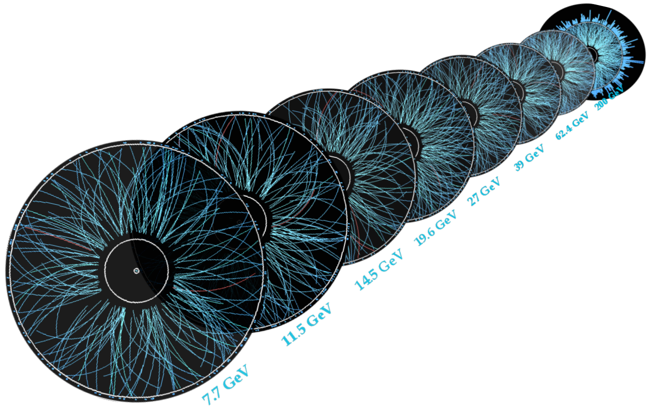
清華大學
Tsinghua University

STAR

Baryon Stopping, Charged and Strange Particle Distributions in Al+Au Collisions at $\sqrt{s_{NN}} = 4.9$ GeV



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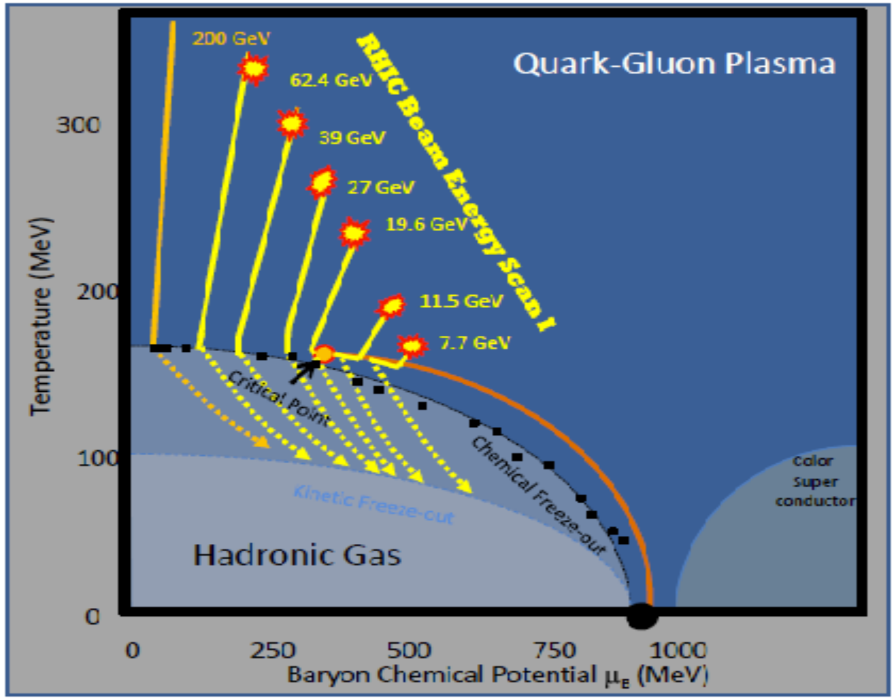
Outlines

- ✓BES-I and STAR Fixed-Target Program
- ✓Overview of the STAR Detector
- ✓STAR Fixed-Target Geometry
- ✓π^-, Proton, K_S^0 and Λ Production from Al+Au Collisions at $\sqrt{s_{NN}}$ = 4.9 GeV
  - ✓Transverse Mass Spectra
  - ✓dN/dy Distributions and Comparison with E802 Experiment at AGS
  - ✓Meson Discussion
  - ✓Baryon Discussion
- ✓Future Upgrades and Fixed-Target Program
- ✓Summary

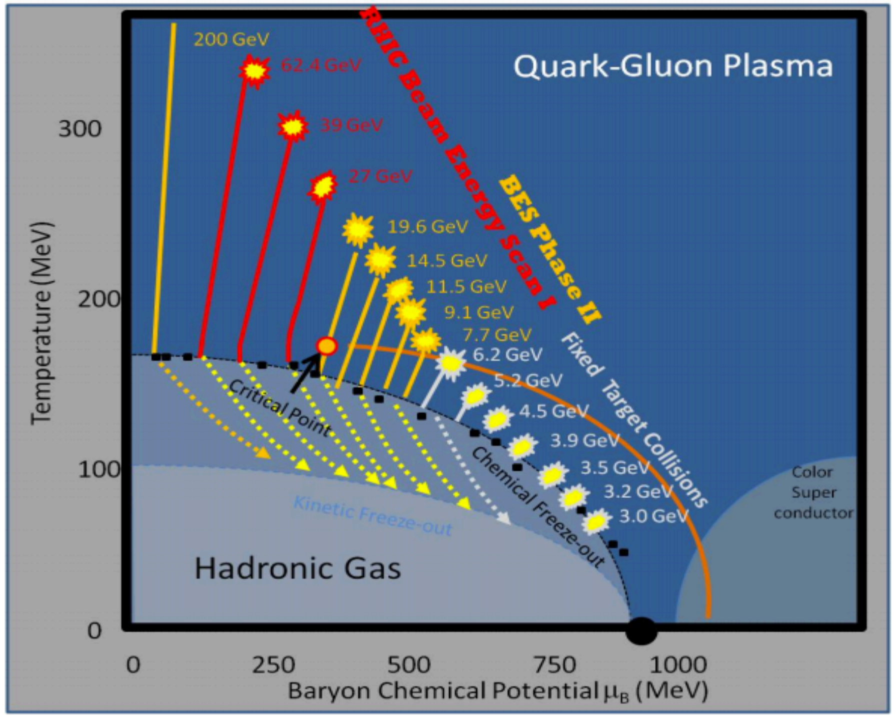
BES-I and STAR Fixed-Target Program

Goals of BES-I

- ✓ *Study the onset of de-confinement and phase boundary.*
- ✓ *Search for the QCD critical point.*
- ✓ *Turn-off of QGP signals.*
- ✓ *Find evidence of the possible first-order phase transition.*



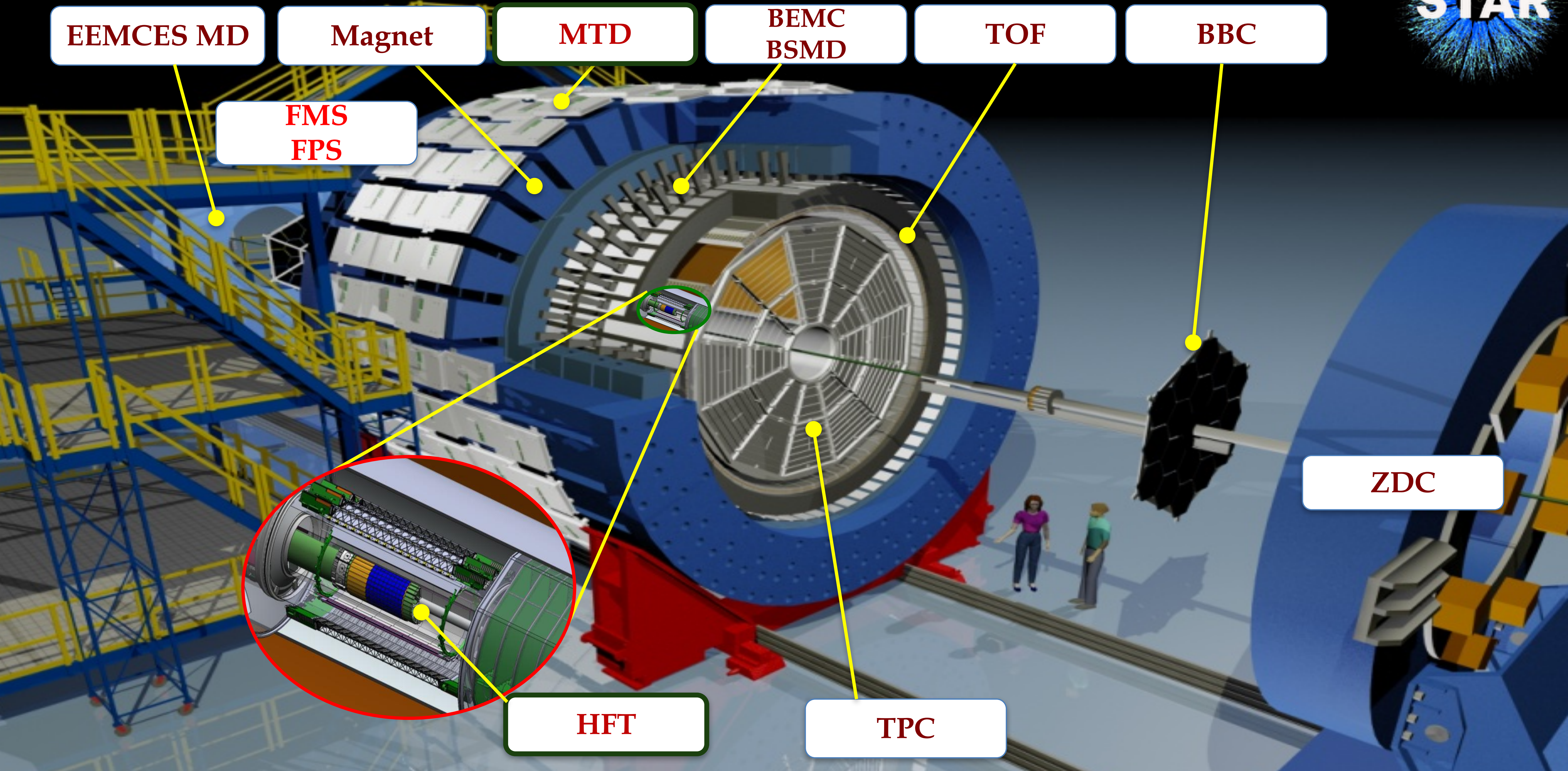
Need to probe lower energies!



