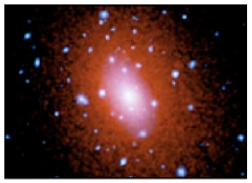


Antimatter Hyper Triton

$$\overline{{}^{3}_{\Lambda}H} \rightarrow \overline{{}^{3}He} + \pi^{+}$$



RHIC Scientists Serve Up "Pe
Early Universe Went With



Posted April

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科学家称初生宇宙可能是液体状的而非气体状

www.XINHUANET.com 2006年04月20日 07:45:55 来源：新京报

【字体：大 中 小】【打印本稿】【读后感言】【进入论坛】【推荐】【关闭】

本报综合报道 4月18日，在美国佛罗里达州坦帕市举行的美国物理协会会议上，有科学家提出，对粒子碰撞的最新研究结果表明，在宇宙诞生的最初百万分之一秒，宇宙可能是液体状的，而不是像过去所认为的那样是炽热的气体状的。

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e nuclei of gold
BBC NEWS

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most basic
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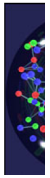

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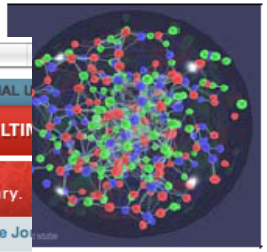
geographic.hu
Tudomány

Magyar részvétellel fedezték fel az univerzum ősanyagát

Az univerzum keletkezése utáni néhány milliomod másodperc állapotát sikerült modellezniük amerikai és magyar tudósoknak. Az Ősrobbanás utáni anyag forró, sűrű és folyékony lehetett.

Az amerikai Brookhaven Nemzeti Laboratórium (BNL) RHIC gyorsítója



szabad kvarkok és gluonok
kedik– olvasható a kfki.hu-n. A
tközi kísérleti együttműködése
t egyszerre fogja közölni.

Universe May Have Begun as Liquid, Not Gas

Associated Press
Tuesday, April 19, 2005; Page A05

The Washington Post

New results from a particle collider suggest that the universe behaved like a liquid in its earliest moments, not the fiery gas that was thought to have pervaded the first microseconds of existence.

Go

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Rowe, (631) 344-505

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Science DOI: 10.1126/science.1183980

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Early Universe was a liquid

Quark-gluon blob surprises particle physicists.

by Mark Peplow
news@nature.com

The Universe co
results from an a

Scientists at the
Laboratory on L
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Neues aus der Welt der Wissenschaft

[ORF ON Science : News : Wissen und Bildung . Kosmos]

Das Universum war am Anfang "flüssig"

Das Universum war direkt nach dem Urknall vermutlich einem Fluidum ähnlich. Das schließen dänische Forscher aus Experimenten am weltstärksten Kernbeschleuniger RHIC am Brookhaven National Laboratory.

Mit seiner enormen Kollisionsenergie bildet der RHIC rund 1.000 Milliarden Grad Celsius heiße Urmaterie vom Anbeginn der Zeit vor rund 13,7 Milliarden Jahren nach.

A24 2010년 3월 5일 금요일 과학

중이온 가속기로 '갓난아기 우주' 재현 성공

국내과학자 포함 국제연구진 '반입자 원자핵' 발견

유인권 교수 이창환 교수

우주의 시작인 빅뱅 이후 수백만분의 1초 만에 태어난 갓난아기 우주를 한국 과학자들이 포함된 대형 국제 연구팀이 찾아냈다. 유인권 이창환 부산대 물리학과 교수가 포함된 국제 연구 그룹 '스타(STAR)'는 4일 "반입자만으로 이뤄진 원자핵을 발견하는 데 성공했다"고 밝혔다. 이제껏 몰랐던 새로운 물질 상태와 초기 우주의 모습을 발견한 것이다. 이 연구는 국제학술지 '사이언스' 5일자에 발표됐다. 스타 프로젝트는 미국 브룩헤이번연구소 중이온 가속기(RHIC)의 대형 검출기를 이용한 실험 프로젝트로 주로 무거운 입자의 성질을 연구한다. 이 프로젝트에는 12개국 54개 연구기관에서 500여 명의 과학자가 참가하고 있다.

