A Fixed Target Program for STAR: Completing the Beam Energy Scan

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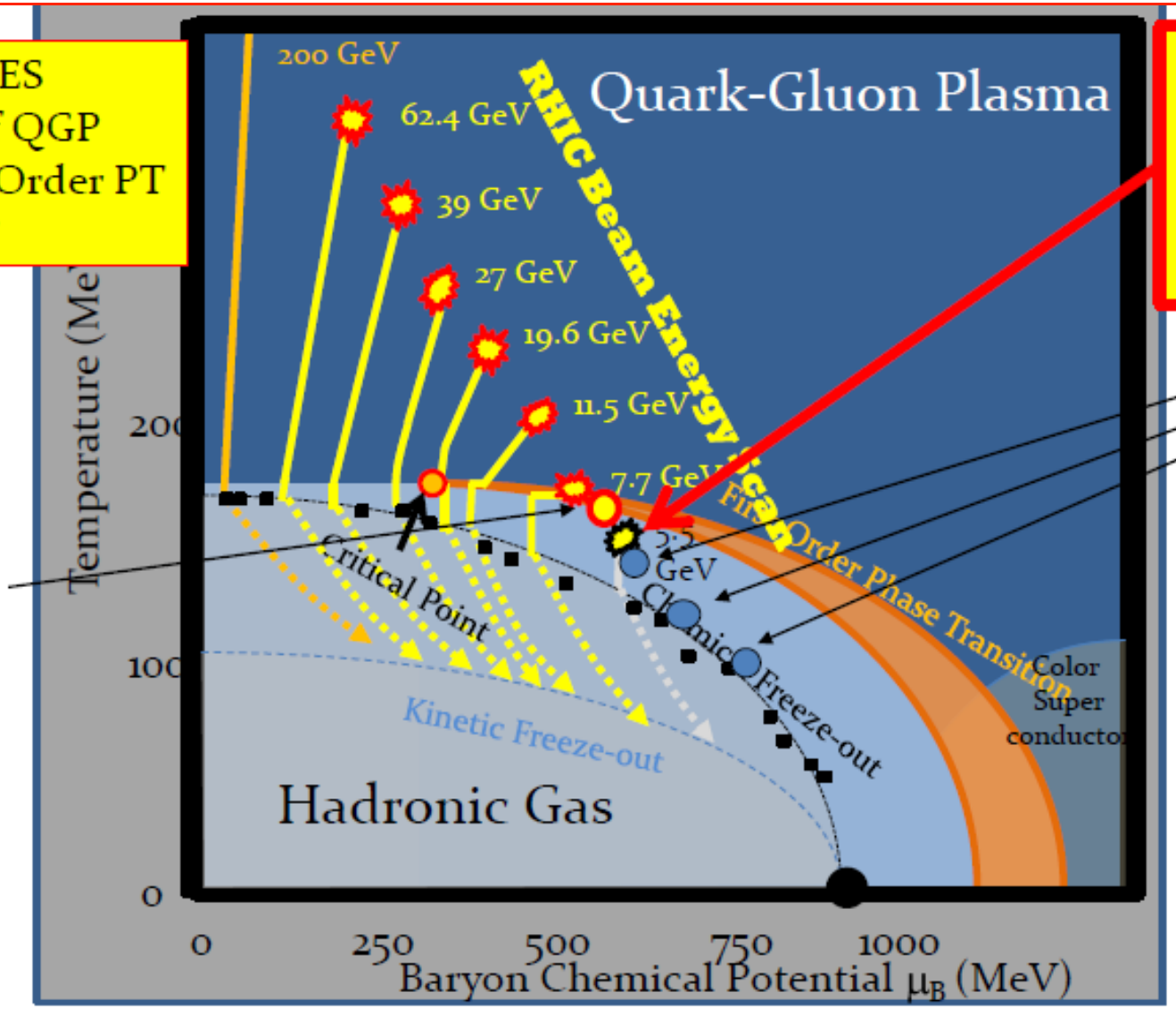
Motivation:

Using collisions of beam ions with nuclei in a gold target inside the beam-pipe allows us to analyze fixed-target interactions with the STAR detector. This provides lower energy collisions to be studied, which will allow us to extend the low energy (high baryon chemical potential) reach of the RHIC Beam Energy Scan.

The Search for the Critical Point

Goals For BES
1) Turn off QGP
2) Find 1st Order PT
3) Find CP



There is still one BES energy that we have not completed.
5 GeV!

Fixed Target points

What if the critical point is here?

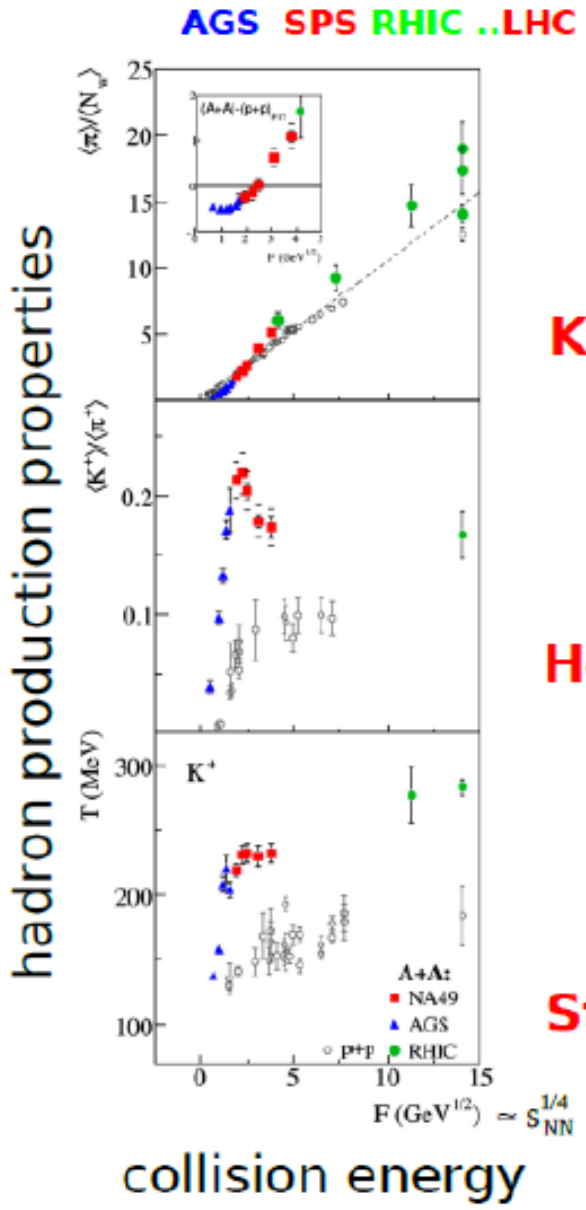
Is the 5 GeV Point Important?

NA49 has completed a beam energy scan. There have claimed to see signatures of the onset of deconfinement at 7.7 GeV. The STAR BES program was designed to check this result. Key to this ability to confirm or falsify this claim is taking data both above and below the reported transition line.

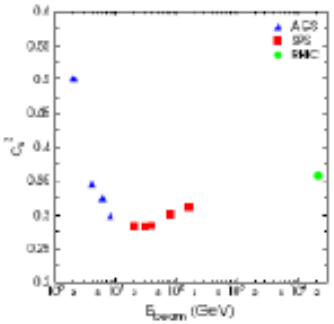
The 5 GeV energy point is needed to to study matter below the proported transition line.

Onset of Deconfinement:
early stage hits transition line,
observed signals: kink, horn, step

Predictions SMES: *Results:*
APP B30 2705 (99), PR C77 024903 (08)



the dale
sound velocity from
width of pion rapidity spectra
nucl-th/0611001



5 GeV in Collider Mode

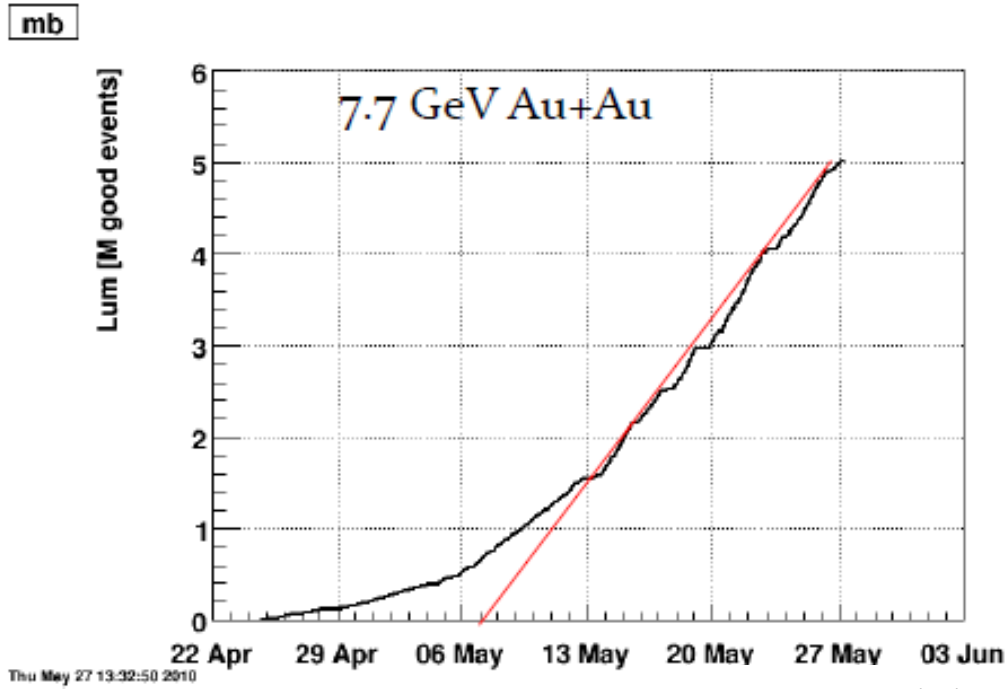
We tried to run 5.5 GeV and failed. Although Christoph Montag thinks that he knows why RHIC could not circulate beams.