Motivation of the Fixed-Target

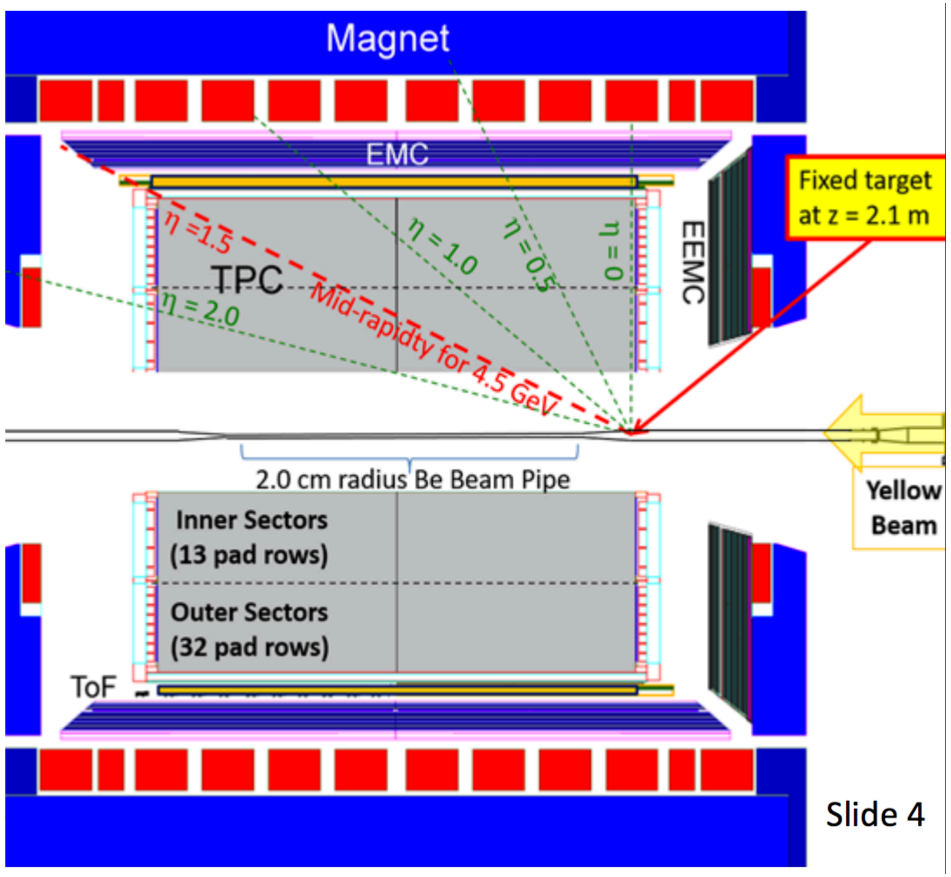
- ✓ *Provide control measurements for searches of the critical point and onset of deconfinement.*
- ✓ *Test run focused on demonstrating STAR FXT capabilities.*
- ✓ *FXT Collisions allow us to extend the μ_B range.*

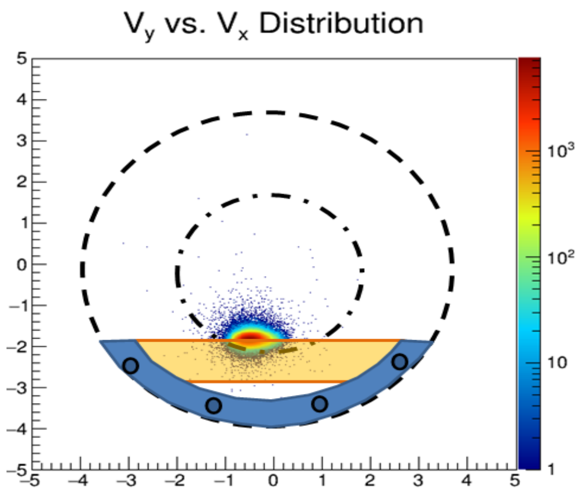
The Solenoidal Tracker At RHIC (STAR)

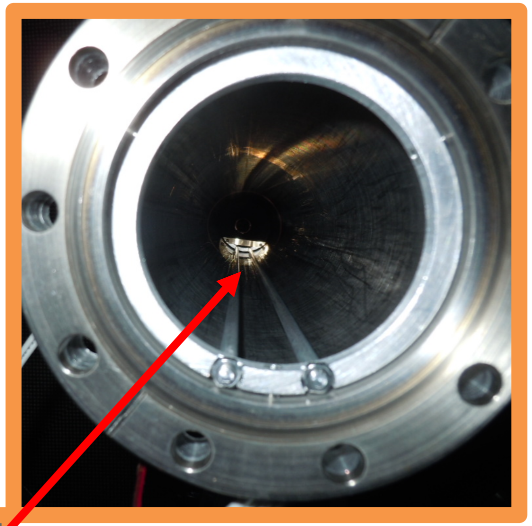


STAR Fixed-Target Geometry

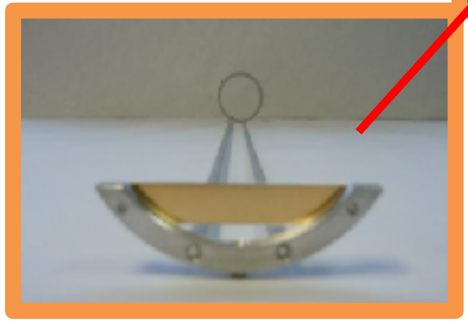
- ✓ *The Fixed Target was installed inside the vacuum pipe at z = 211 cm*
- ✓ *Gold foil is 1 mm thick with about a 4% interaction probability*
- ✓ *3.4 M Al+Au events with top 30% centrality trigger*