금 원자핵 충돌시키자 미니빅뱅 상태서 발생
초기우주입자 추정… 물질탄생 비밀 벗길 단서

● 금 원자핵 빛의 속도로 충돌시켜

중이온 가속기는 무거운 금속 원자를 충돌시켜 일어나는 다양한 현상을 관찰한다. 정부가 1월 세종시에 유치하겠다고 발표한 국제과학비즈니스벨트에도 중이온 가속기 설치 계획이 들어 있다. 스타 연구진은 이번 가속기 실험에서 두 개의 금 원자핵을 빛과 같은 속도로 충돌시켰다. 금 원자핵 하나는 무려 1000억 eV(전자볼트)의 에너지를 갖고 있다.

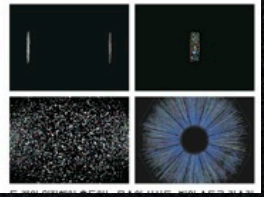
두 개의 금 원자핵이 충돌하자 신기한 현상이 나타났다. 수조 도의 상상도 못할 고열이 발생하면서 원자핵이 모두 녹아 거대한 에너지로 바뀌어 버렸다. 우주가 태어나기 직전의 거대 에너지 상태 즉 '빅뱅이 일어나기 직전'의 축소판이 된 것이다.

이 에너지는 가속기 안에서 '미니 빅뱅'을 일으키며 우주가 처음 태어날 때 만들어

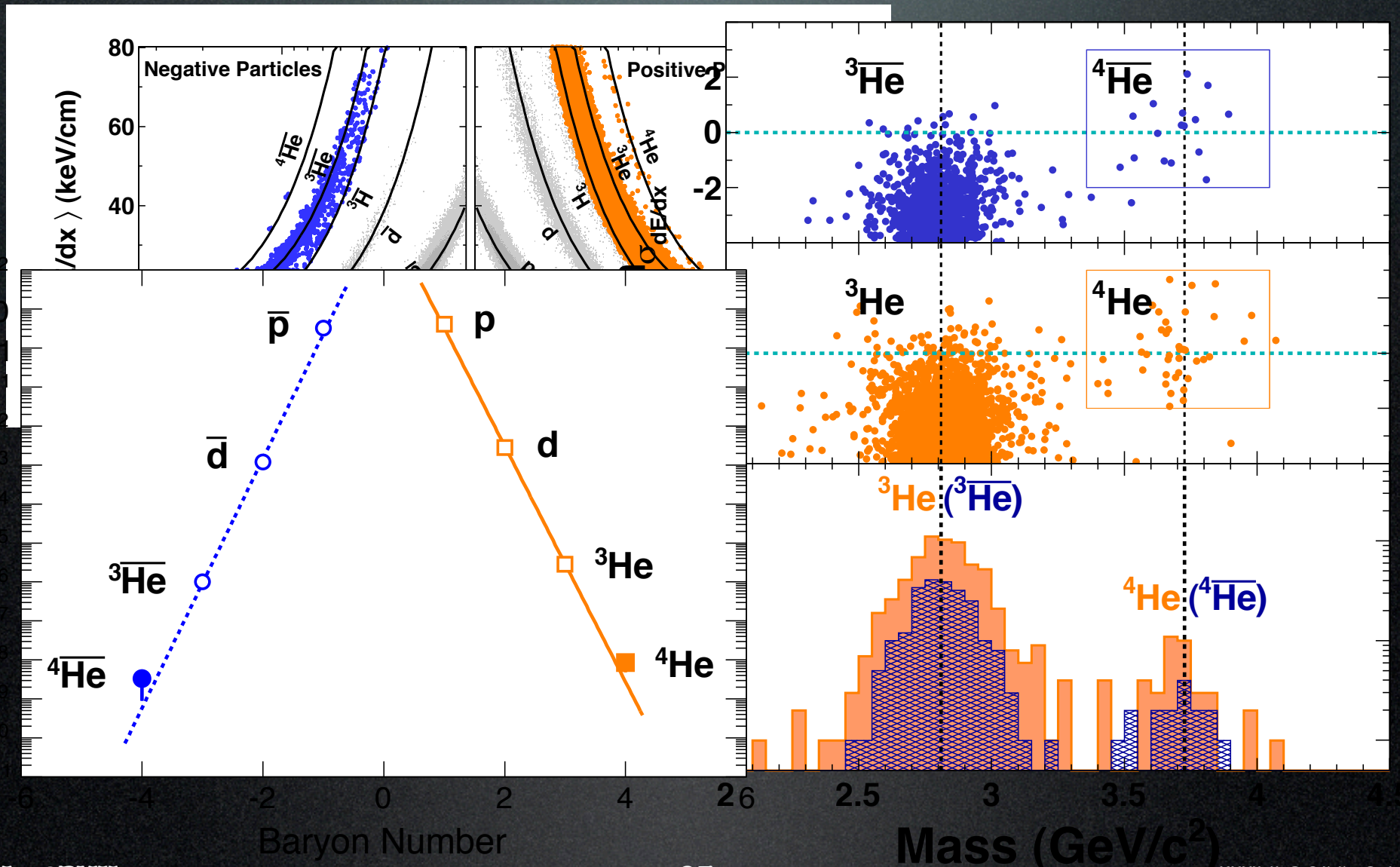
태어난 우주의 첫 모습을 밝히고 물질의 신비도 벗겨낼 수 있기 때문이다. 이 교수는 "지금은 존재하지 않지만 빅뱅 이후 만들어진 첫 물질 중 하나에 가장 가까이 다가간 셈"이라며 "우주의 진화와 물질의 탄생을 열 수 있는 열쇠를 발견한 것"이라고 비유했다.