However, remember that the event rate is expected to go at $1/\gamma^3$.

In order to get 5 M events at 5 GeV, we will need about 75 days (maybe we can do it in two months. But that is still a lot of beam team).

20 days x $(5.0/7.7)^{-3}$ = 73 days

For a large investment of accelerator time for a 5 GeV run, we have a high burden of proof. We will need to build a strong data-driven case for the 2012 PAC.



The Fermilab Pelletron

The Pelletron is a 3 M$, 3-story, 6MV Van der Graaf generator, electron accelerator, and recycler all in one. The electron beam generated by the Pelletron has been used for electron cooling of the antiprotons in the Recycler and has resulted in a increase in Luminosity at the Tevatron of a factor of two.

This surplus Pelletron could be moved to BNL and installed for about 1 M$.

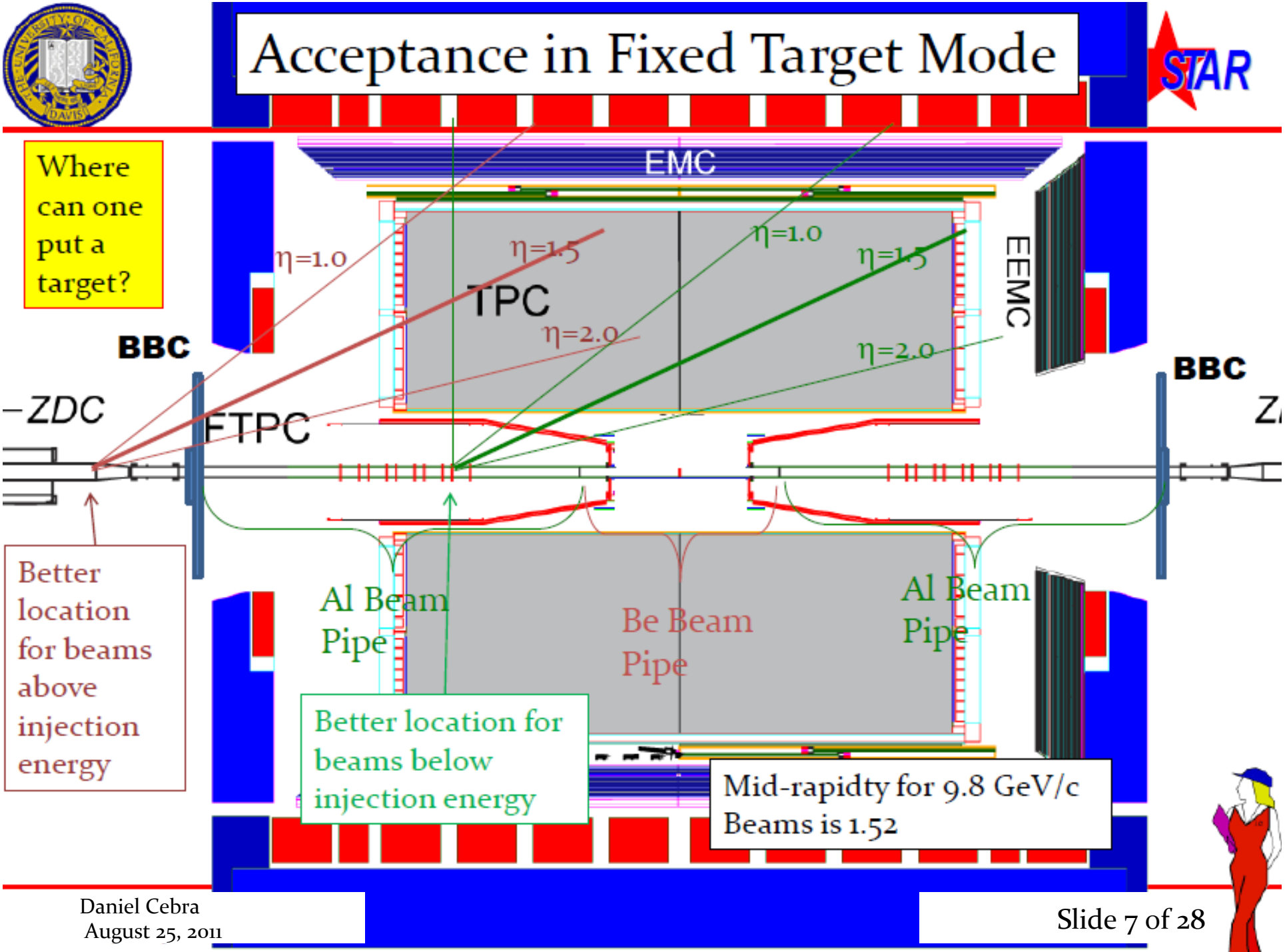
For stable operations, you can not go above 5MV electrons, which can cool ion beams up to injection energy. Expected improvements:

15-20 GeV: factor of **10**
11-16 GeV: factor of **6**
7-11 GeV: factor of **2-6**
Below 7 GeV: maybe **2-6**

Low Energy Reach of Fixed Target

Collision Energy (GeV)	Single Beam Energy	Single Beam Pz (GeV/c)	Fixed Target Root S	Single Beam Rapidity	Center of Mass Rapidity
200	100	99.995	**13.71**	5.37	*2.69*
62.4	31.2	31.19	**7.74**	4.20	*2.10*
39	19.5	19.48	**6.17**	3.73	*1.87*
27	13.5	13.47	**5.19**	3.37	*1.68*
19.6	9.80	9.76	**4.47**	3.04	**1.52**
11.5	5.75	5.67	**3.53**	2.51	**1.25**
7.7	3.85	3.73	**2.98**	2.10	**1.05**
5.5	2.75	2.59	**2.62**	1.75	**0.87**

Acceptance in Fixed Target Mode



Specific Proposal

- During this summer shutdown, disconnect the beam pipe at the 4 meter bellows and install an annular gold target at z=2m. (Beam pipe will be open from September 1st to October 21st.)

- Develop a fixed target trigger configuration.

- During Au+Au running in Run 11, take fixed target data at injection energy with a special fixed target trigger.

