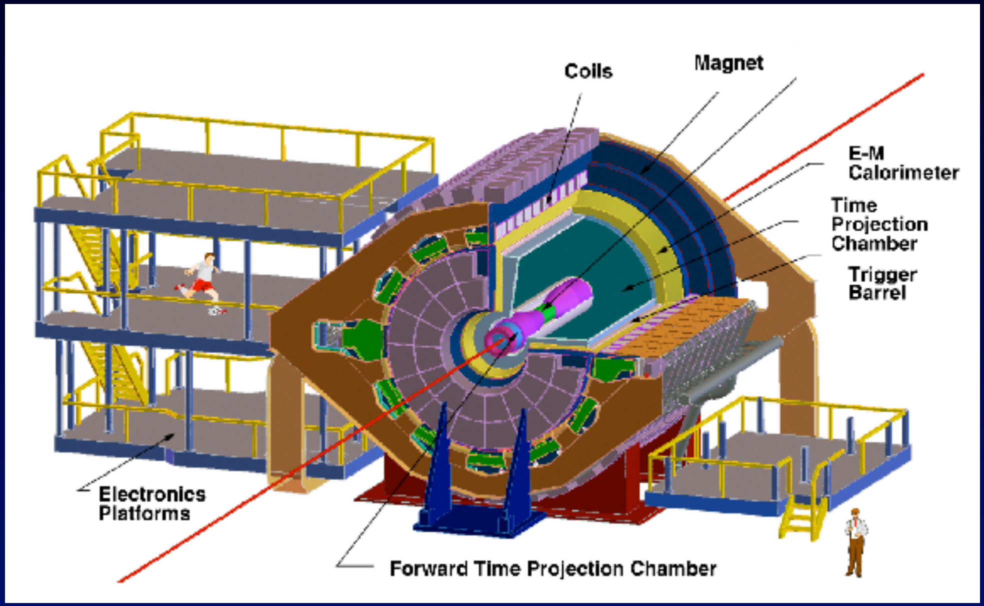
Analysis of fixed target collisions with the STAR detector



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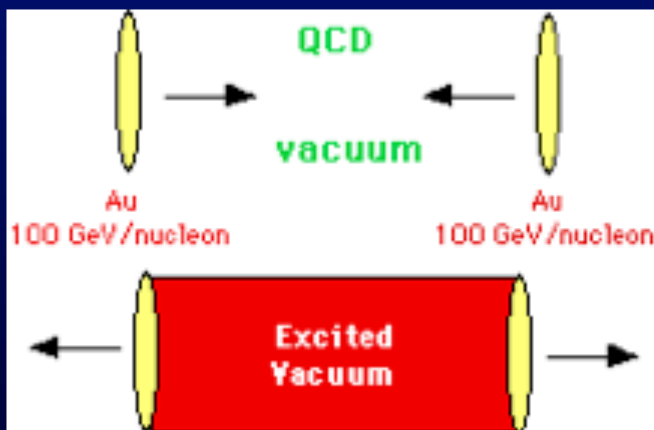
Hartnell College / University of California, Davis

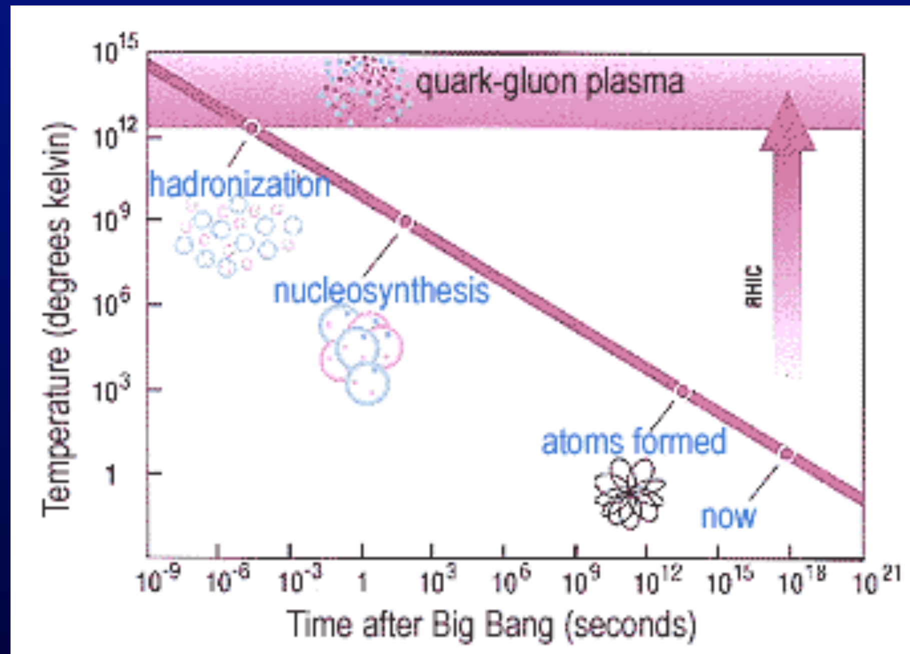
Presented at the Meeting of the California Section of the APS