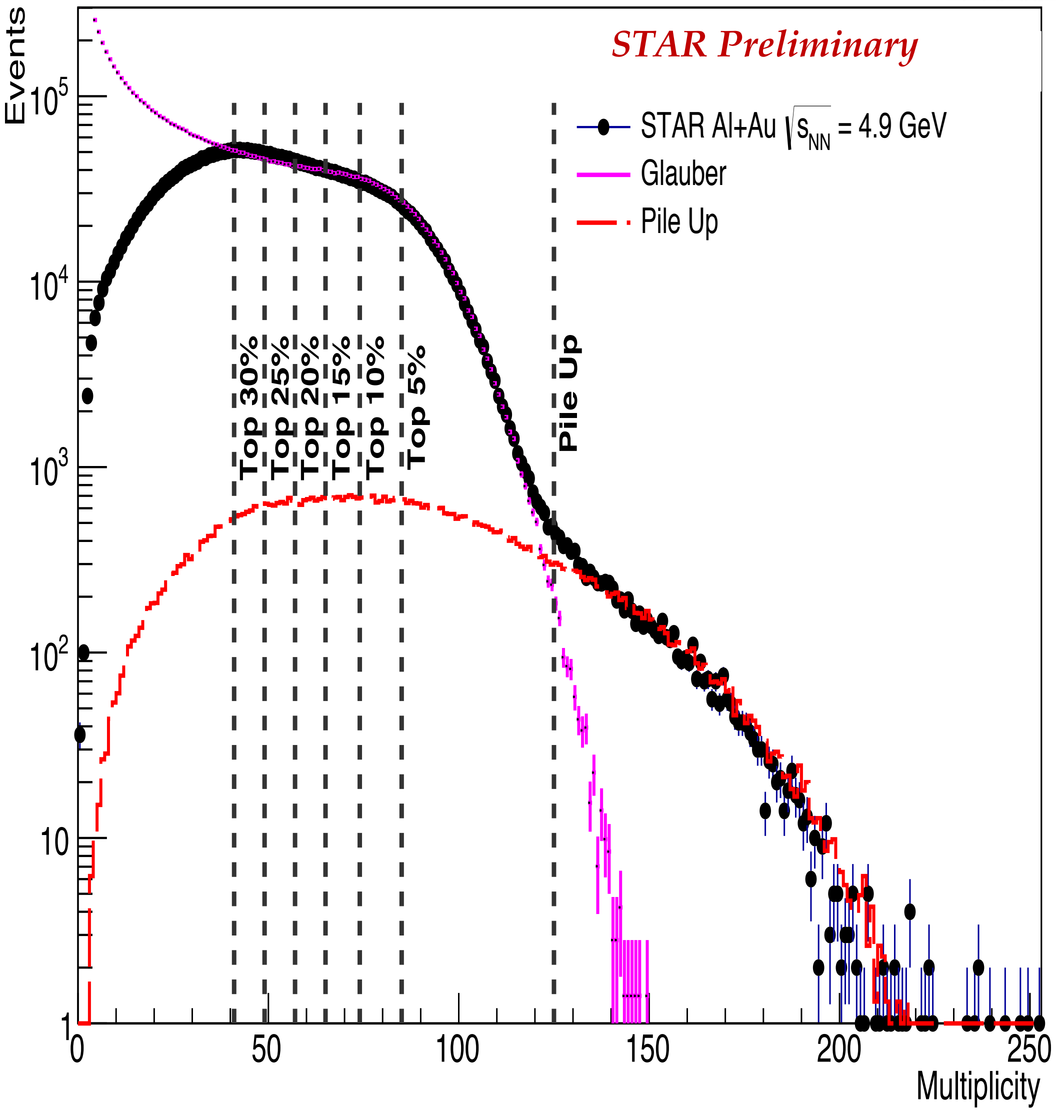
Beam Pipe



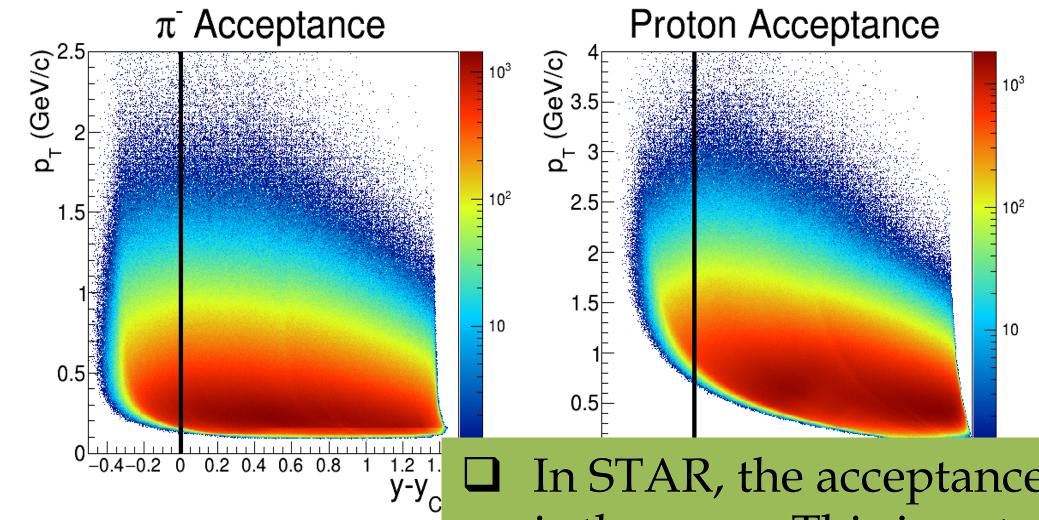
Au-Target

Centrality Determination

- ✓The centrality variable is the number of tracks that pass our basic track QA cuts.
- ✓3.4 M Al+Au events collected with the top 30% centrality.
- ✓Events with a multiplicity greater than 125, were excluded from all analyses since this region of multiplicity is dominated by pile-up events.
- ✓It is not a beam pipe study.



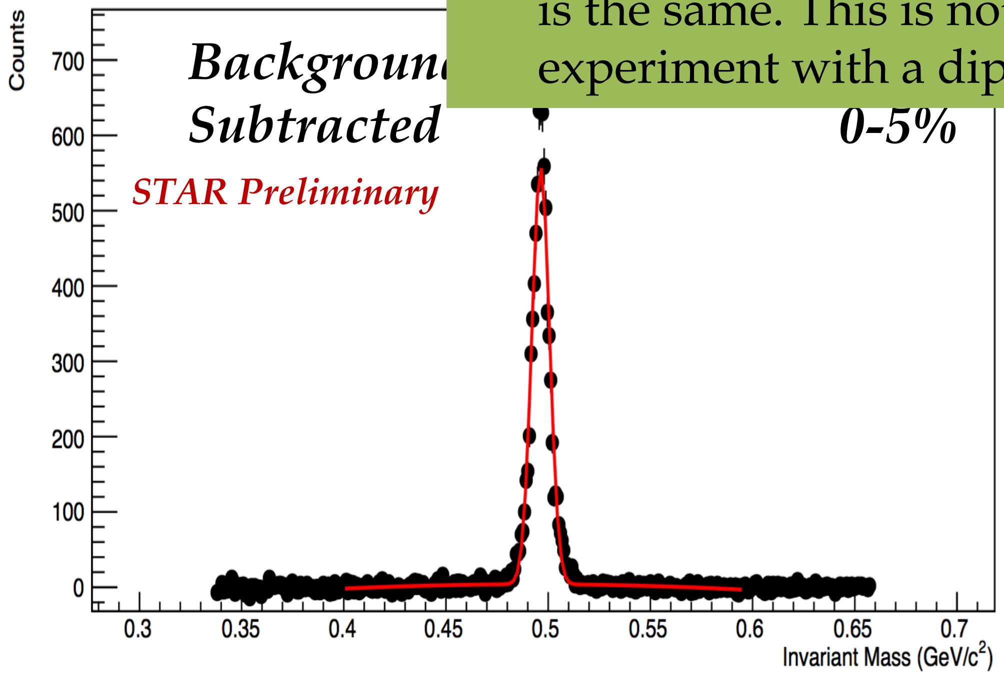
π^-, Proton, K_S^0 and Λ Production

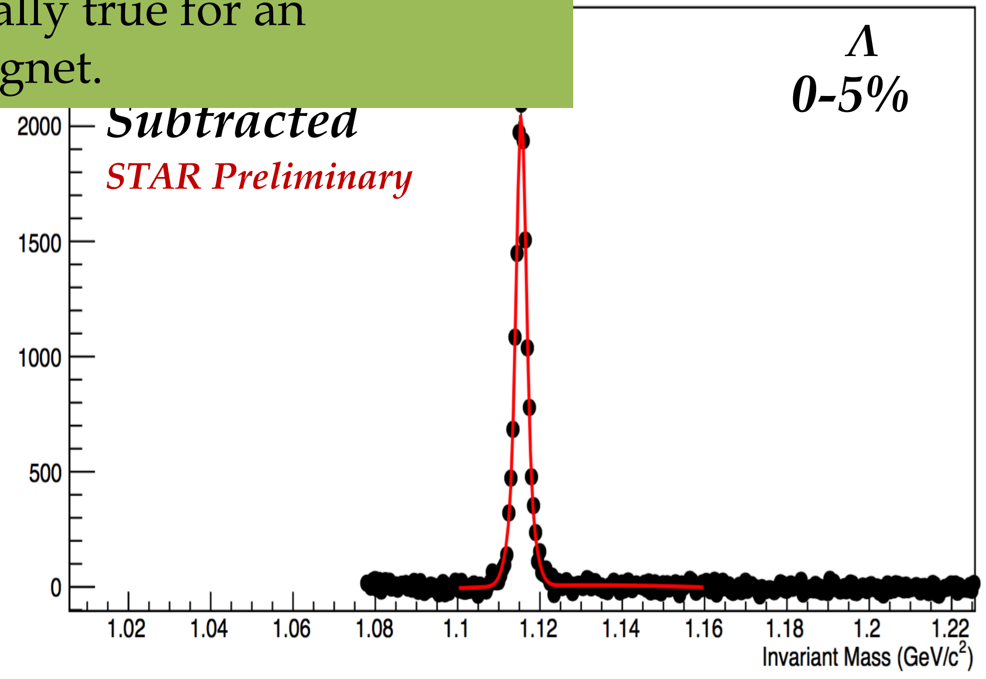


- ✓ **Al+Au 4.9 GeV, 0-5%, full p_T range**
  - ✓ $K^0_S \rightarrow \pi^+ + \pi^-$
  - ✓ $\Lambda \rightarrow p + \pi$