The Beam Pipe

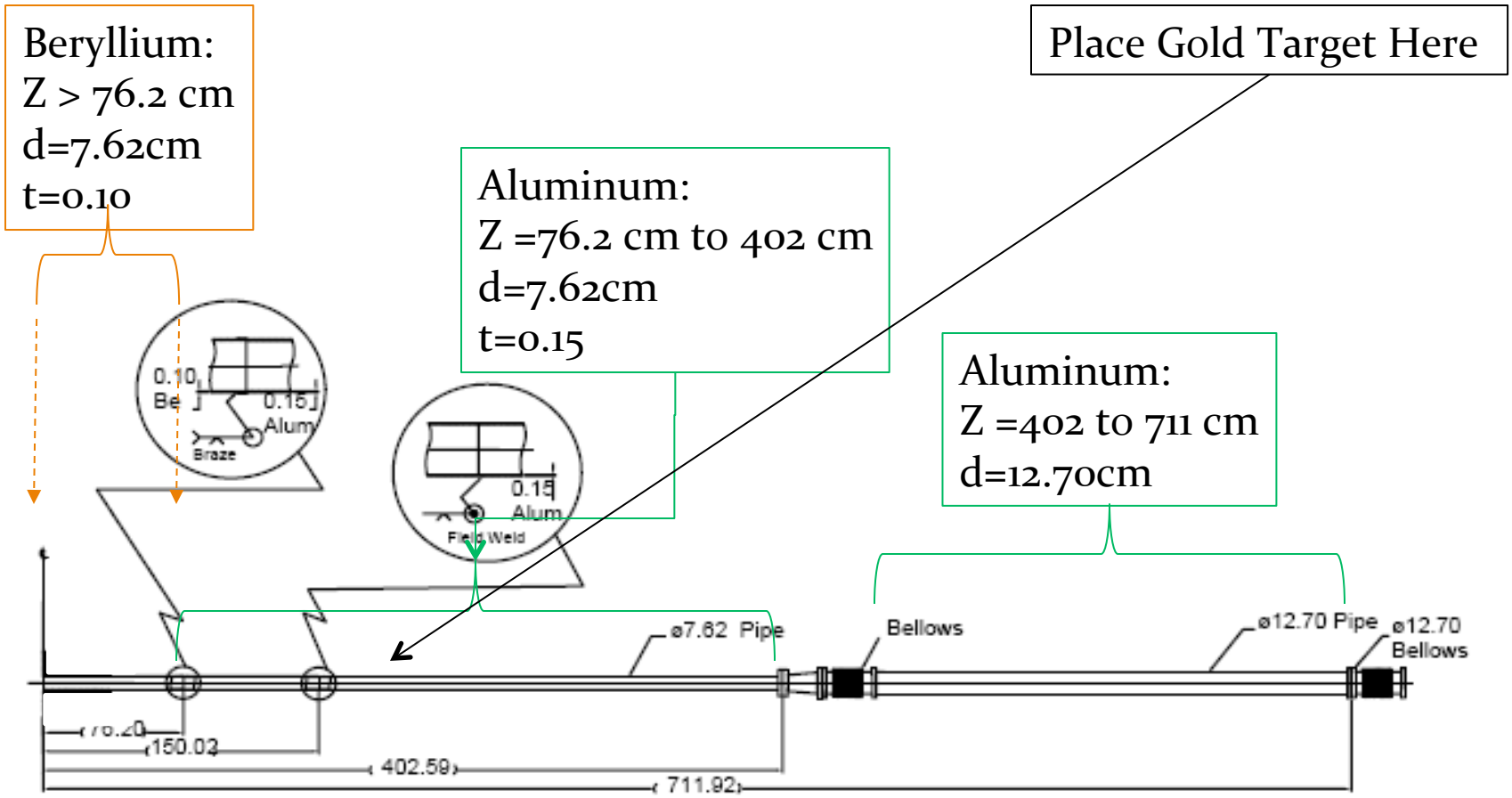


Fig. 6. Half-section of the STAR beam pipe. The envelope of the SVT is drawn to show where the transition from beryllium to aluminum occurs. All units are in cm. The beam pipe is supported by the SVT and by a magnet adjacent to the end bellows.

Gold Target

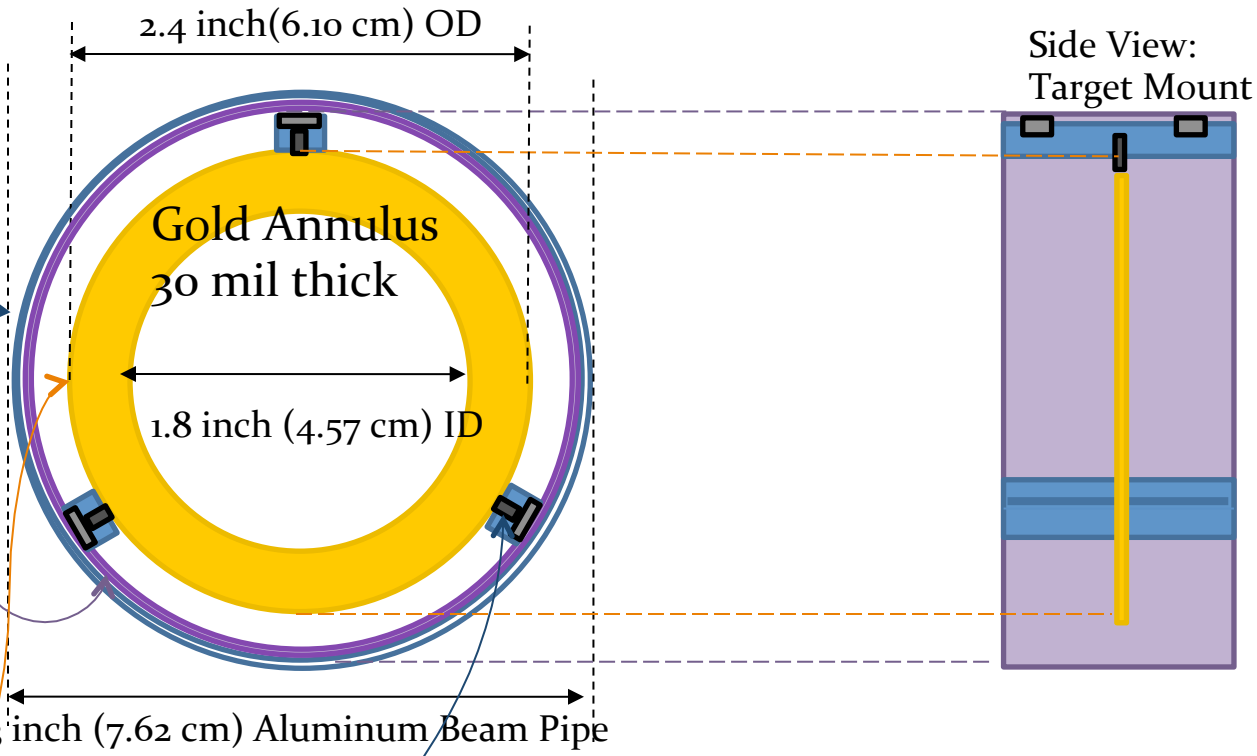
Diagram is 1:1 Scale

Beam Pipe:
Aluminum
OD: 3" (7.62 cm)
Thickness: 60 mil (1.5 mm)
ID: 3.88" (7.47cm)

Target Mount Sleeve:
Aluminum
OD: 3.8" (9.65 cm)
Thickness: 60 mil (1.5 mm)
ID: 3.68" (9.35 cm)
Length: 1.2 " (3.04 cm)

Target Sheet:
Gold
OD: 2.4" (6.10 cm)
Thickness: 30 mil (0.8 mm)
ID: 1.8" (4.57cm)

Mounting Bars:
Aluminum with steel set screws and springs
1.2 " x 0.3" x 0.2"



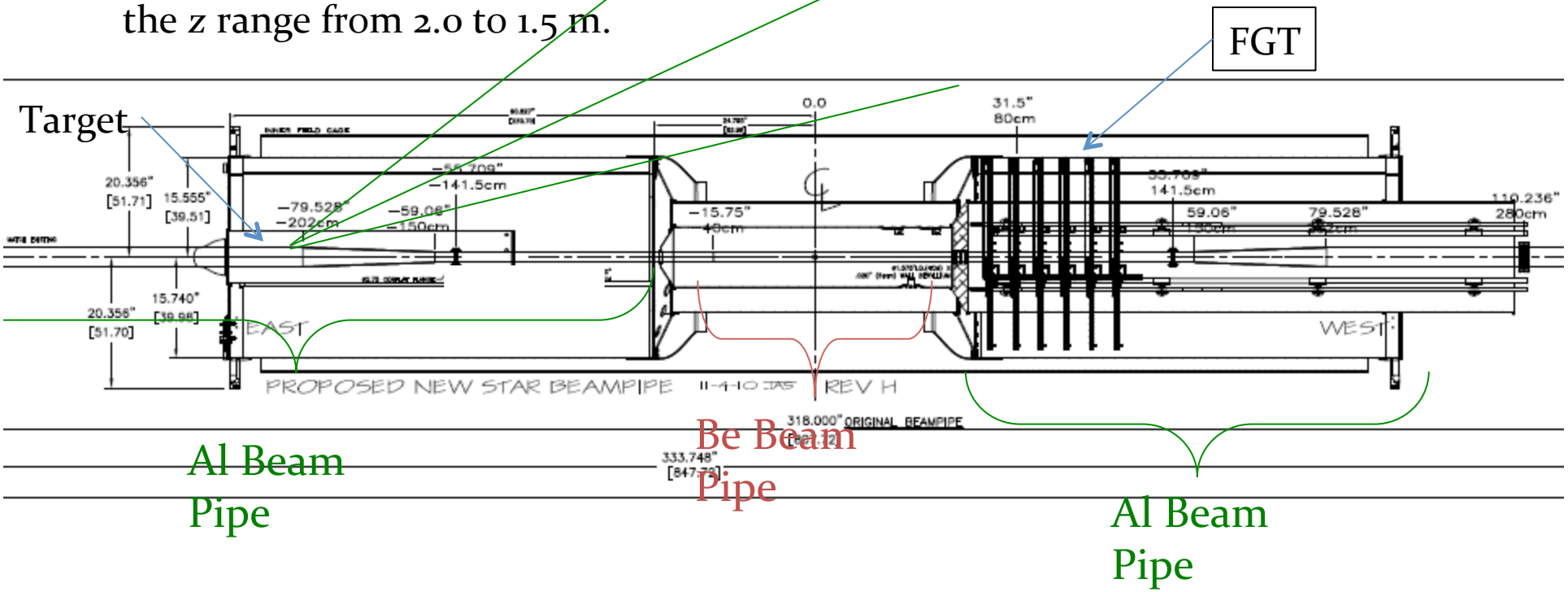
This is a 3% target. Au ions which pass through the target will lose some energy and will then end up somewhere in the ring.

Target mounting sleeve slides inside the beam pipe.

Will We be Buried in Background?