한때 빅뱅 이후 첫 우주는 기체에 가까운 플라스마 상태여서 초기에 만들어진 입자들이 자유롭게 움직인다고 생각했다. 그러나 유 교수는 "요즘에는 첫 우주가 매우 끈적끈적한 액체와 비슷한 상태였을 거라고 많이 생각한다"며 "이번 연구는 그것을 증명해주는 것"이라고 설명했다. 유 교수에 따르면 초기 우주에서는 수많은 입자들이 강하게 상호작용을 하며 서로 얽혀 존재한다. 이 중에는 마치 패거리처럼 떼를 지어

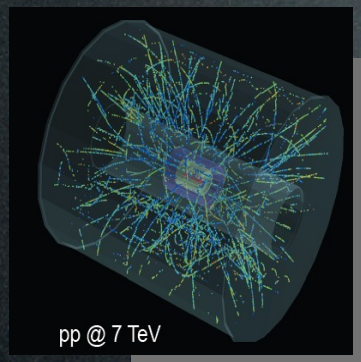
한국 과학자가 포함된 국제 연구진이 '빅뱅'을 작은 규모로 재현한 '미니빅뱅'에 성공했다. 미니빅뱅은 초기 우주를 낳았다. 사진 제공 NASA



Antimatter Helium



A Large Ion Collider Exp. @ LHC



A Large Ion Collider Exp. PbPb@ 2.76TeV

Energy density from $dN_{ch}/d\eta$

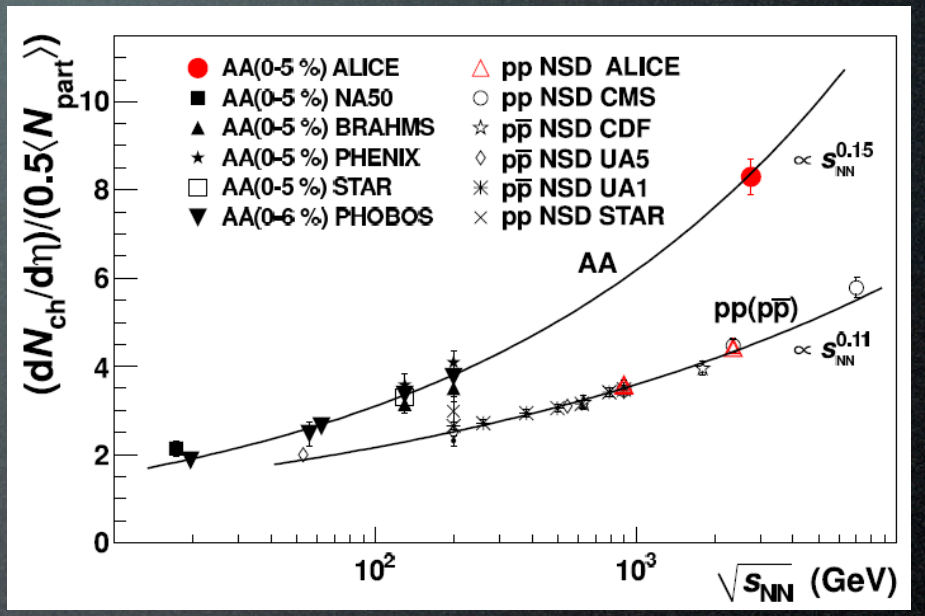
$dN_{ch}/d\eta$ = 1599 ± 4 (stat.) ± 80 (syst.)