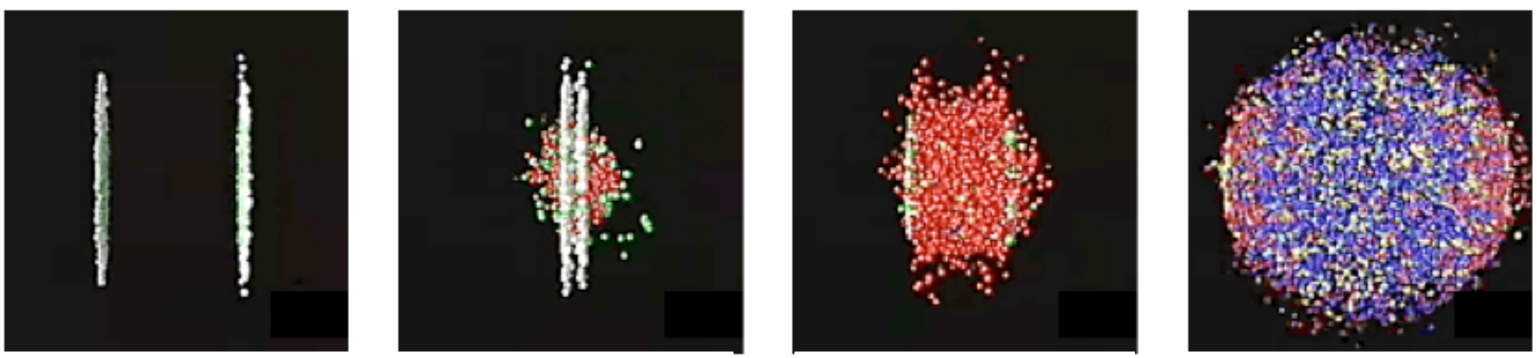
November 11, 2011

Creating mini-big bangs in the laboratory

Goal: Use relativistic collisions of nuclei to create hot dense matter which reproduces the earliest stages of the universe

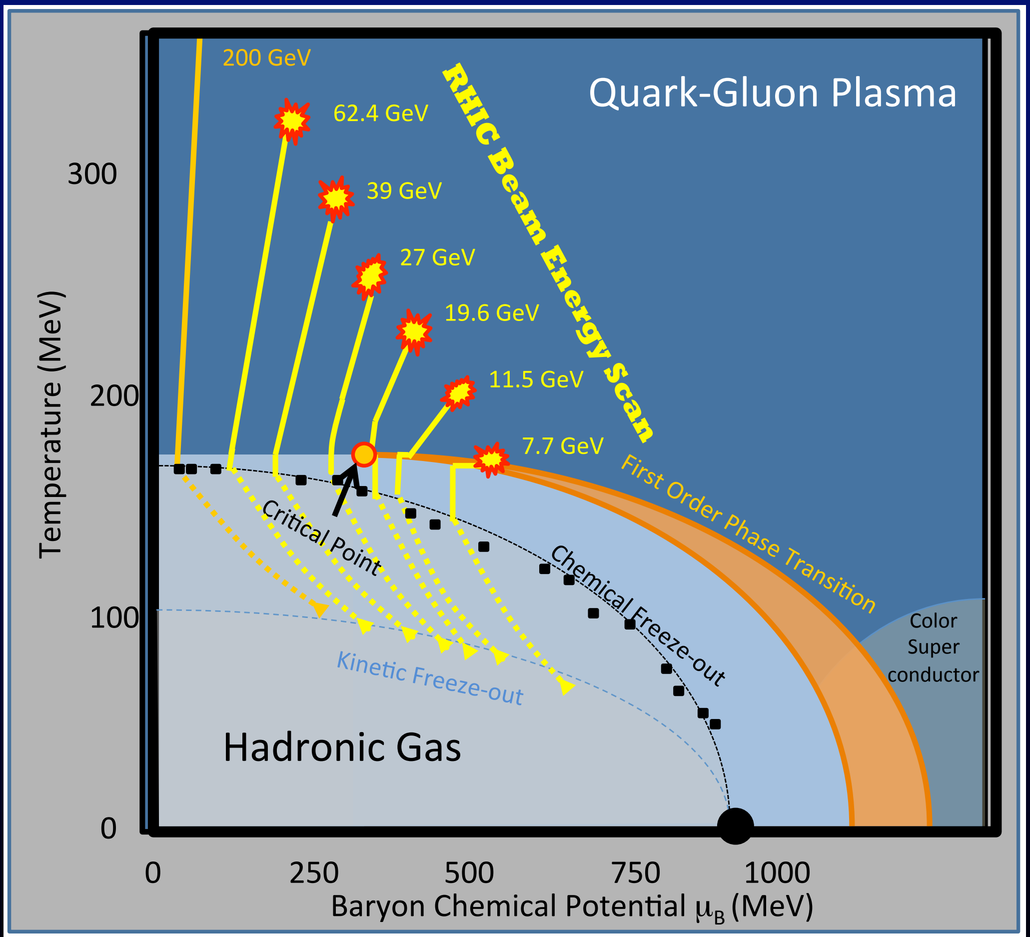






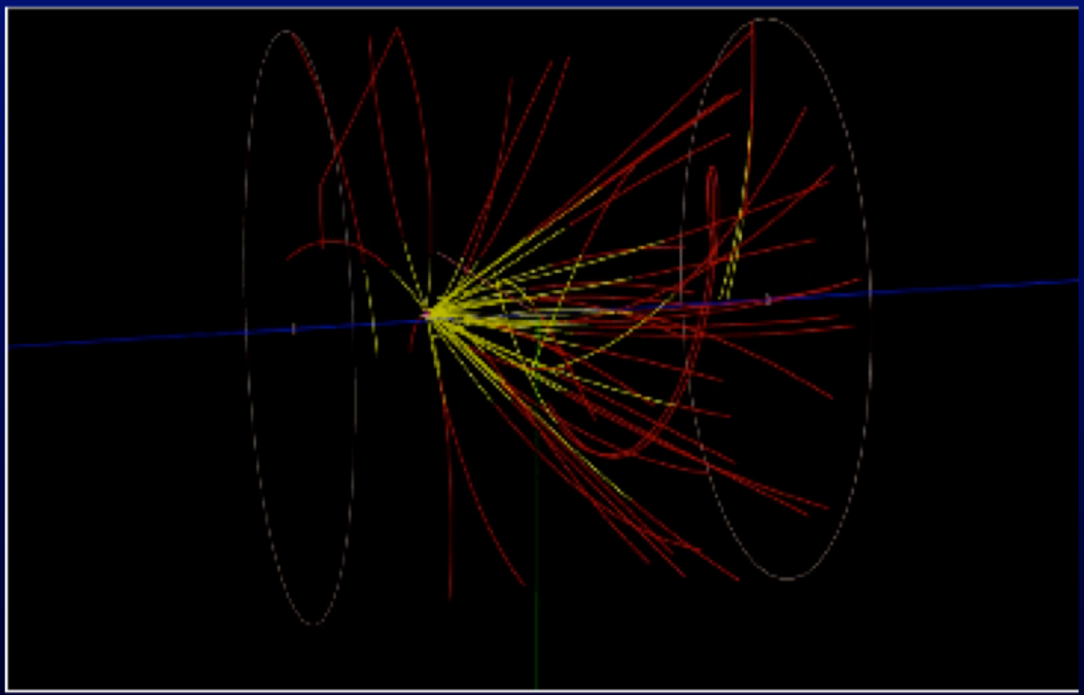
ions about to collide | ion collision | plasma creation | hadron production