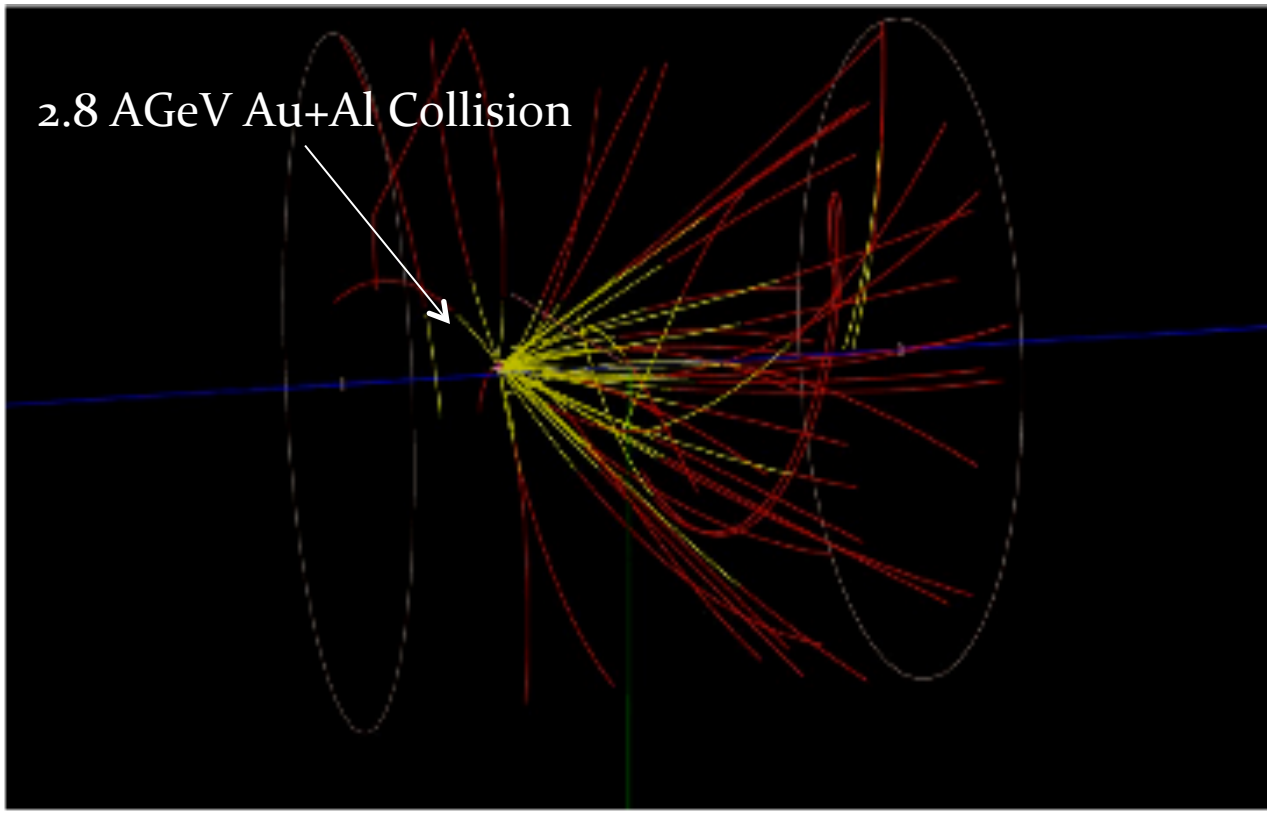
- The quadrupole triplets are the "defining aperature" of the RHIC lattice.
- This is what is going to allow us to change to a new beam pipe next year.

- This pipe will taper down from a diameter of 3" (7.62 cm) to 1.575" (4 cm) in the *z* range from 2.0 to 1.5 m.



What ever background is generated by a 3% Au target will be far worse nest year with the 4cm beampipe.

Can You Do Physics With These Data?



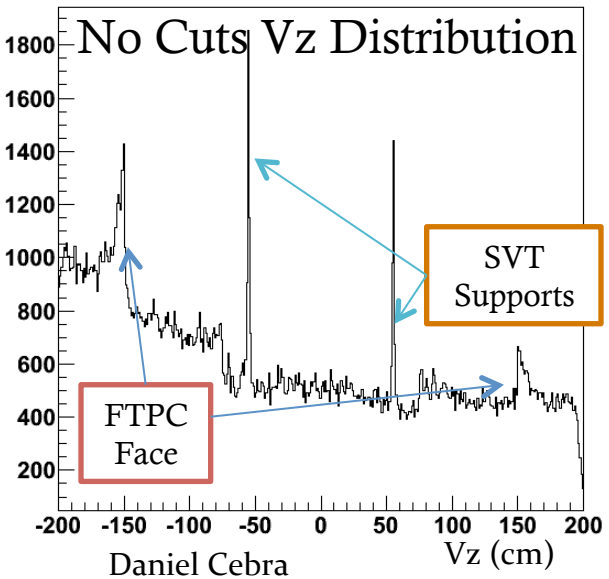
These events are forward focused. The detector was designed for mid-rapidity studies. Do we know how well it will work as a fixed target detector?

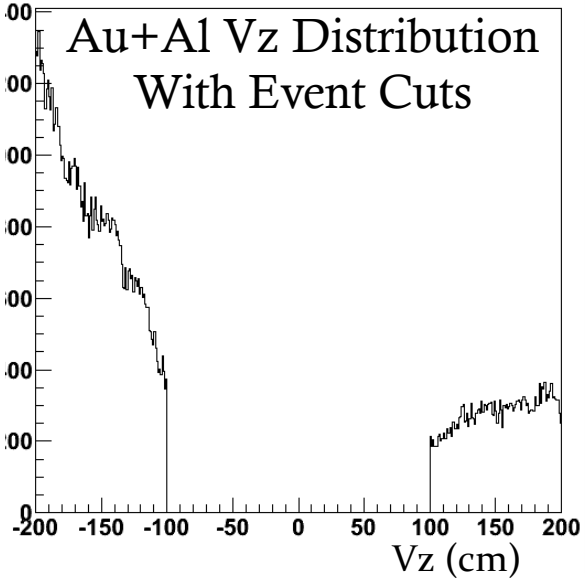
We have been testing just this with Au+Al collisions between beam halo and the beam pipe

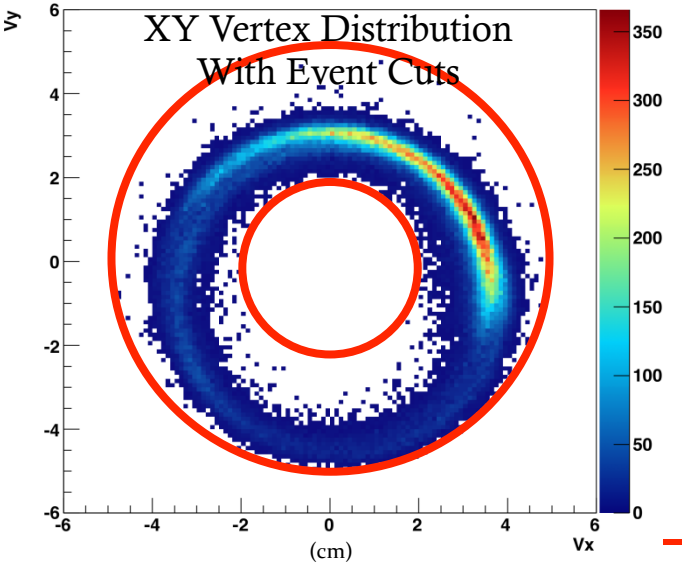
Au+Al Event Selection

Sam Brovko

- Ensure Au+Al collisions
  - Require *z*-vertex position on Al portion of beam pipe via geometric cuts
- Ensure Event is on the beam pipe
  - Require radial vertex position near beam pipe radius
  - Removes vertices on FTPC face and SVT support structures