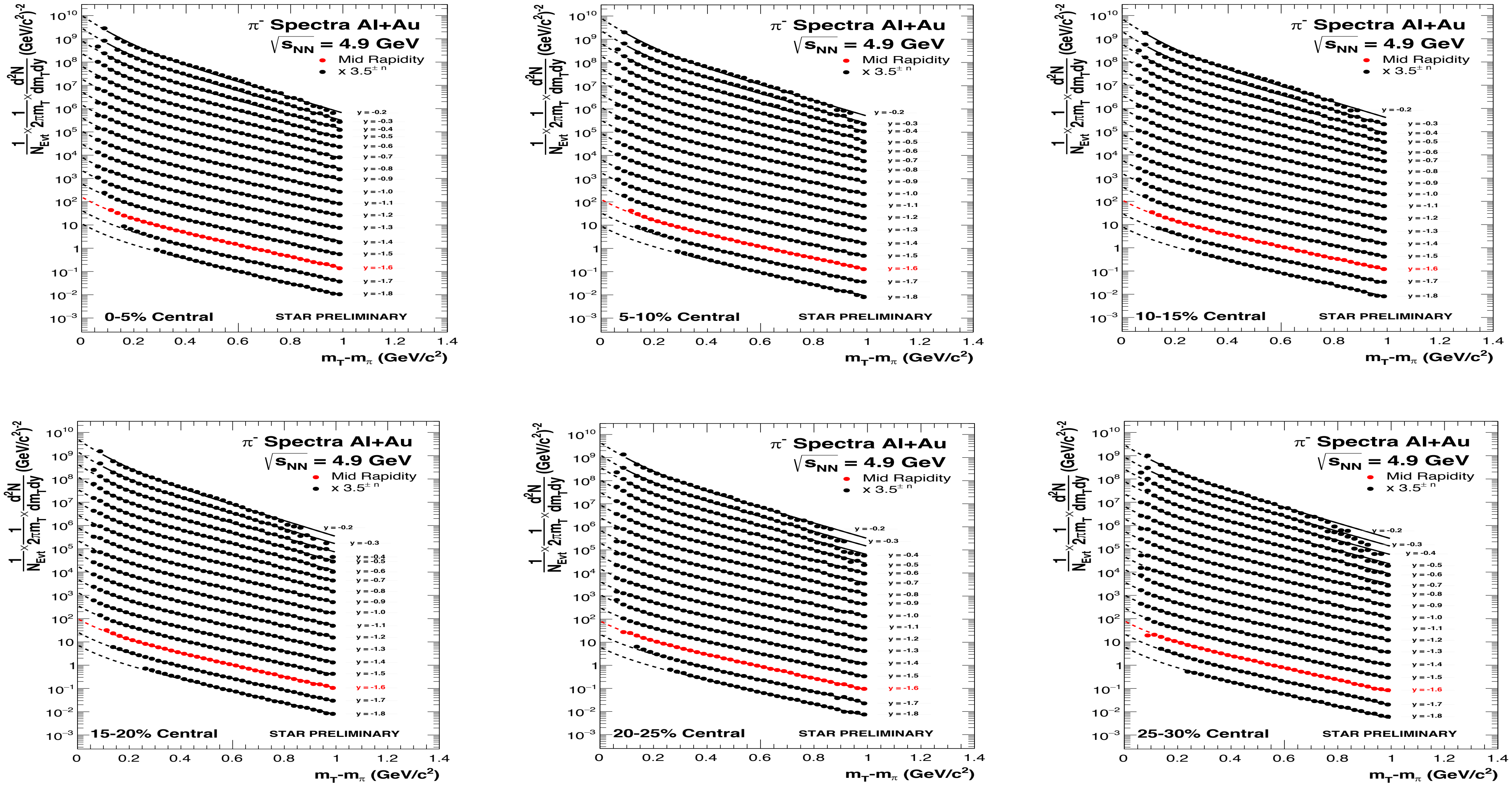
π ,K, p are identified with TPC dE/dx reconstruct the secondary vertex

- In STAR, the acceptance for particles and anti-particles is the same. This is not normally true for an experiment with a dipole magnet.



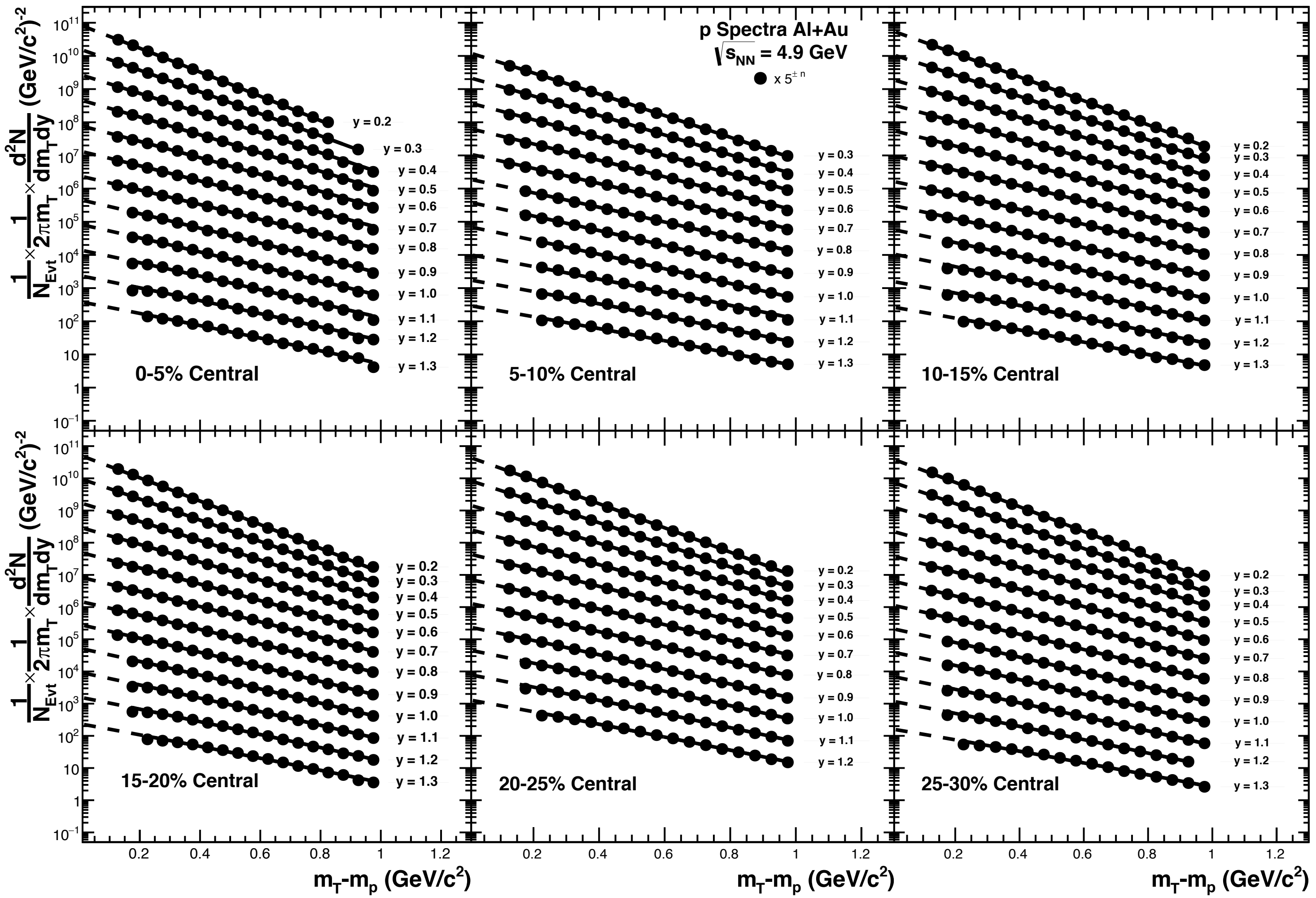


π^- Spectra



- ✓ π^- *spectra for different rapidity ranges and different centralities scaled by the factor of* $3^{\pm n}$. *n=0 for mid rapidity*
- ✓ π^- *data extrapolated to low and high* m_T *with the double Bose-Einstein fitting function.*