QCD phase diagram



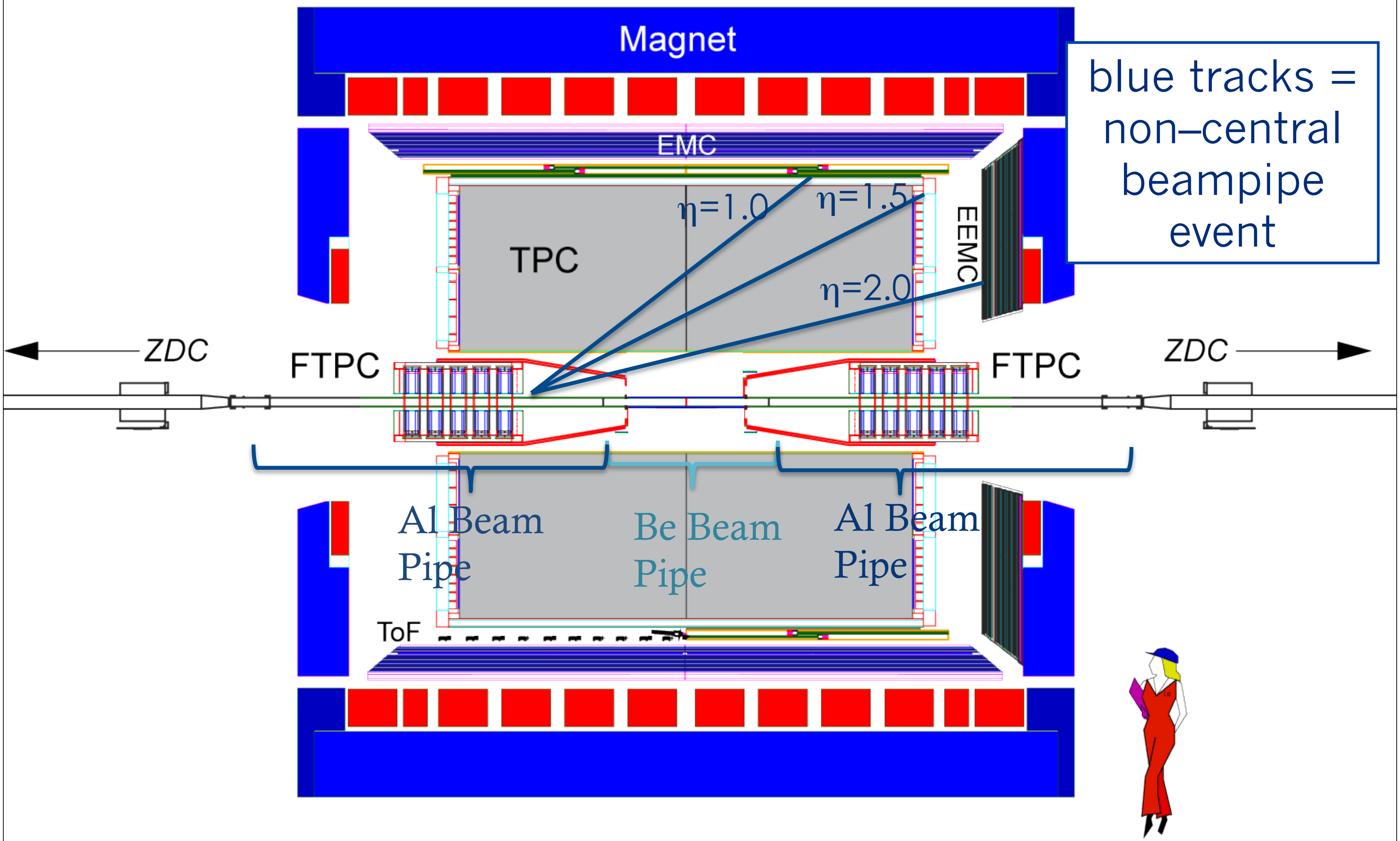
- We have created a new state of matter consistent with the QGP !
- In 2010 (and continuing through 2011) an extensive beam energy scan was undertaken at RHIC with a major goal to find the critical point.
- Fixed target collisions could extend the physics analysis to even lower √s.

STAR has fixed target events



- gold beam ions collide with aluminum beam pipe atoms
- the events are asymmetrical
- acceptance is not optimal ...