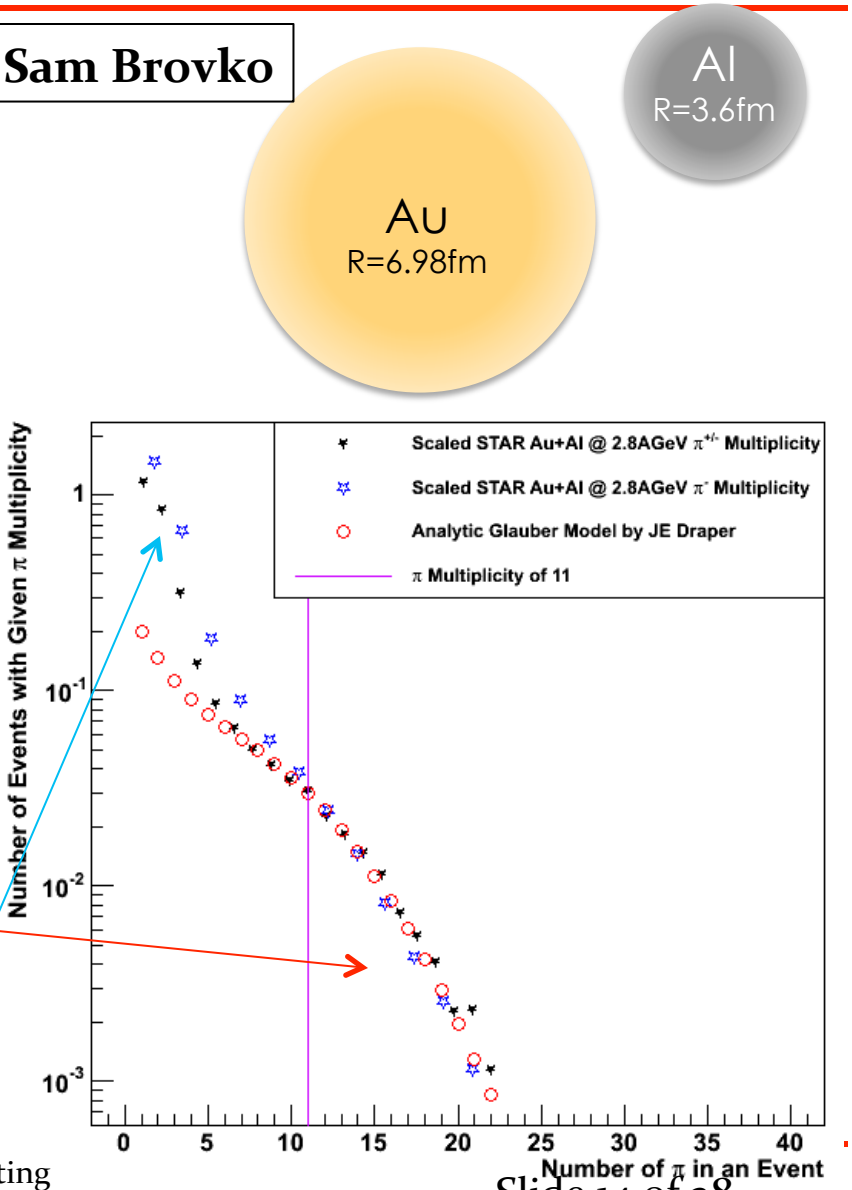




Au+Al 2.8 AGeV – Determining Centrality

Sam Brovko

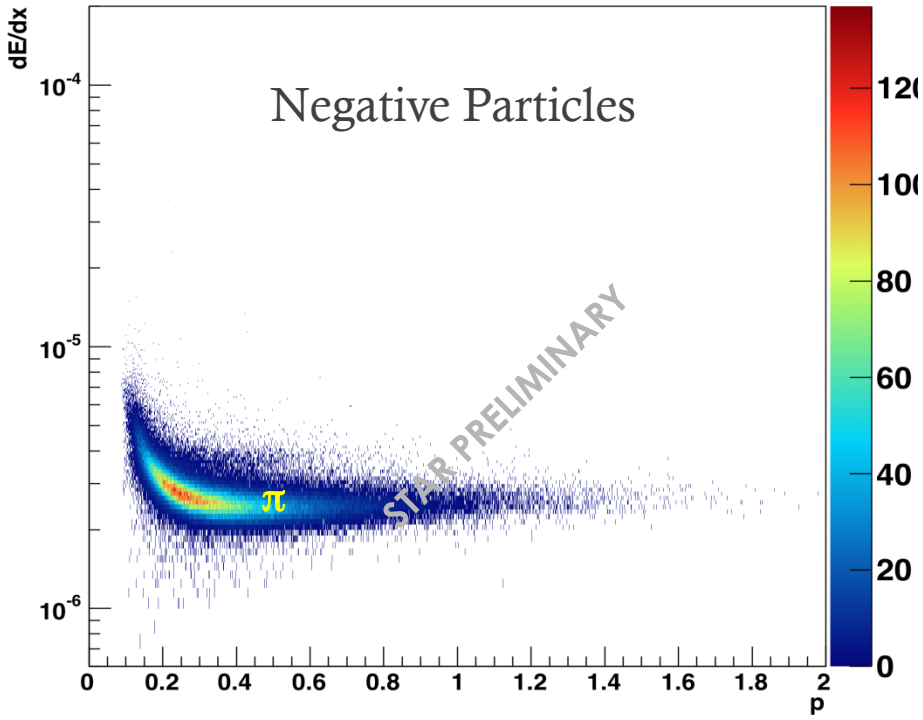
- All Al nucleons can be participants in the collision for a range of impact parameters
- Total Charged Particle Multiplicity is a poor observable for centrality
  - Includes spectators from Al remnant
- Total π multiplicity matches best to Glauber distribution above M_π of 8
- Cut on π multiplicity of 11
  - Top 40% of Au+Al centrality
  - Some events with fewer π are not Au+Al

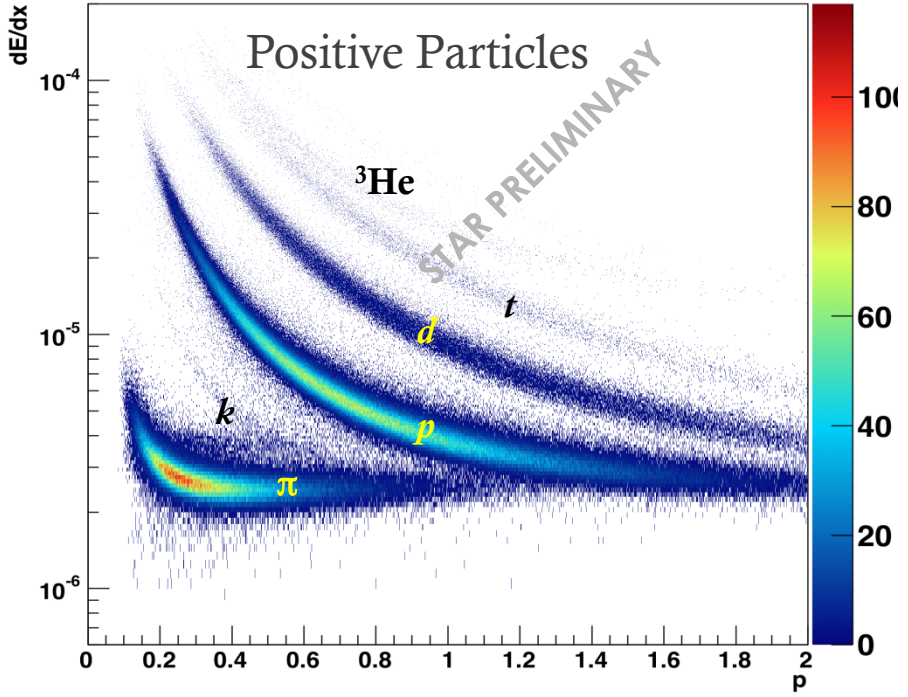


Au+Al 2.8 AGeV – dE/dx for Charged Particles

Sam Brovko

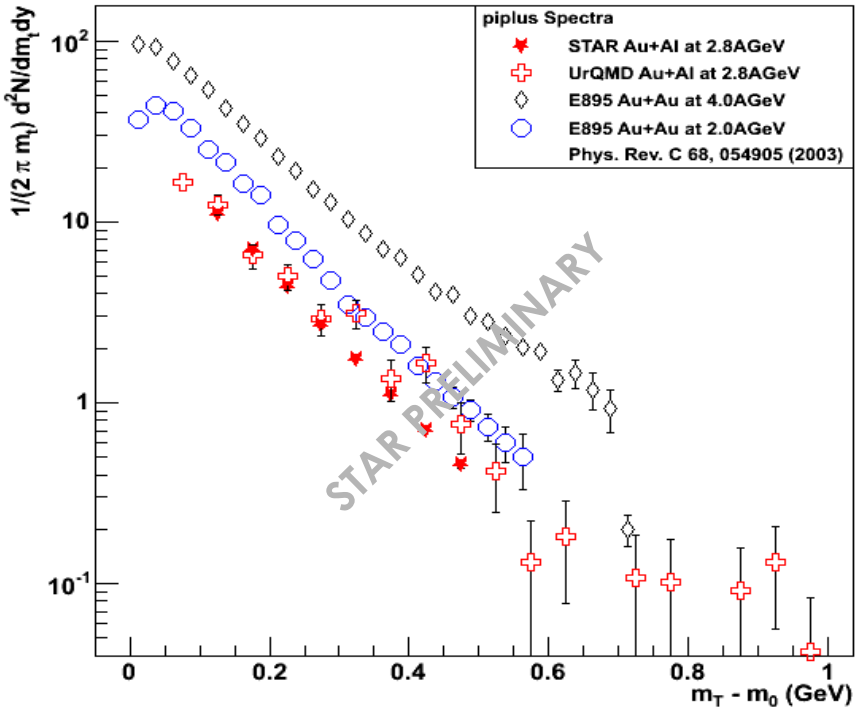
Clean particle identification through dE/dx

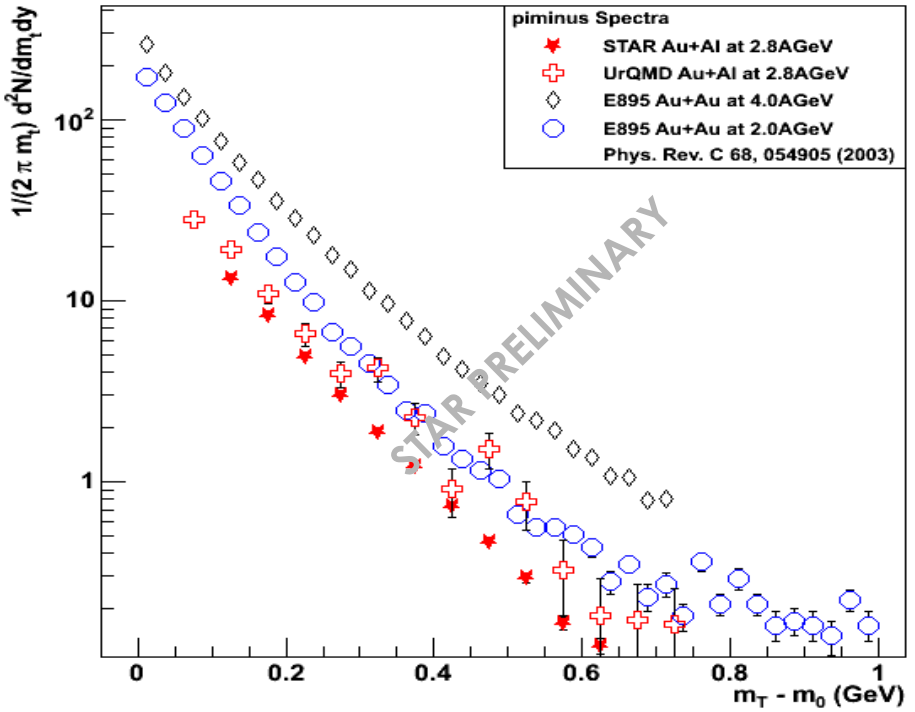




Momentum distribution does not populate overlap regions

2.8 AGeV Au+Al: Spectra π^+ and π^-





- No efficiency or acceptance corrections
  - Currently in progress
- Comparison to UrQMD suggests high efficiency for $\pi^{+/-}$