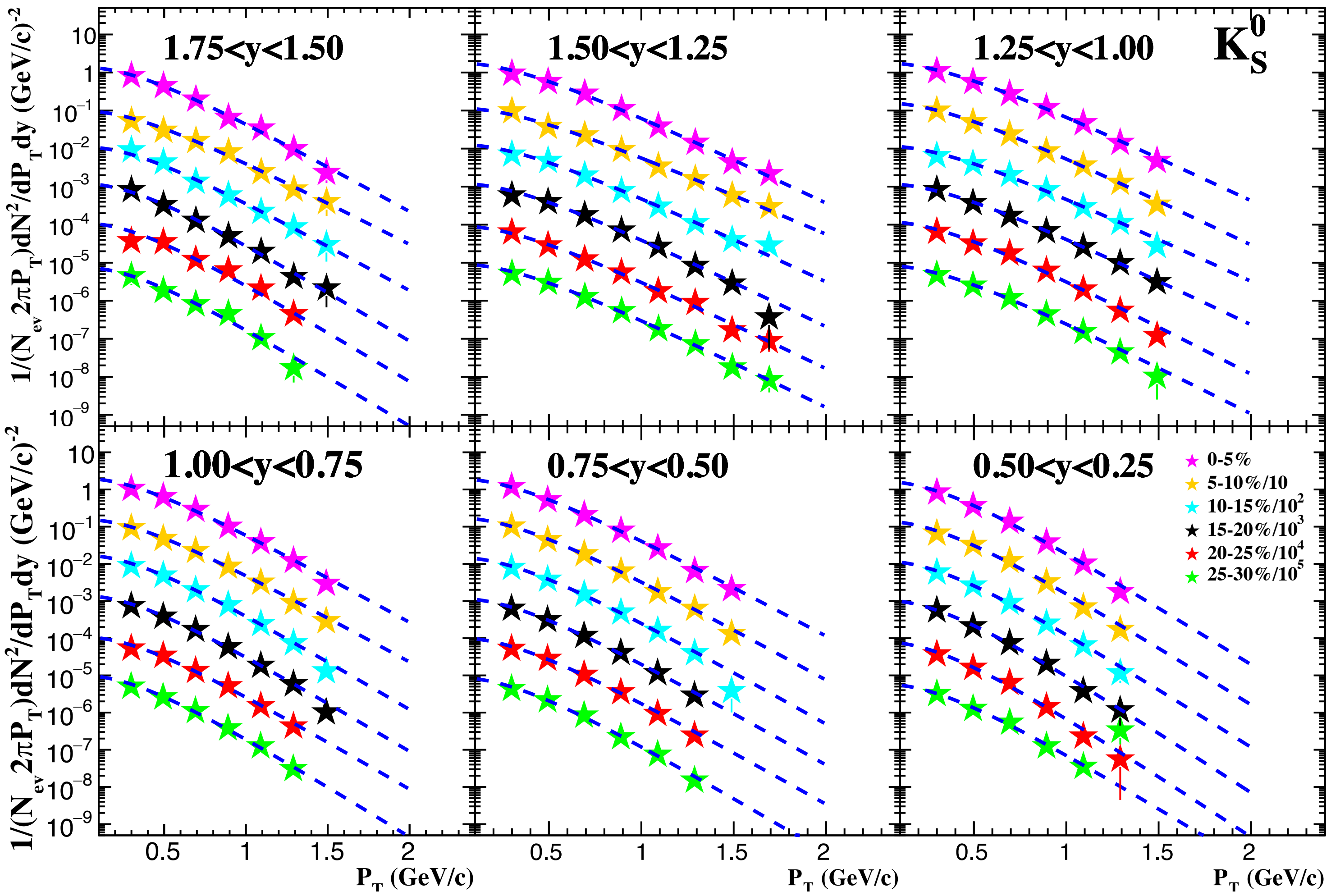
Proton Spectra



- ✓ *$m_T - m_0$ range up to 1 GeV/c²*

- ✓ *Proton spectra for different rapidity bins and different centralities scaled by the factor of $5^{\pm n}$.*
- ✓ *Proton data is extrapolated to low $m_T - m_0$ with the thermal fitting function.*
- ✓ *Systematic uncertainties are included.*

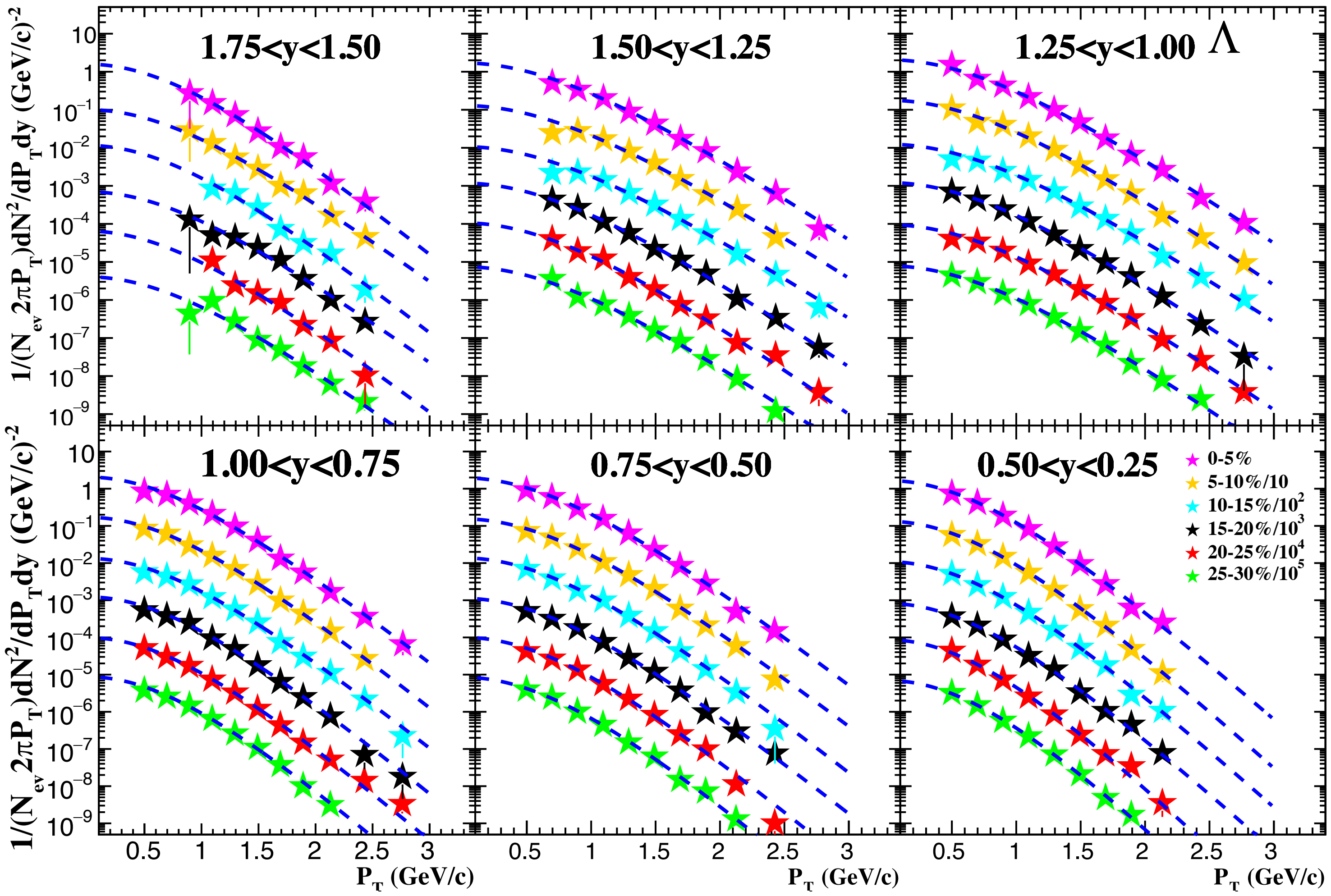
K_S^0 Spectra



- ✓ P_T range upto 1.5 GeV/c

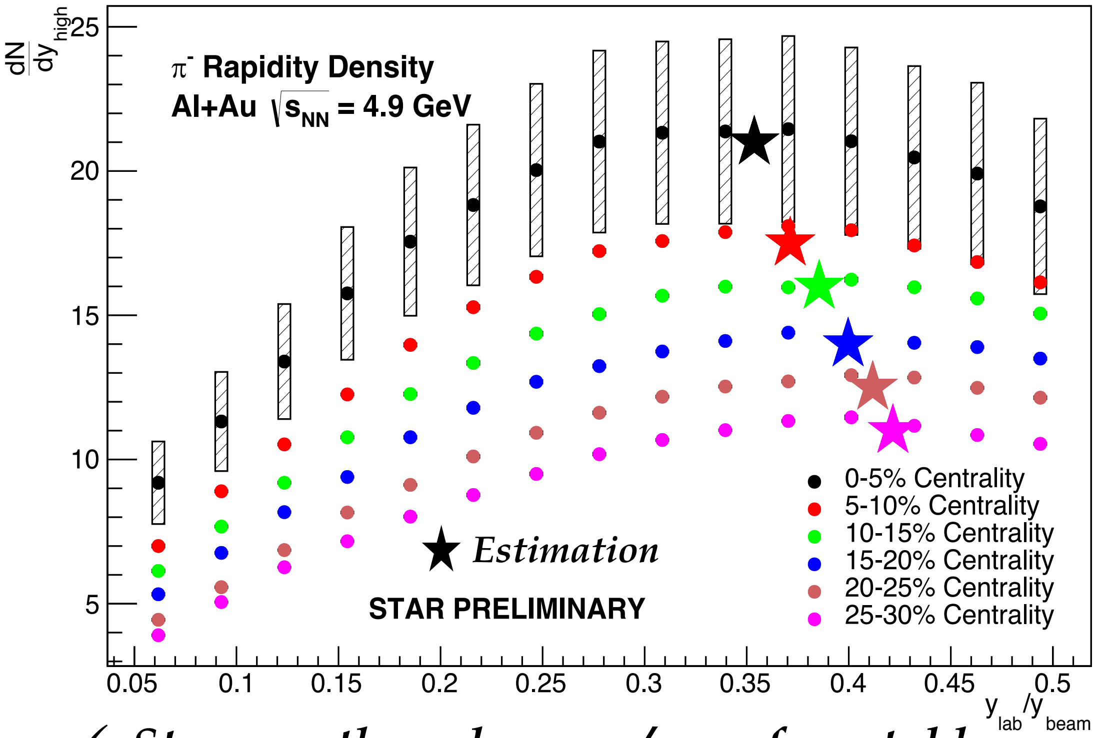
- ✓ *K_S^0 spectra for different rapidity ranges and different centralities scaled by the factor of 10.*
- ✓ *K_S^0 data is extrapolated to low and high P_T with the exponential fitting function.*
- ✓ *Systematic uncertainties are included.*

Λ Spectra



- ✓ *Λ spectra for different rapidity ranges and different centralities scaled by the factor of 10.*
- ✓ *Λ data are extrapolated to low and high P_T with the Boltzmann fitting function.*
- ✓ *Systematic uncertainties are included.*
- ✓ *P_T range upto 2.5 GeV/c*