STAR detector array



Kinematic Calculations

Collision Energy (GeV)	Single Beam Energy	Single Beam P_z (GeV/c)	Fixed Target $\sqrt{s}$	Single Beam Rapidity	Center of Mass Rapidity
19.6 Au+Au	9.8	9.76	4.47 Au+Al	3.04	1.52
11.5 Au+Au	5.75	5.67	3.53 Au+Al	2.51	1.25
7.7 Au+Au	3.85	3.74	2.99 Au+Al	2.10	1.05

$\sqrt{(s_{NN})}$ = center of mass energy

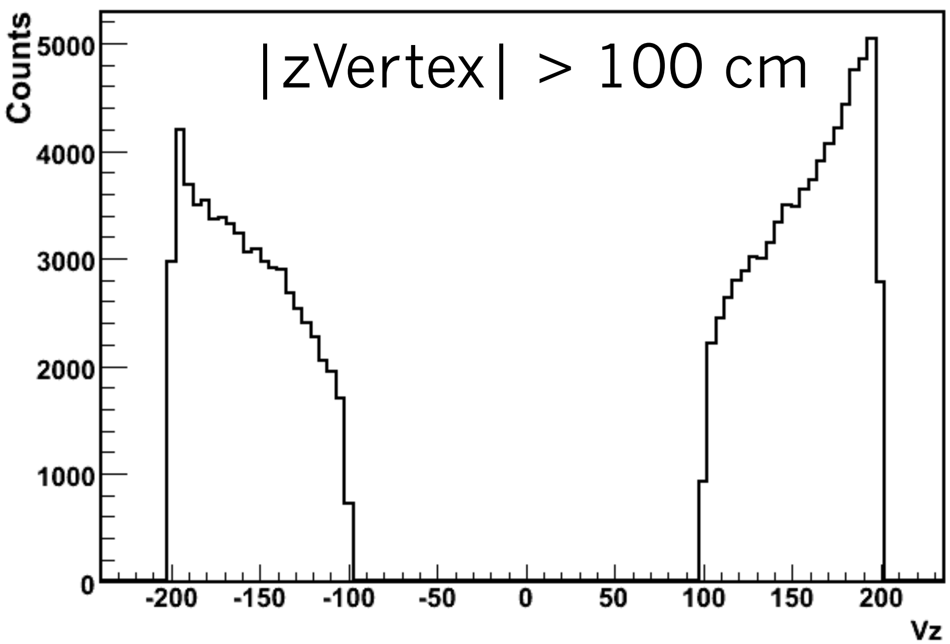
- $\sqrt{(s_{NN})} = \sqrt{(2m^2 + 2Em)}$
  $m = 0.9315$ GeV/c^2 ; $E = 9.8$ GeV
- $\sqrt{(s_{NN})} = 4.47$ GeV

- $p_z = \sqrt{(E^2 - m^2)} = 9.76$ GeV/c

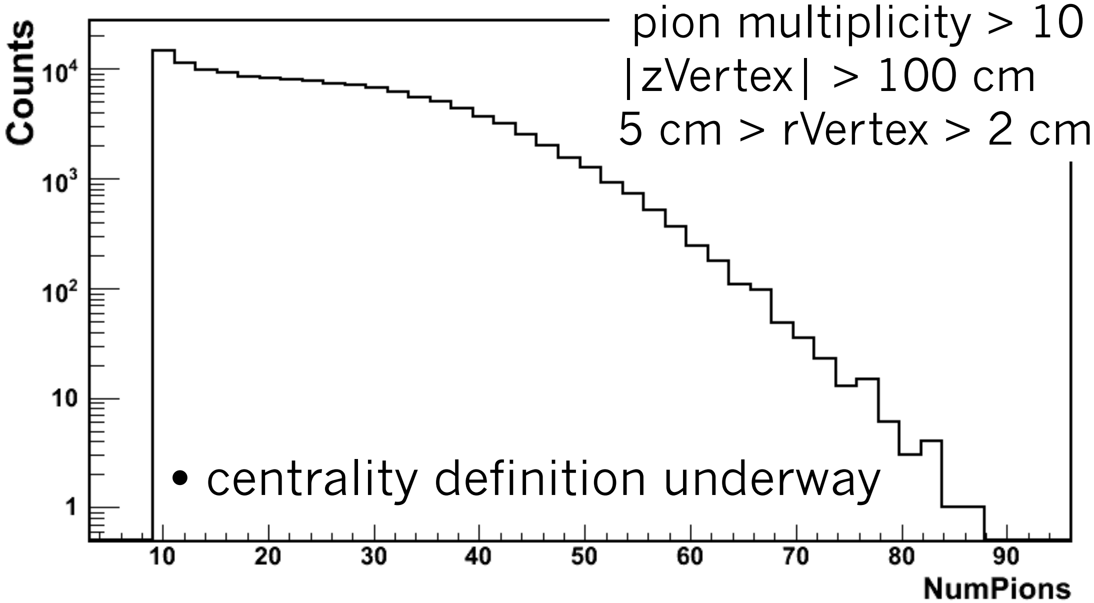
rapidity (y)