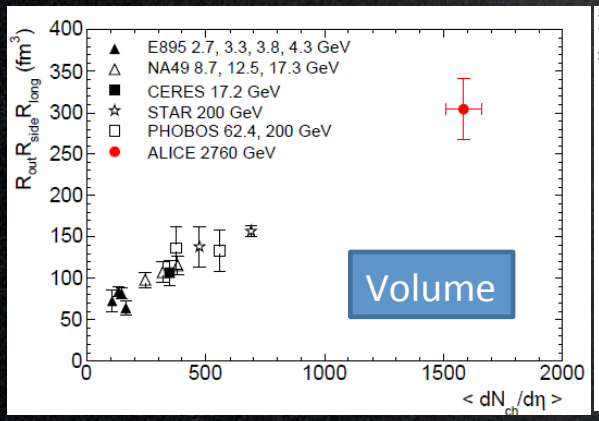
constrains / rules out models

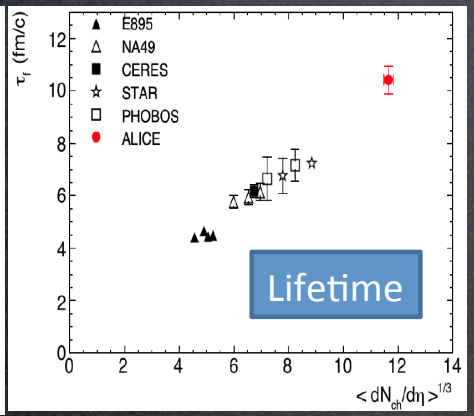
100 times cold nuclear matter density

~3 times the density reached at RHIC

($\varepsilon \approx 15$ GeV/fm^3)







Volume and lifetime from HBT

Freeze-out volume ~ 300 fm^3

~ 2 times the volume measured at RHIC (AuAu@200 GeV)