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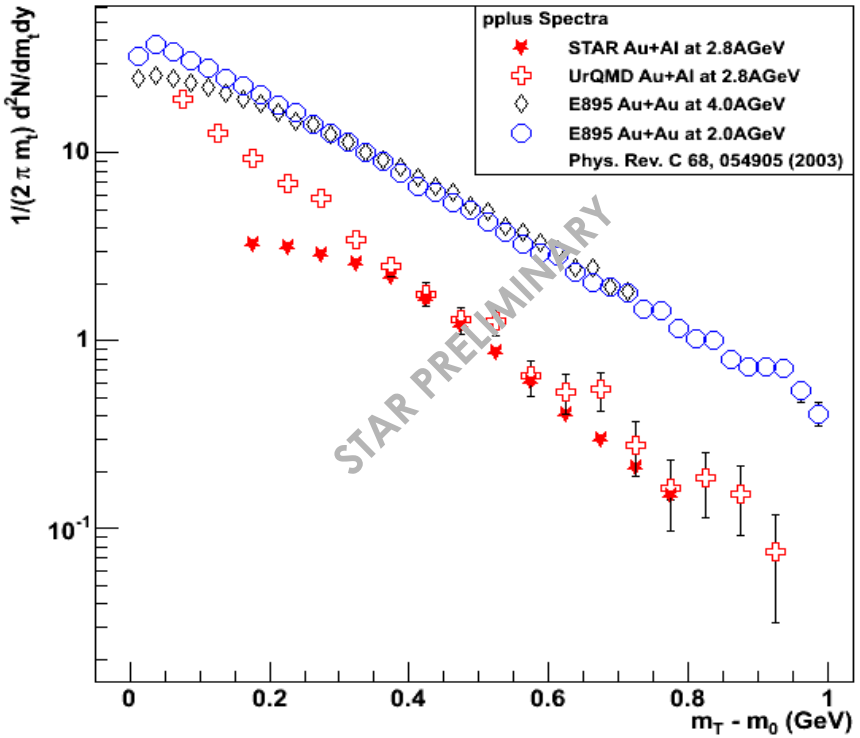
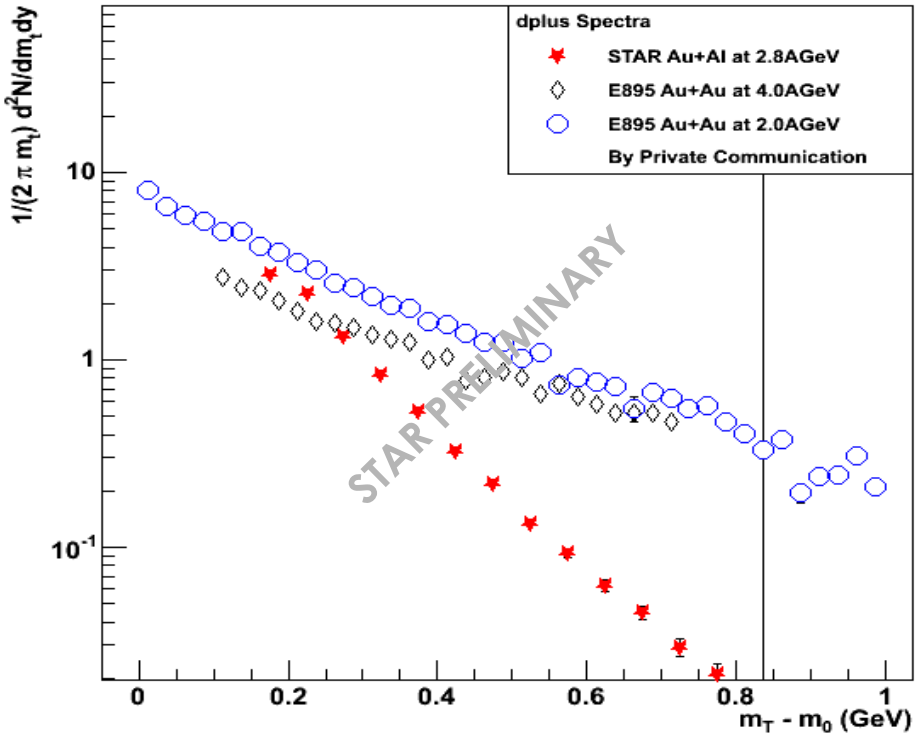
2.8 AGeV Au+Al: Spectra *p* and *d*





- No efficiency or acceptance corrections
  - Currently in progress
- Can see an inefficiency in *p* spectrum at low end

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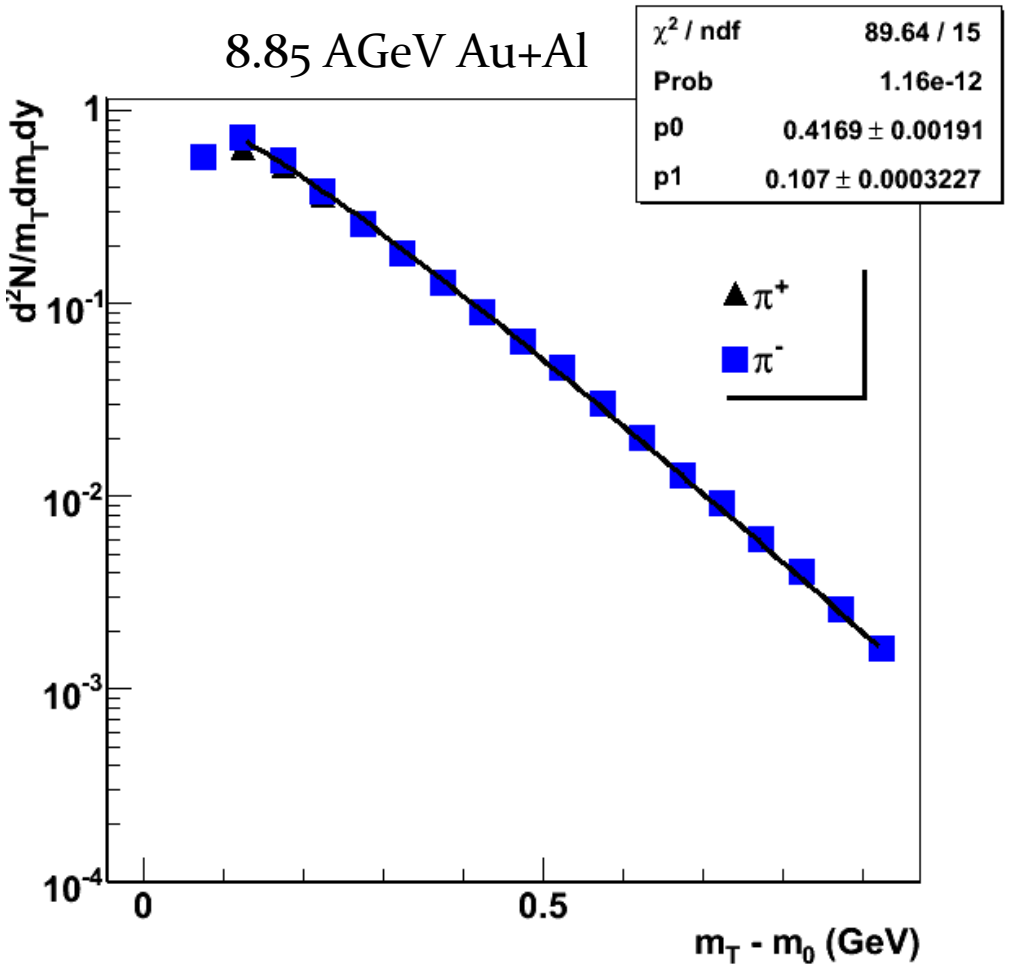
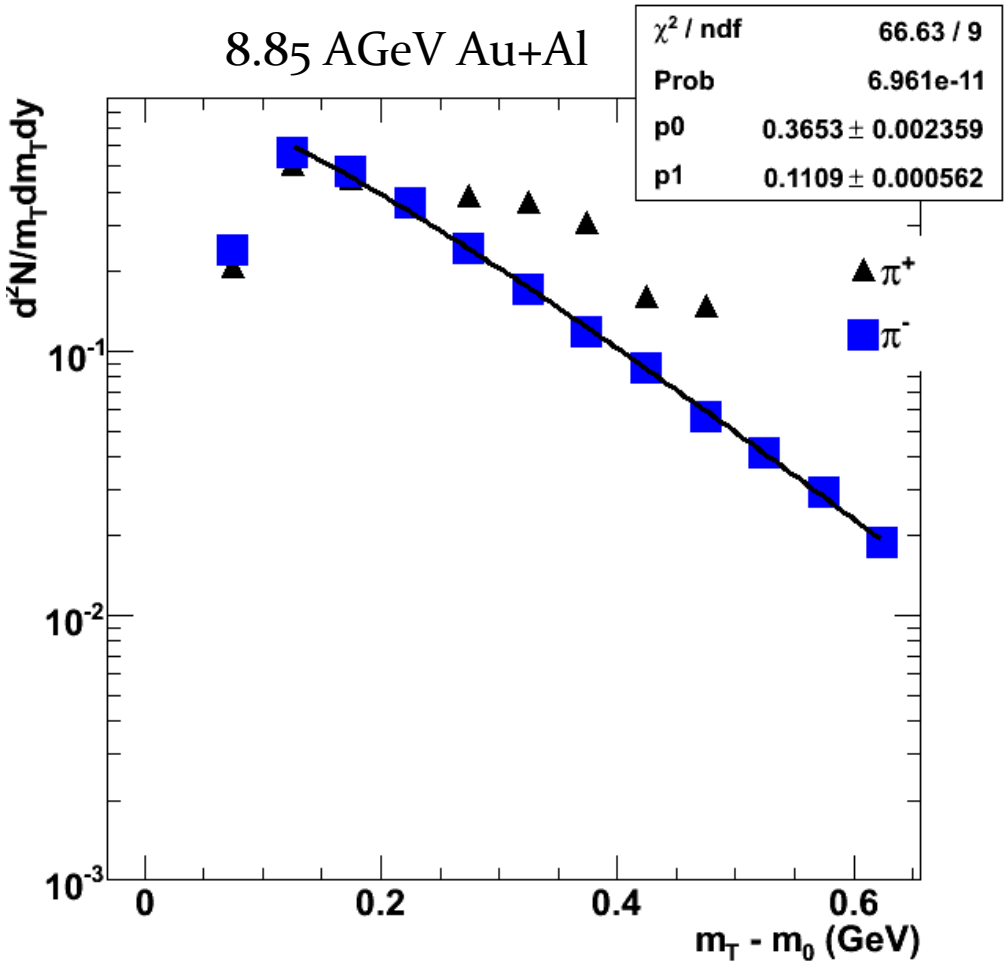
8.85 AGeV Au+Al: π spectra, $y-y_{cm} = 0$