- $y_{beam} = 0.5*[\ln(E + p_z)/(E - p_z)]$
- $y_{beam} = 3.0$
- $y_{cm} = 1.5$

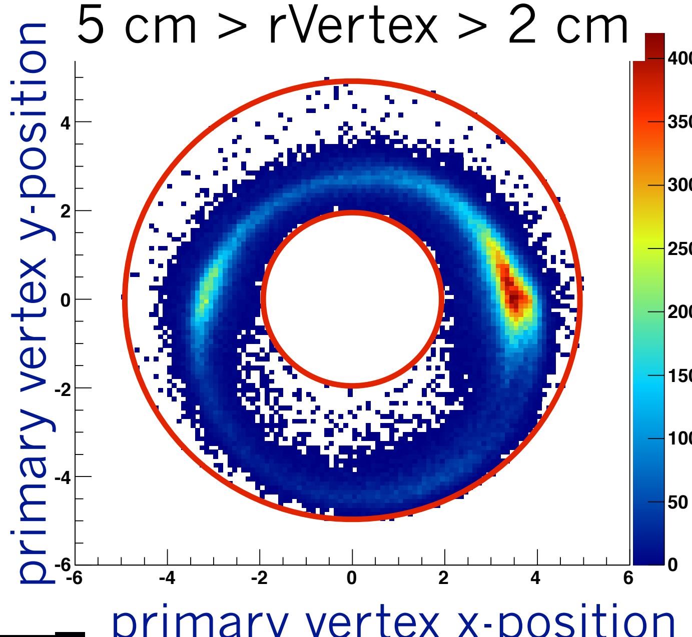
Event Selection



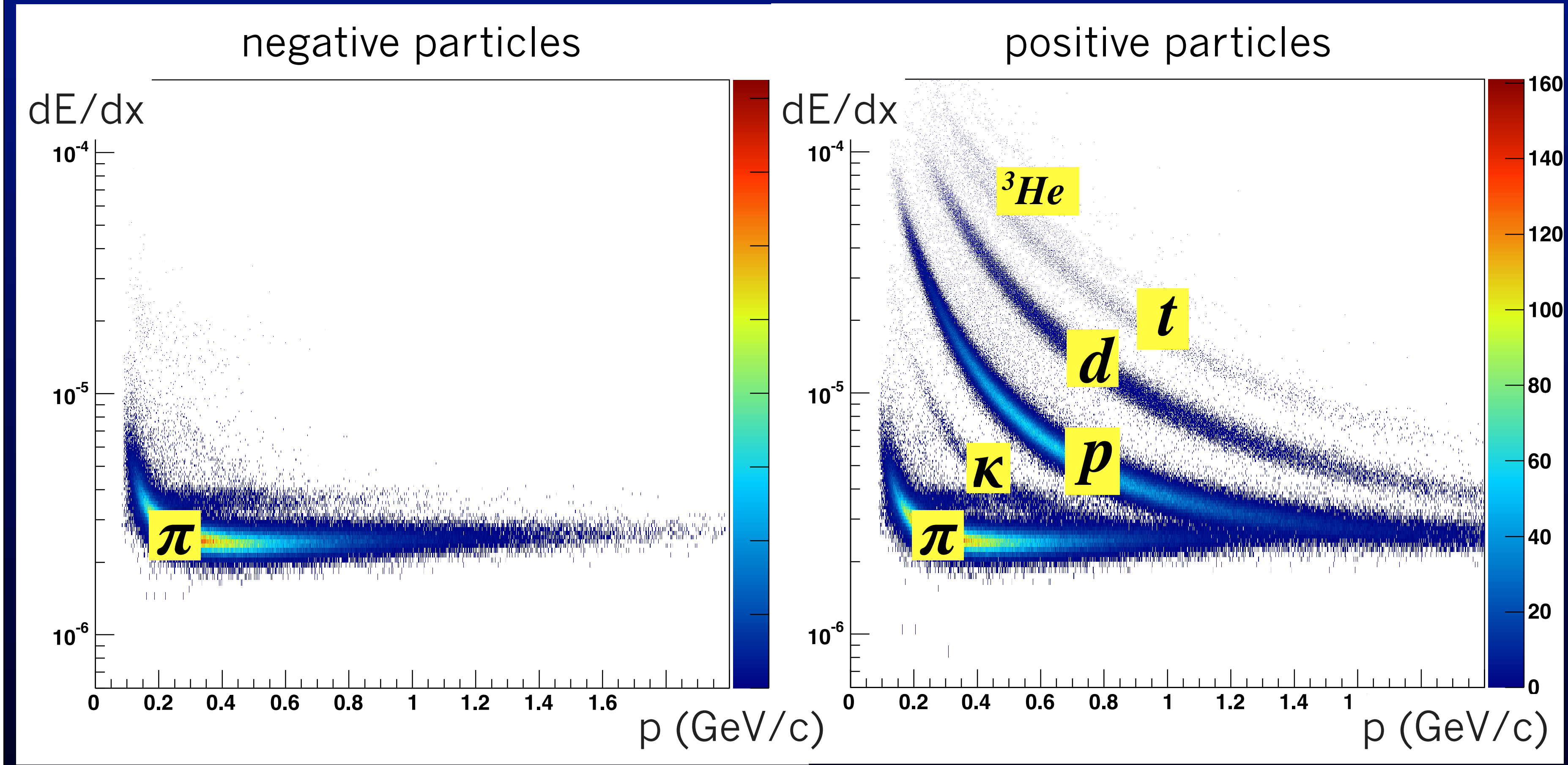
- Run 11 – 19.6 AuAu collider data
- Au+Al $\sqrt{s_{NN}}$ = 4.5 GeV
- 137k events pass selection cuts from 146 M total events