π^- dN/dy Distributions



- ✓ *Stars are the values y_{lab}/y_{beam} from table*

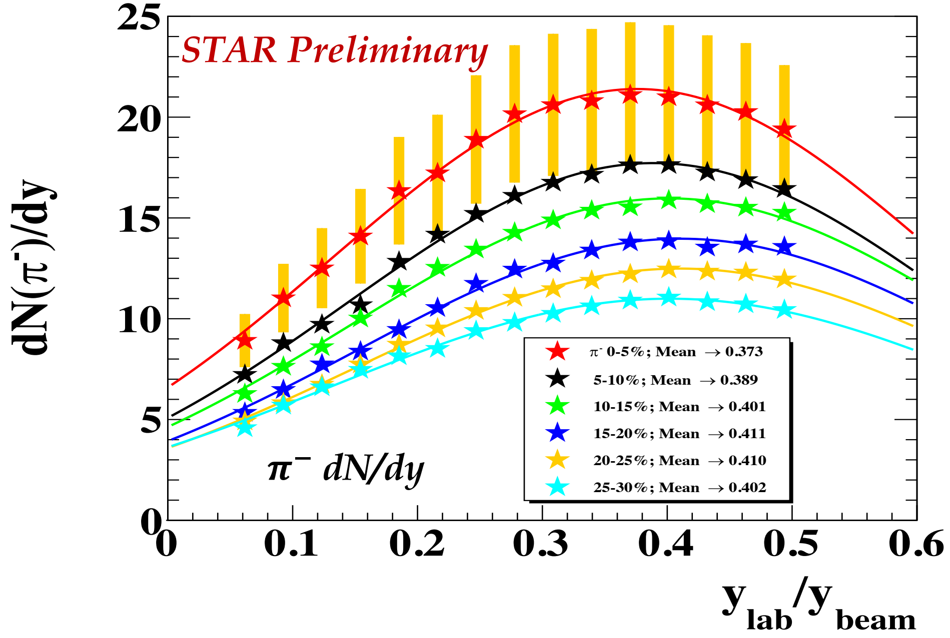
$$y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$
$$p_z = \langle N_{part}\rangle^{Al}\, p_z^{beam}$$
$$E = \langle N_{part}\rangle^{Al}\, E^{beam} + \langle N_{part}\rangle^{Au}\, m_{nucleon}$$

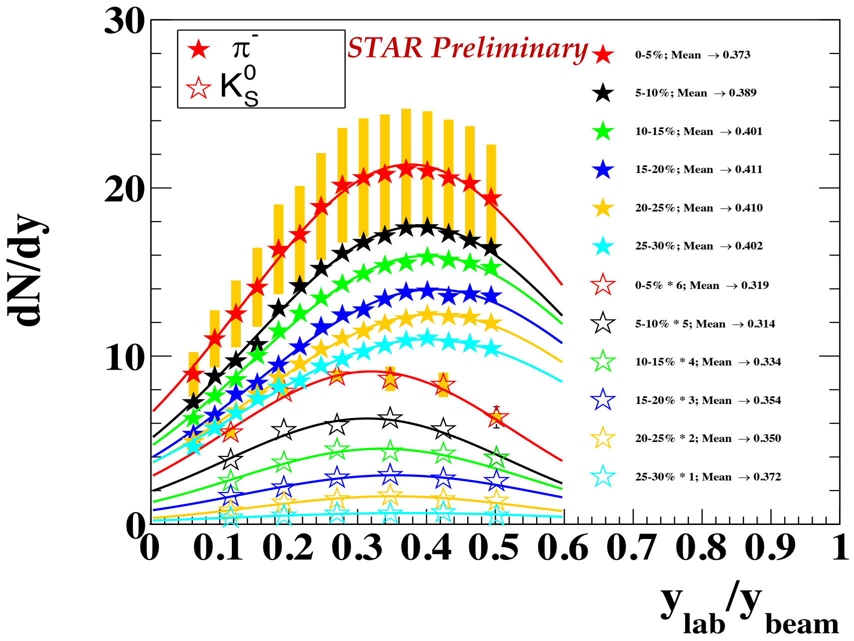
$$m_{nucleon} = 931.5\text{MeV}$$
$$p_z^{beam} = 11.69\text{GeV}$$
$$E^{beam} = 11.73GeV$$

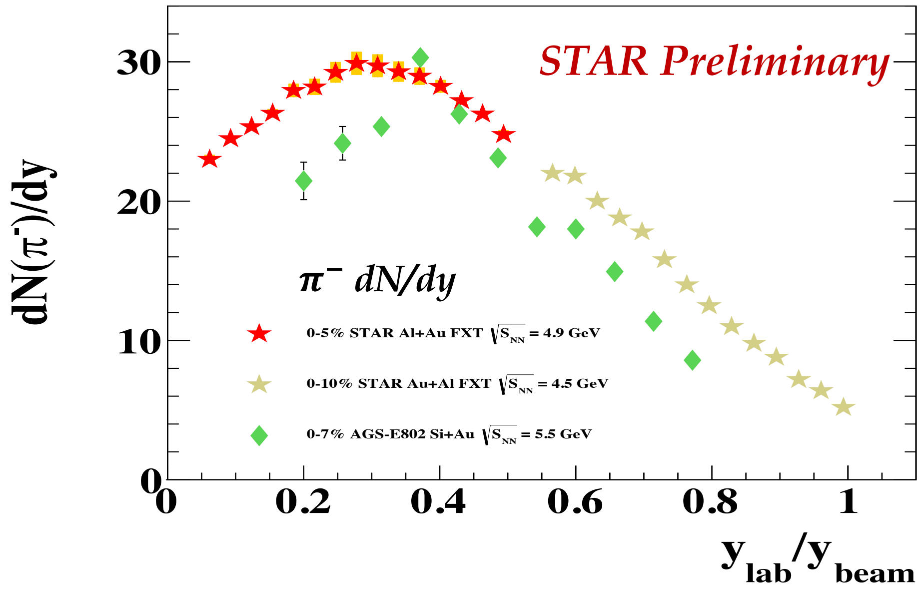
- ✓ *π^- are produced by a source travelling with the rapidity of the interaction zone.*
- ✓ *The peak of π^- is shifted towards the interaction zone rapidity*

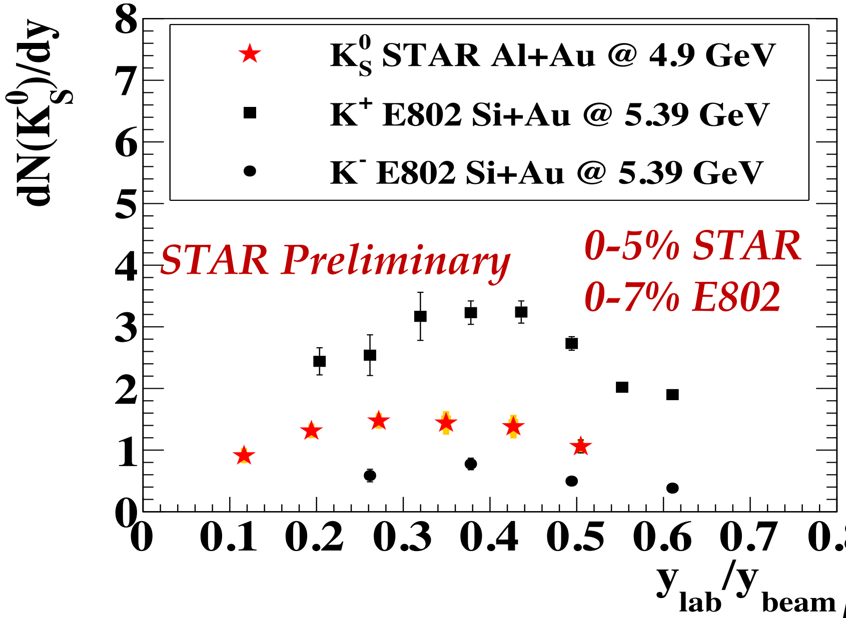
Centrality (%)	Y_{lab}/y_{beam}	$\langle N_{part}\rangle$	$\langle N_{part}\rangle^{Al}$	$\langle N_{part}\rangle^{Au}$
0-5	0.354	100.3	26.51	73.78
5-10	0.371	89.28	25.89	63.39
10-15	0.389	80.01	24.92	55.09
15-20	0.400	70.20	23.43	46.77
20-25	0.412	61.16	21.59	39.57
25-30	0.422	53.13	19.62	33.51