Brooke Haag

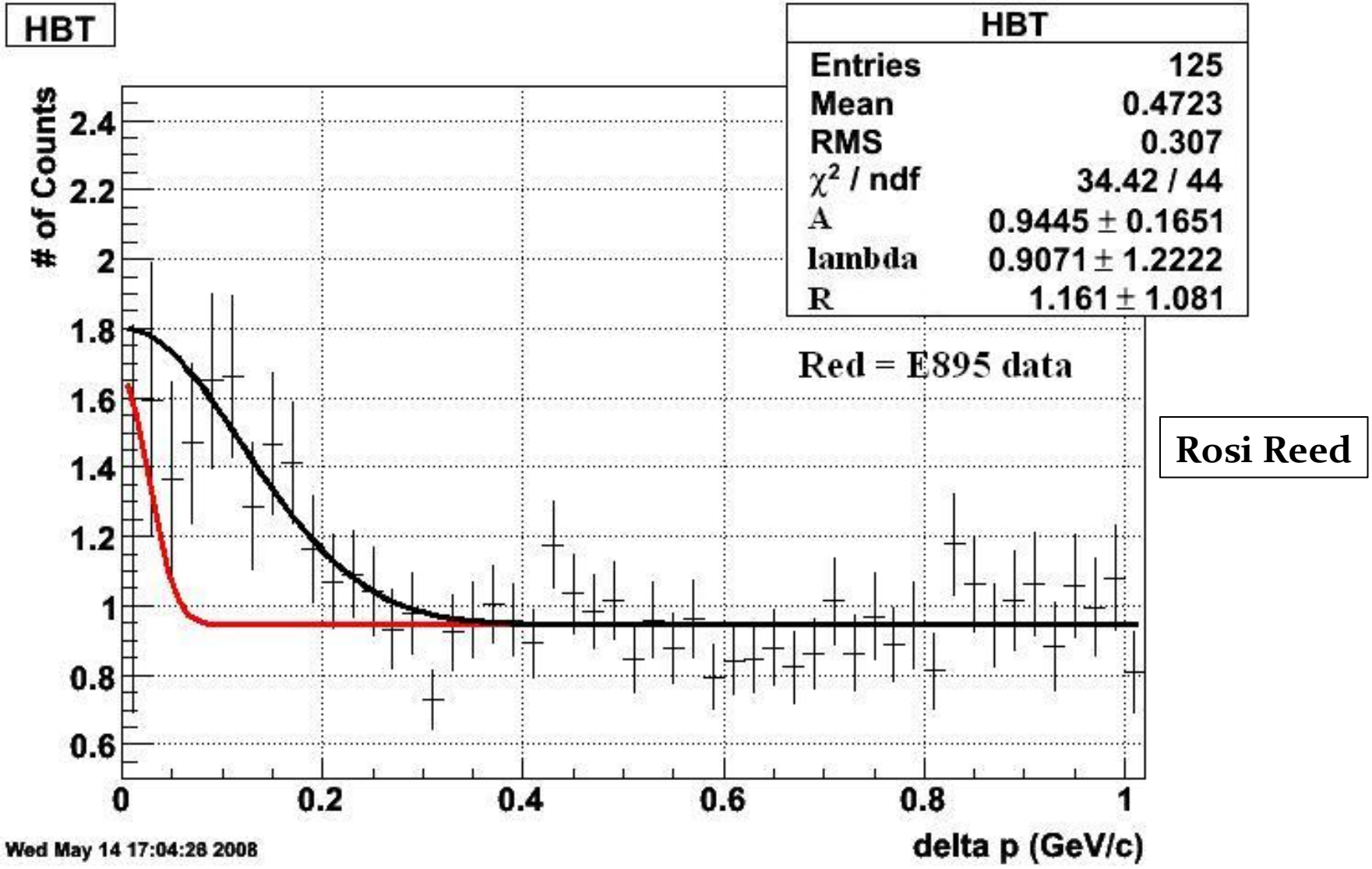


8.85 AGeV Au+Al: π spectra, $y-y_{cm} = +0.1$

Brooke Haag

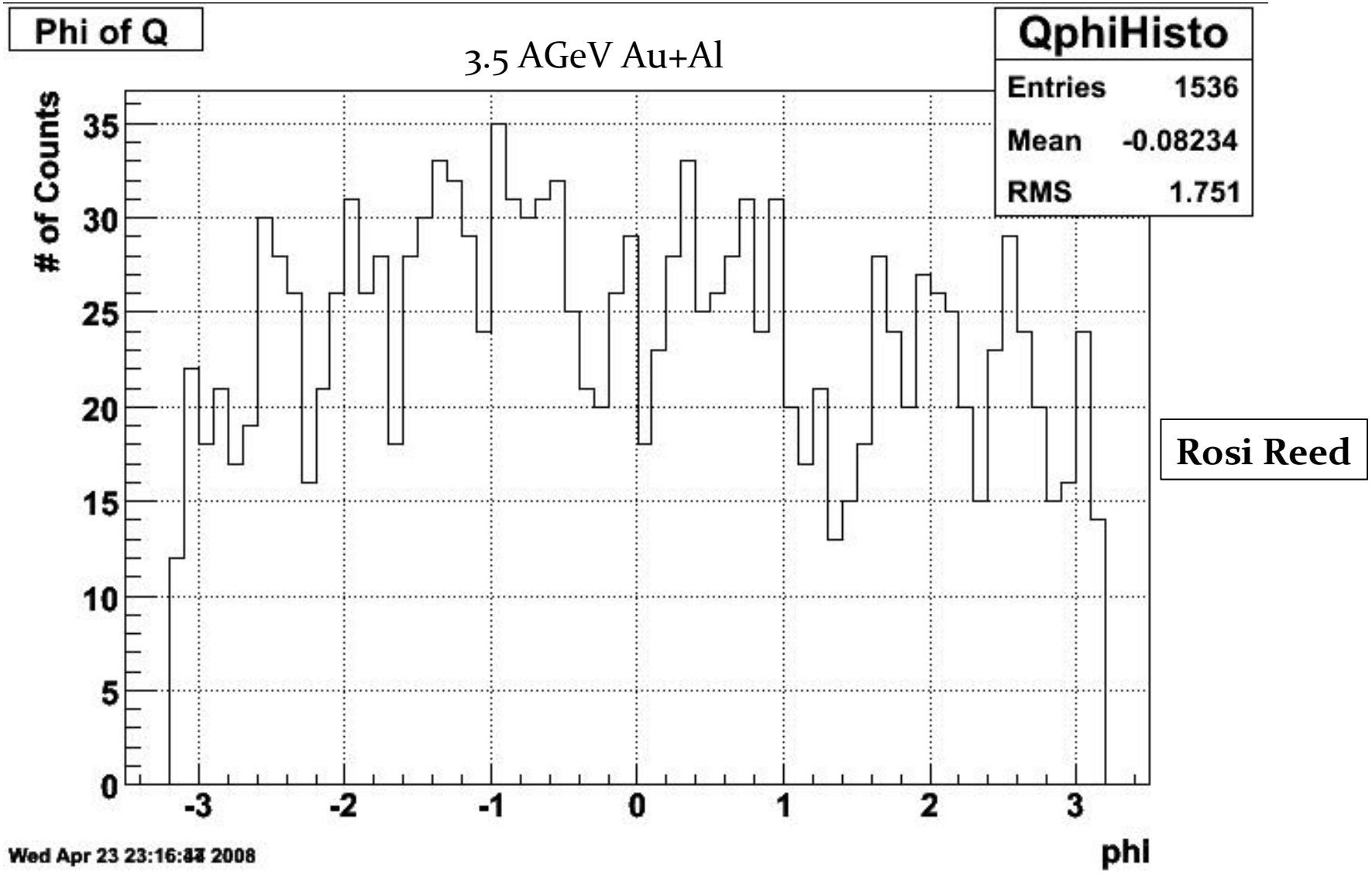


3.5 AGeV Au+Al: HBT Analysis



Rosi Reed

ϕ Distribution of Reaction Plane Vector



Rosi Reed

Detector Performance To Do List

Run UrQMD events through GEANT to estimate the detector acceptance For fixed target events (forward rapidity).