- centrality definition underway

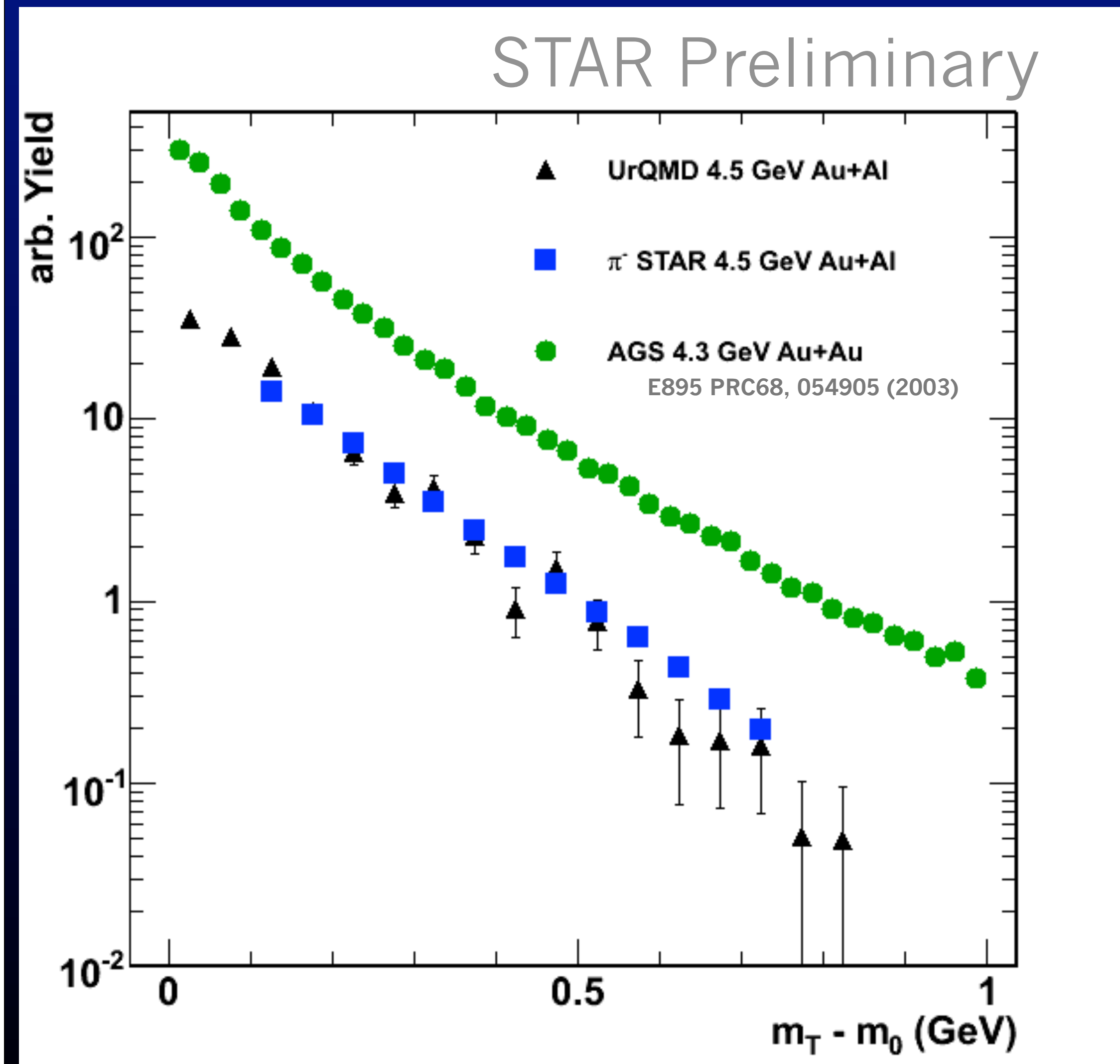


Particle identification via dE/dx



- dE/dx from beampipe events as per selection criteria in slide 8
- particle bands are well separated

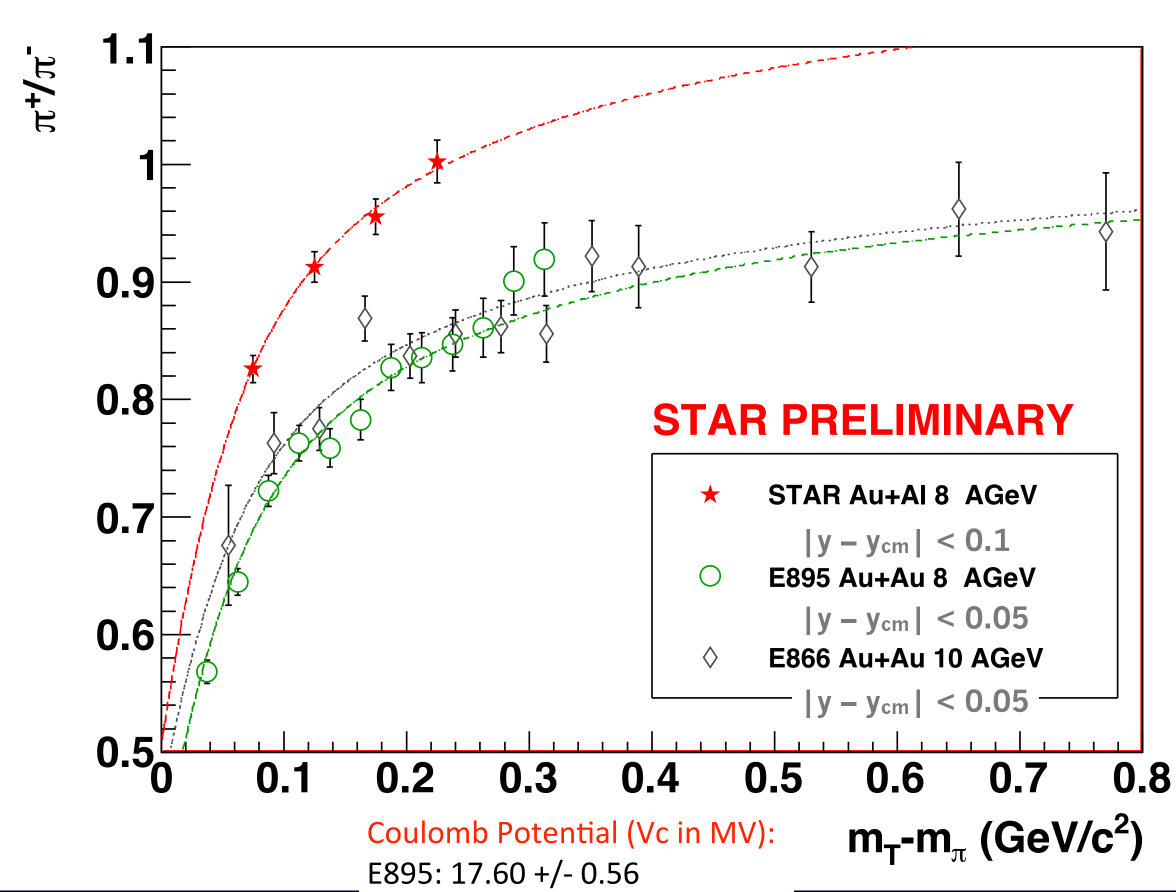
π^- spectra comparisons



- uncorrected STAR data points
- slopes of π^- spectra STAR data, AGS data, and UrQMD compare reasonably
- AGS yields are predictably above STAR for Au+Au (AGS) vs. Au+Al (STAR)

π^+/π^- yield ratios

- Net positive charge in the collision zone
  - expanding spherical source → effective potential
- Extracted parameters include initial ratio R and the full coloumb potential Vc
- Coloumb potential (Vc) of the source modifies momentum distribution
  - greater effect for low–momentum π
- R–primordial ratio from initial yields, unmodified by the coloumb source