Meson dN/dy Distributions



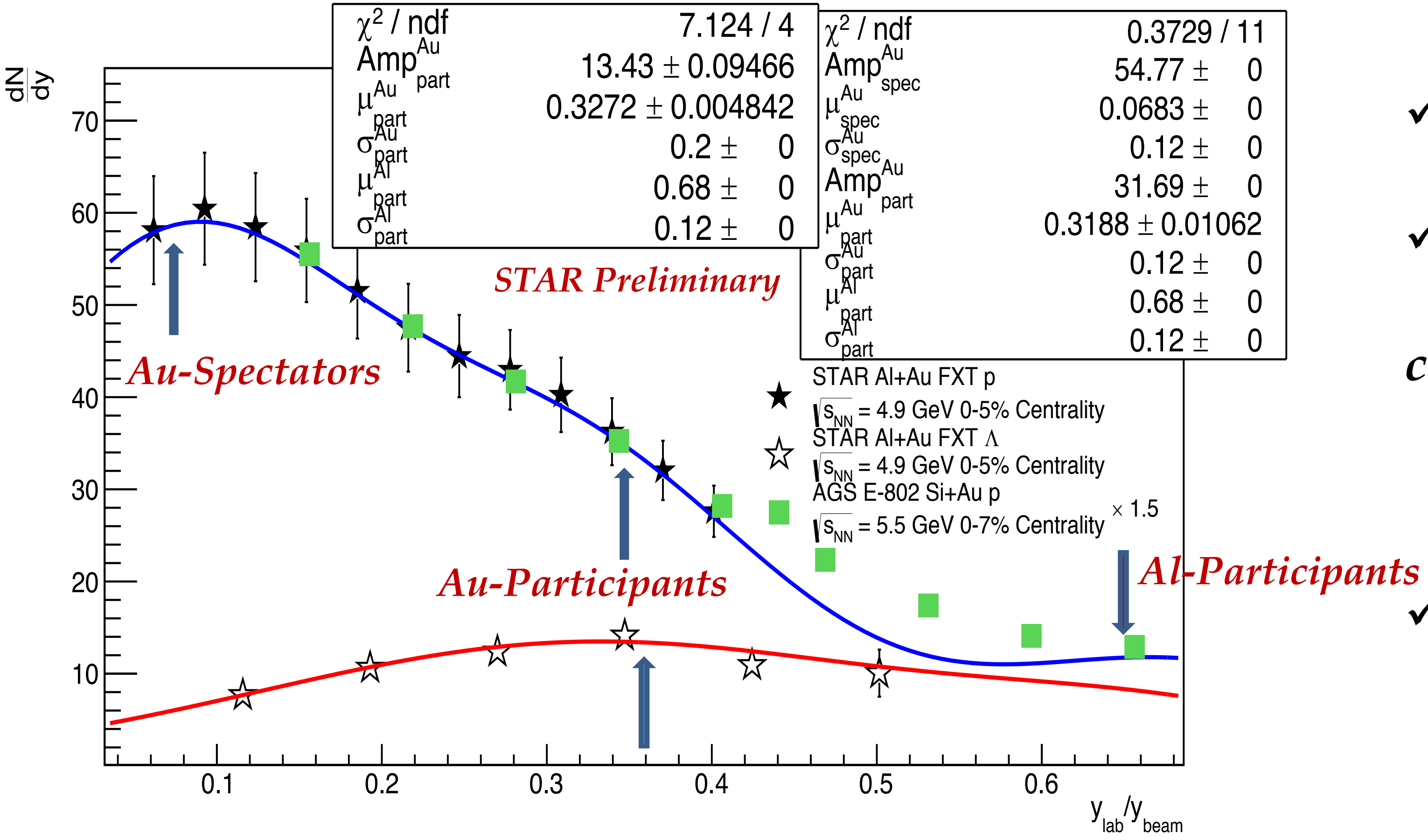






- ✓ *π^- and K_S^0 peak are shifted towards the interaction zone rapidity.*
- ✓ *K_S^0 dN/dy distributions are scaled for better visualization.*
- ✓ *Significant difference, in the π^- dN/dy with AGS-E802 experiment, however when scaled, shapes are the same.*
- ✓ *0-5% π^- and K_S^0 has the Systematic uncertainties.*

Baryon dN/dy Distributions



- ✓ *Definition of Stopping is:*

  $\delta_y = y_{beam} - y_{peak}$

- ✓ *For Au-Spectators y_{beam} = 0, and*

  $\delta_y = y_{peak}$

- ✓ *For Au-Participants*

  $y_{peak}/y_{beam} = 0.32$

  converting this back to the lab rapidity,

  $\delta_y = 0.32 * 3.24 = 1.03$ *(Proton)*

  $\delta_y = 0.33 * 3.24 = 1.06$ *(Λ)*

- ✓ *For Al-Participants y_{peak}/y_{beam} = 0.6886*

  $\delta_y = y_{beam} - y_{peak}$

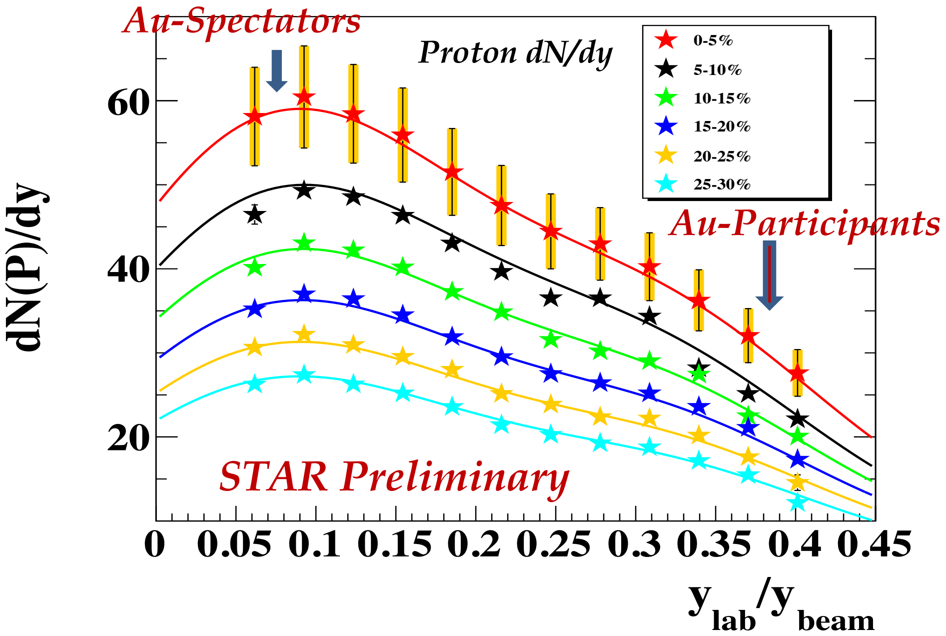
  $\delta_y = 1 - 0.6886 = 0.3114$

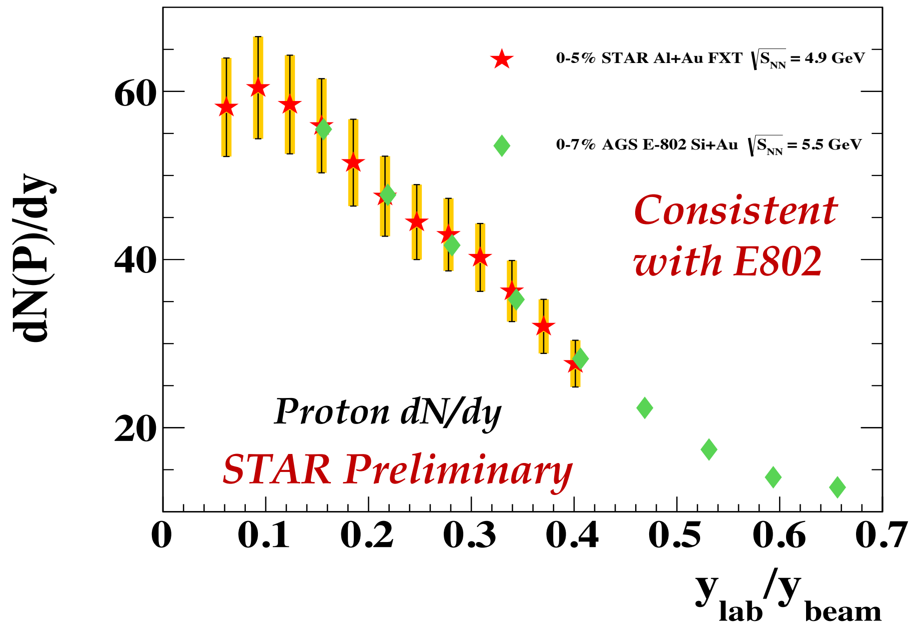
  converting this back to lab rapidity,

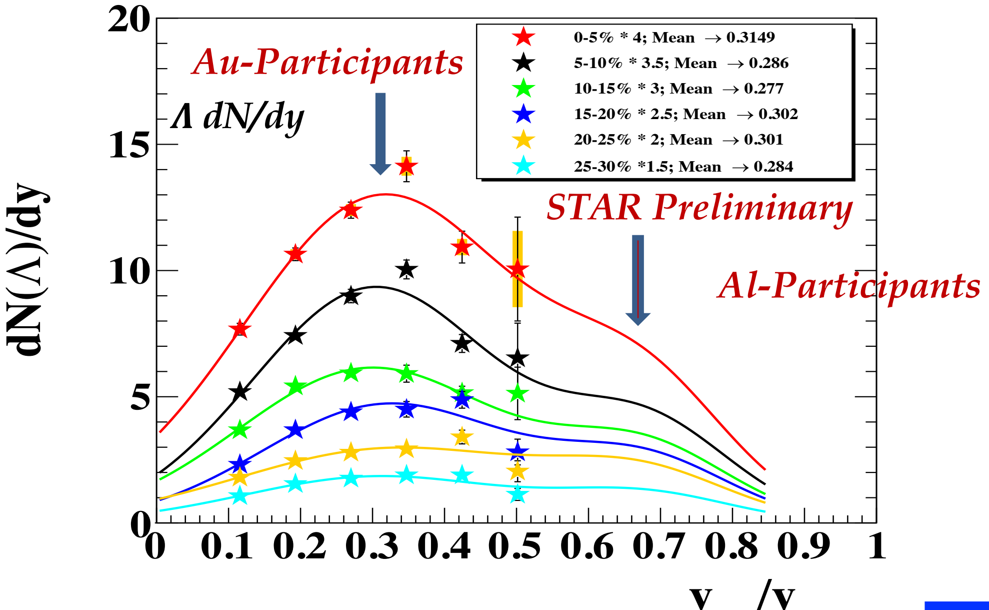
  $\delta_y = 0.3114 * 3.24 = 1.01$

- ✓ *Systematic uncertainty, added up in quadrature with statistical Error for protons and Λ.*
- ✓ *No systematic error for AGS-E802 data points.*