Lifetime until freeze-out ~ 10 fm/c

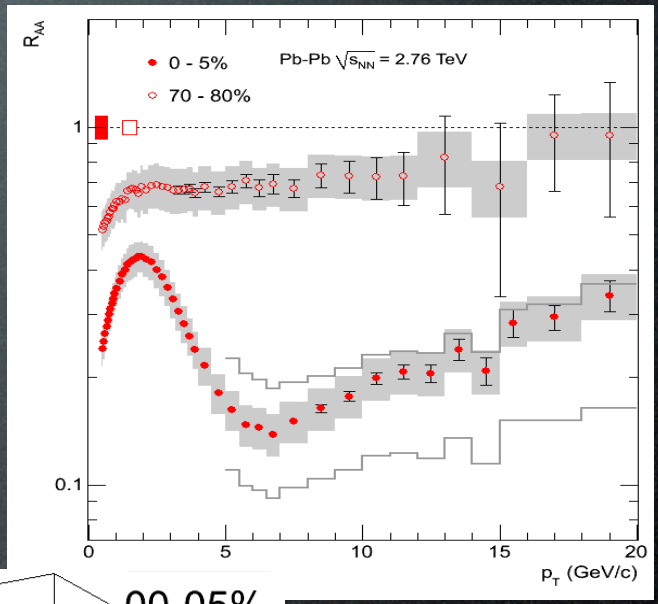
A Large Ion Collider Exp. PbPb@ 2.76TeV

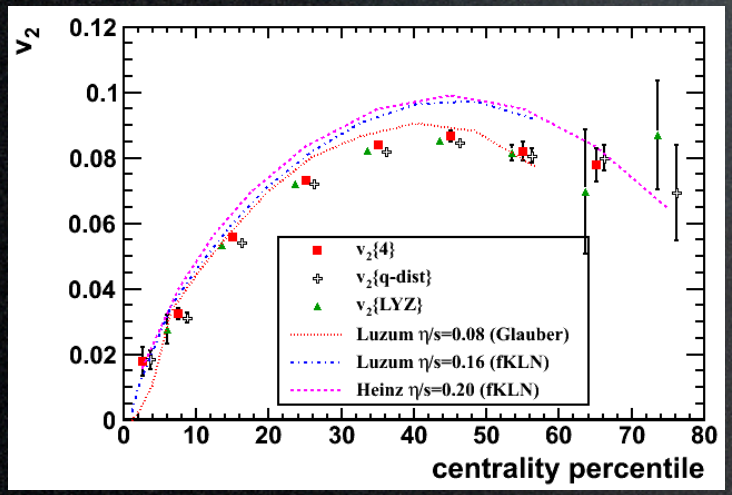
Strong energy loss in hot and dense medium

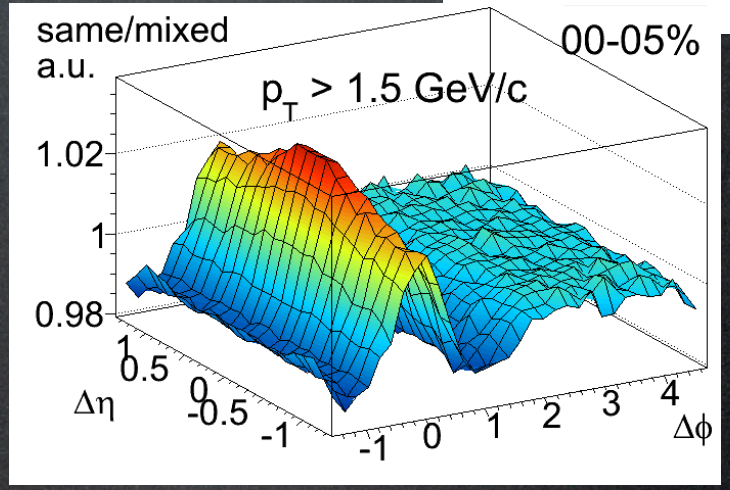
Quantified by nuclear suppression factor R_{AA}