Coulomb Potential (Vc in MV):
E895: 17.60 +/- 0.56
E866: 16.32 +/- 1.92
Au+Al: 16.45 +/- 1.74

Ratios:
E895: 0.717 +/- 0.004
E866: 0.771 +/- 0.011
Au+Al: 0.858 +/- 0.008

Conclusions and Outlook

- We can do physics with STAR as a fixed target experiment !
  - We have been able to extract pion spectra for fixed target collisions at lab rapidity
    - working to understand detector efficiency at high rapidities via simulated events
    - checking pion contamination, stability of multiplicity as a function of zVertex
  - Yields and slopes compare favorably with published data in this energy range
  - We **can** extend the search for the critical point to lower energies
    - We have more fixed target data at $\sqrt{(s_{NN})}$ of 3.0 and 3.5 GeV

Backup Slides

Source Coulomb Potential

$$\boxed{\frac{\pi^+}{\pi^-}(m_T - m_\pi) = R\,\frac{\exp\left[\left(E + V_{\text{eff}}\right)/T_\pi\right] - 1}{\exp\left[\left(E - V_{\text{eff}}\right)/T_\pi\right] - 1}\cdot J}$$

Ratio as a function of transverse kinetic energy with transformed B-E distribution

$$J = \frac{E - V_{\text{eff}}}{E + V_{\text{eff}}}\,\frac{\sqrt{\left(E - V_{\text{eff}}\right)^2 - m_\pi^2}}{\sqrt{\left(E + V_{\text{eff}}\right)^2 - m_\pi^2}}$$

Jacobian of the transformation

$$V_{\text{eff}}\left(\gamma_\pi\beta_\pi\right) = V_C\left(1 - e^{-E_{\max}\left(\gamma_\pi\beta_\pi\right)/T_p}\right)$$

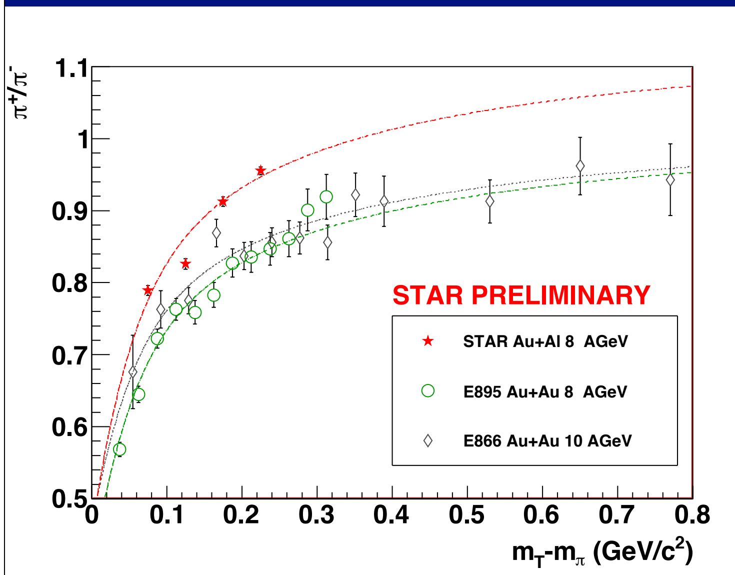
Effective Coulomb potential accounting for the reduced charge seen by low momentum π

$$E_{\max}\left(\gamma_\pi\beta_\pi\right) = \sqrt{\left(m_p\gamma_\pi\beta_\pi\right)^2 + m_p^2} - m_p$$

Maximum kinetic energy of the corresponding π velocity

- Net positive charge in the collision zone
  - Expanding spherical source → effective potential
- Coulomb potential (V_c) of the source modifies momentum distribution
  - Greater effect for low-momentum π
- R – primordial ratio from initial yields, unmodified by the coulomb source
- Extracted parameters include initial ratio R and the full coulomb potential V_c

π^+/π^- yield ratios fit parameters



EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	7.71114e-01	1.14871e-02	1.22945e-05	-5.15275e-04
2	p1	1.63202e+01	1.92414e+00	2.05922e-03	
					-1.39505e-05
3	p2	1.12800e-01	fixed		
4	p3	0.00000e+00	fixed		
5	p4	2.28900e-01	fixed		

E866 Chi^2 1.20046

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	7.17317e-01	4.43901e-03	8.06105e-06	-5.22883e-05
2	p1	1.75996e+01	5.60205e-01	1.01731e-03	8.87560e-07
3	p2	9.80000e-02	fixed		
4	p3	0.00000e+00	fixed		
5	p4	2.25000e-01	fixed		

E895 Chi^2 1.17822

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	8.58428e-01	8.42426e-03	3.77270e-06	-1.17553e-04
2	p1	1.64496e+01	1.74370e+00	7.80892e-04	
					1.14995e-06
3	p2	9.80000e-02	fixed		
4	p3	0.00000e+00	fixed		
5	p4	2.25000e-01	fixed		

STAR Au+Al Chi^2 0.184964

Coulomb Potential:

E895: 17.60 +/- 0.56

E866: 16.32 +/- 1.92

Au+Al: 17.60 +/- 0.86

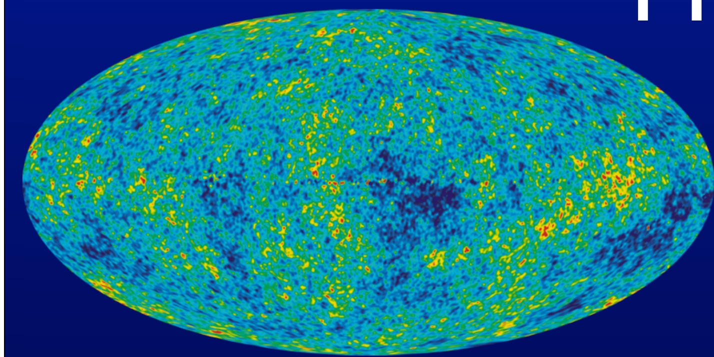
Ratios:

E895: 0.72 +/- 0.00

E866: 0.77 +/- 0.01

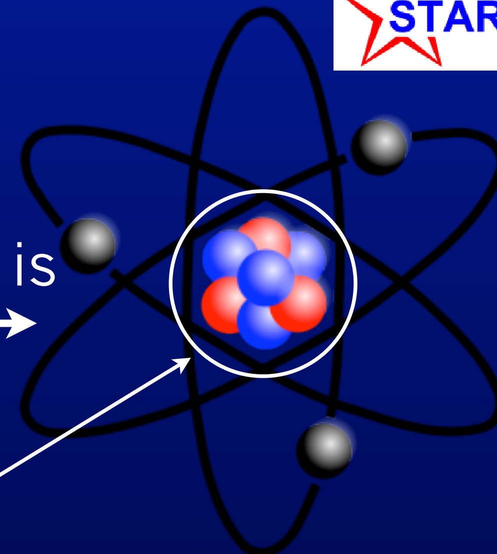
Au+Al: 0.81 +/- 0.00

The Basics

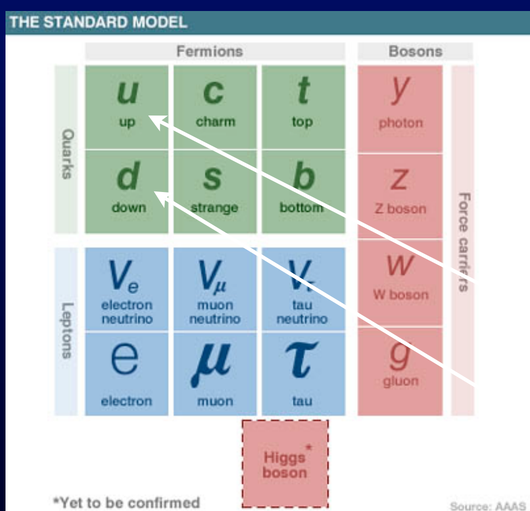


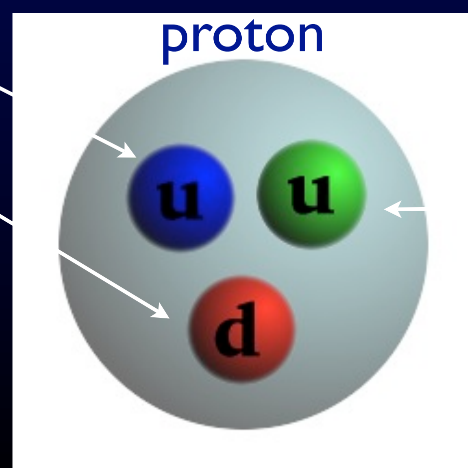
matter in the universe is

made of atoms



nucleus = protons
+ neutrons

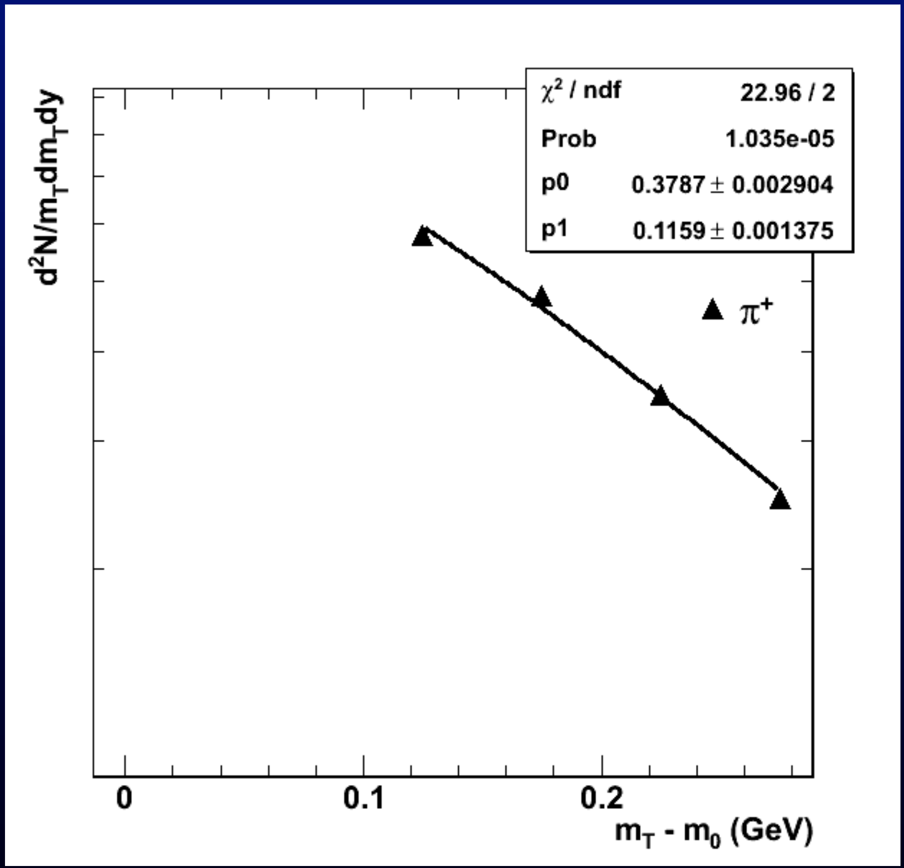




nucleons are hadrons
(made of quarks)

mesons = 2 quarks
baryons = 3 quarks

π^+ spectra



χ^2 / ndf 22.96 / 2
Prob 1.035e-05
p0 0.3787 ± 0.002904
p1 0.1159 ± 0.001375
π^+
$d^2N/m_T dm_T dy$
0
0.1
0.2
$m_T - m_0$ (GeV)