Baryon dN/dy Distributions

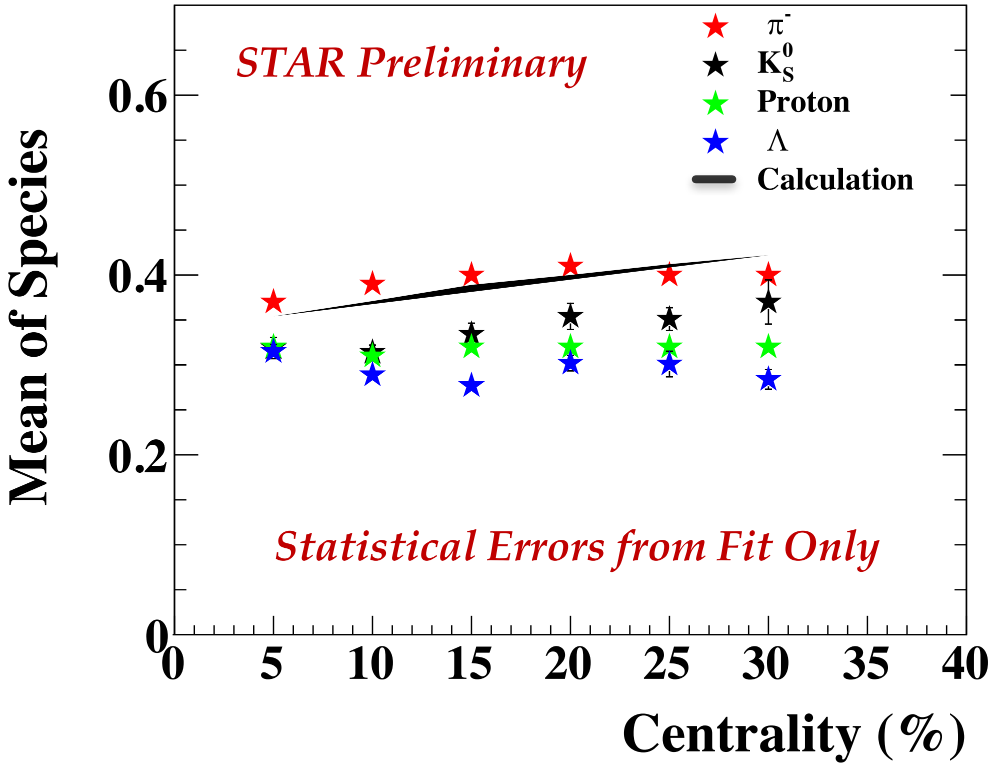






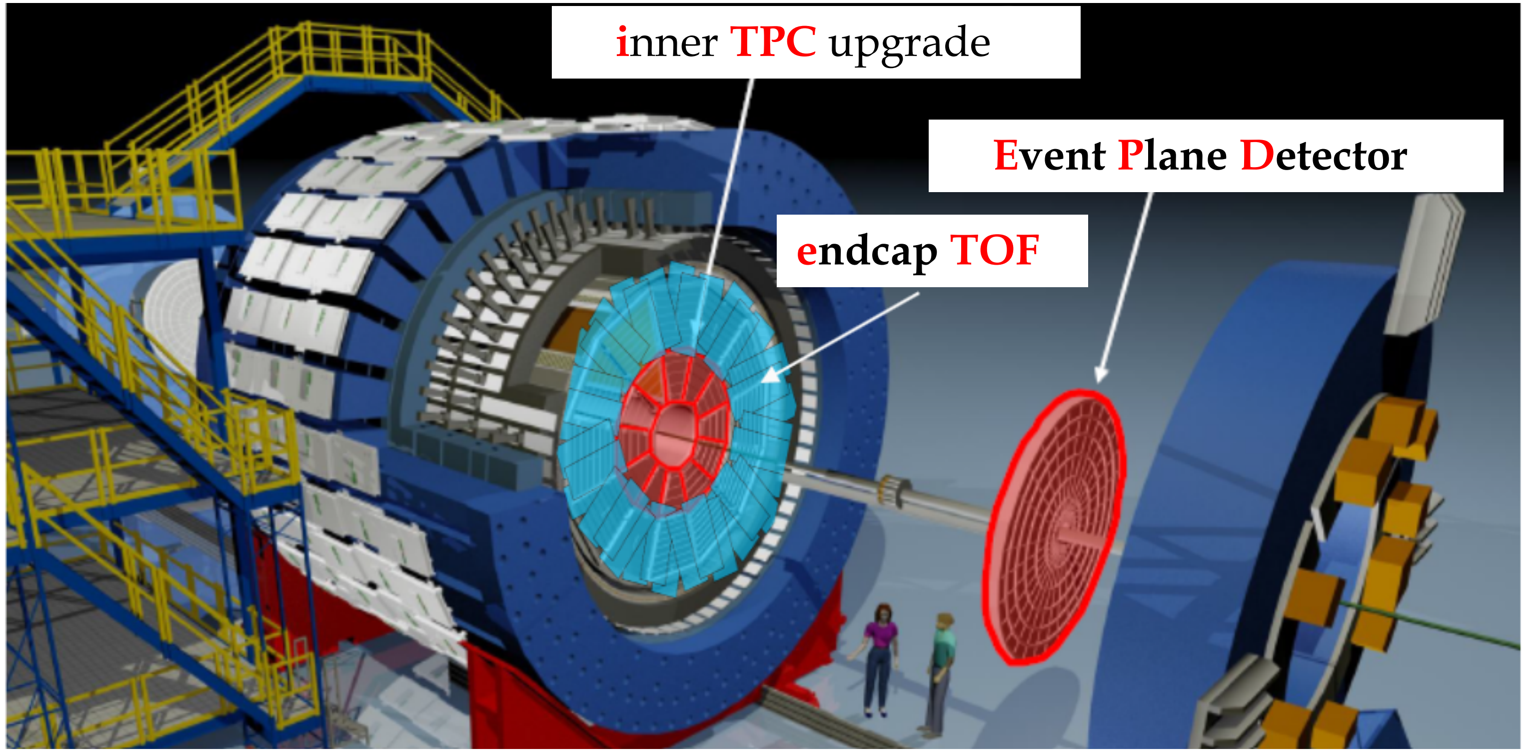
- ✓ *0-5% proton has systematic uncertainty, added up in quadrature with statistical error.*
- ✓ *Double Gaussian is used to fit Λ and proton dN/dy distributions.*
- ✓ *For protons Au-Participant peak is observed around 0.329*
- ✓ *For Λ, Au-Participant peak is observed around 0.314*
- ✓ *Λ peak is about 0.1 units less than for protons.*
- ✓ *0-5% Λ dN/dy distributions has systematic uncertainty.*

Summary Plot



- ✓ *The trend of the peaks of the* K_S^0 *and* π^- *dN/dy distributions are same, but the peak of* K_S^0 *is shifted toward the target by roughly 0.2 unity of rapidity.*
- ✓ *The proton dN/dy show both target and the interaction zone components. The Interaction zone component was used to estimate the stopping "δy" of the gold nucleons to be about 1.0*
- ✓ *The peak of the Λ dN/dy is consistent to the protons.*

The STAR Upgrades and the FXT program



iTPC Upgrade:

- ✓ Improved dE/dx resolution
- ✓ Better momentum resolution
- ✓ Extends η coverage from 1.0 to 1.5
- ✓ p_T >60 MeV/c
- ✓ Ready in 2019

EndCap TOF Upgrade:

- ✓ Mid-rapidity coverage is critical
- ✓ Needed for PID at mid-rapidity
- ✓ **$-1.6<\eta<-1.1$**
- ✓ Allows higher energy range of FXT program
- ✓ Ready in 2019

EPD Upgrade:

- ✓ Better trigger
- ✓ Reduces background
- ✓ Improves event plane resolution
- ✓ **$2.1<|\eta|<5.1$**
- ✓ Ready in 2018

Star Note 0644 : Technical Design Report for the iTPC Upgrade

https://arxiv.org/pdf/1609.05102.pdf

Star Note 0666 : An Event Plane Detector for STAR

Summary

- ✓*Centroids of the high temperature component of the* π^- *yield is consistent with the interaction zone rapidity.*
- ✓*The peak of the* K_S^0 *dN/dy distributions follows* π^-*, but is shifted toward the target by roughly 0.2 unit of rapidity.*
- ✓*The proton dN/dy distributions show both target and the interaction zone components. The Interaction zone component was used to estimate the stopping "δy" of the gold nucleons to be about 1.0 units.*
- ✓*The peak of the Λ dN/dy is consistent to the protons.*
- ✓*FXT program proposed during RHIC BES-II will extend the energy down to* $\sqrt{s_{NN}}$ *= 3.0 GeV (*μ_B*=720 MeV).*
- ✓*iTPC, eTOF and EPD upgrades will allow more comprehensive and refined measurements.*

Thank You!