Maximum suppression R_{AA} ~ 1.5 – 2 x

stronger than at RHIC

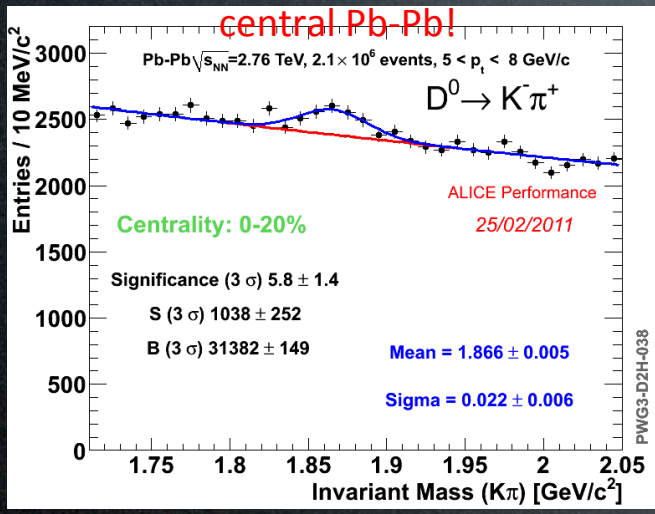




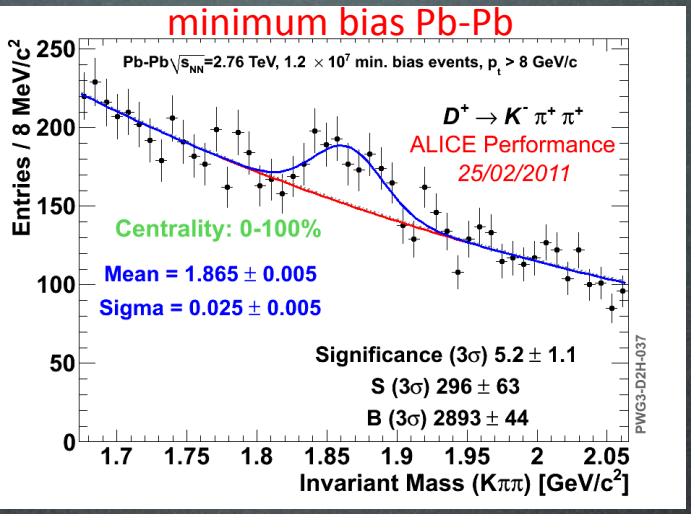


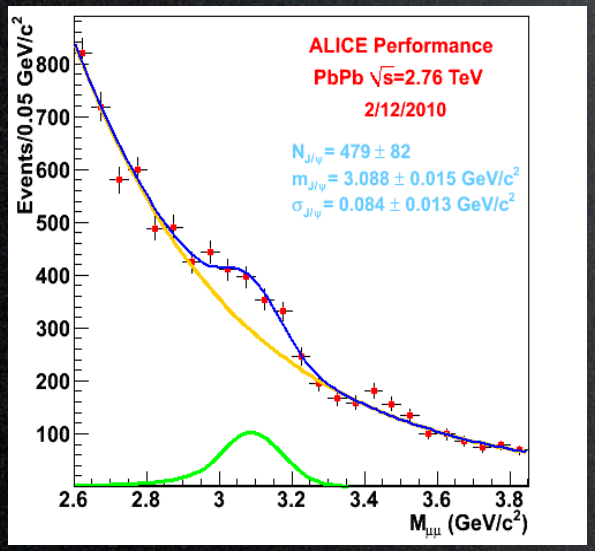
A Large Ion Collider Exp. PbPb@ 2.76TeV

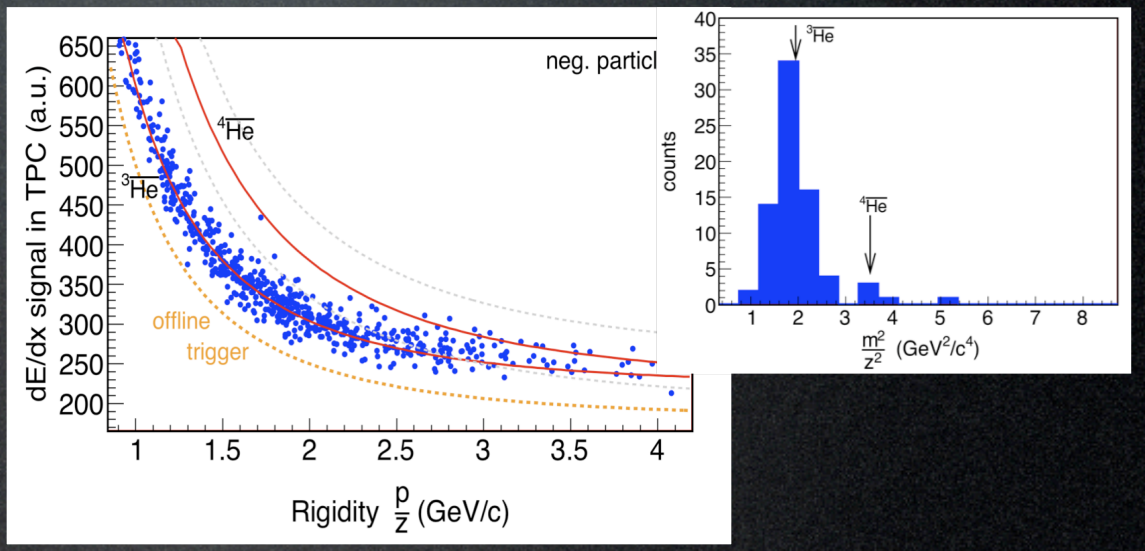
central Pb-Pb!



minimum bias Pb-Pb







Thanks!

- 35 Heavy Ion Meetings since 2004-12
- 290 Talks / avrg. 35 participants
- 101 foreign invitees
- Asian Triangle HI Conferences (ATHIC)
- http://him.phys.pusan.ac.kr