Study the effect of fixed target acceptance on the physics observables proposed for the beam energy scan.

Determine the TOF capabilities for z=2m events (projective geometry).

Determine the BEMC capabilities for z=2m events (projective geometry).

Determine the EEMC capabilities for fixed target collisions.

Optimize TPC analysis for forward tracks.

Consider whether a target trigger detector would be needed.

Study the BBC preformance for fixed target.

Study whether the FGT would be beneficial in future fixed-target runs.

Count Rate Estimates

This Program proposes using collisions between the beam halo and a fixed target.
Making count rate estimates is a challenge because the beam halo is not well understood.

The MAXimum event rate is defined by DAQ1000 and the Machine performance. For a beam which Is producing collisions 50% of the time on average, then one can record upto (24 hours)(50% uptime)(3600 Sec/hour)(1000 Hz) = 43 M events/day.

However, then one needs to determine whether it will be possible to fill the 1 khz bandwidth with triggers, and what fraction of those triggers will be good Au+Au fixed-target events.

Can we fill the DAQ bandwidth with Fixed-Target Events?

We need a better understanding of the make-up of the RHIC beam halo. The trigger detectors are firing at a very high rate. Much of the "background" that we actually "see" with STAR can be associated with beam-on-beampipe collisions.

STAR Electronic Logbook 25-Apr-2011 -- 19.6 GeV Au +Au

Rates at the start of a fill:
ZDC and -- 185 Hz
ZDC E ---1065
ZDC W -- 2800
BBC and --- 1650 Hz
BBC E --- 46 kHz
BBC W --- 51 kHz
Yellow Bkgd --- 650
Blue bkgd --- 550

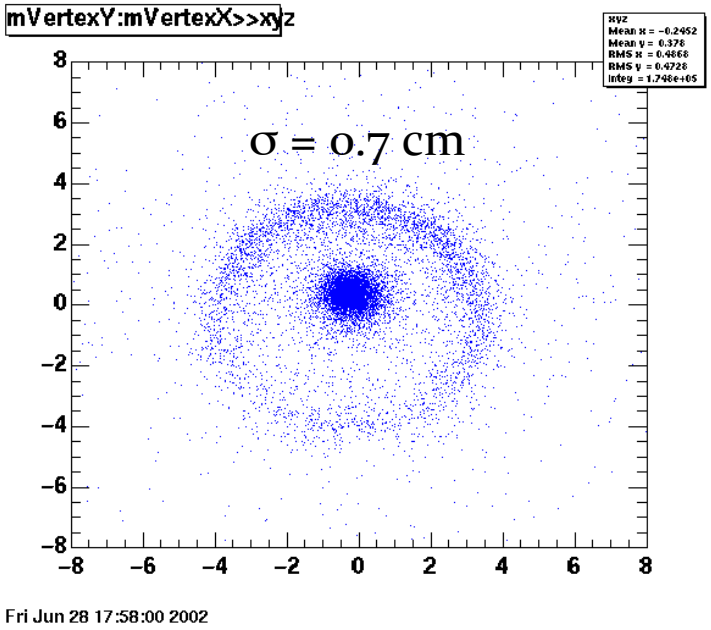
Gold Beam Parameters
10^9 Ions per bunch
105 bunches
610.17538 m Radius of RHIC
78196 Revolutions per second

8.2×10^{15} Gold ions per second

Will "Fixed-Target" Triggers Be Swamped with Background

Issue: We do not actually know the beam profile of the halo

Assume a Gaussian Beam Profile:
The relative rate of collisions at various radii can be determined by integrating the 2D Gaussian



$$\int_{R_1}^{R_2} e^{-r^2/2\sigma^2}\left(r/\sigma^2\right)dr = e^{-R_1^2/2\sigma^2} - e^{-R_2^2/2\sigma^2}$$

Jim Draper

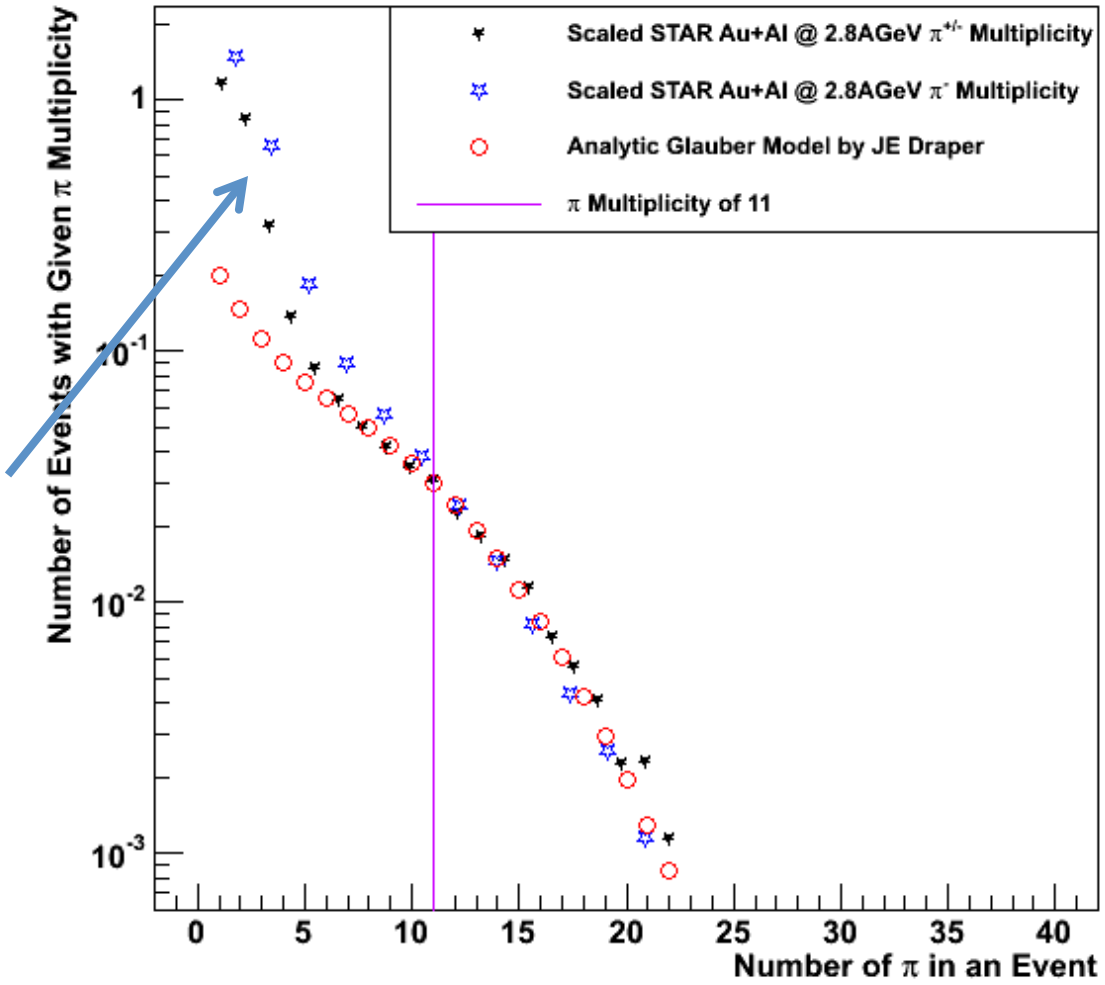
For a target at 2 m, the relative rate of Au+Au fixed target collisions vs. the Au +beampipe collisions will be 7700:1

What about background from light nuclei in the halo?

This will probably our biggest challenge.

In our 7.7 GeV data set, beampipe vertices were associated with light ion impact in about 80% of triggers. A simple multiplicity selection could reduce this background dramatically, but it may be hard to quantify.

A much better understanding of the make-up of the beam halo is necessary for this program.



Can We Trigger on Fixed-Target Events?

Remember, the BES trigger was designed to NOT trigger on Au+Al events. The BBC East-West coincidence requirement should eliminate fixed-target events.

Somehow all the beam-on-beampipe collisions were triggered – Random coincidence.

For a dedicated fixed-target trigger, we would probably want a BEMC-BBC East coincidence.

SUMMARY

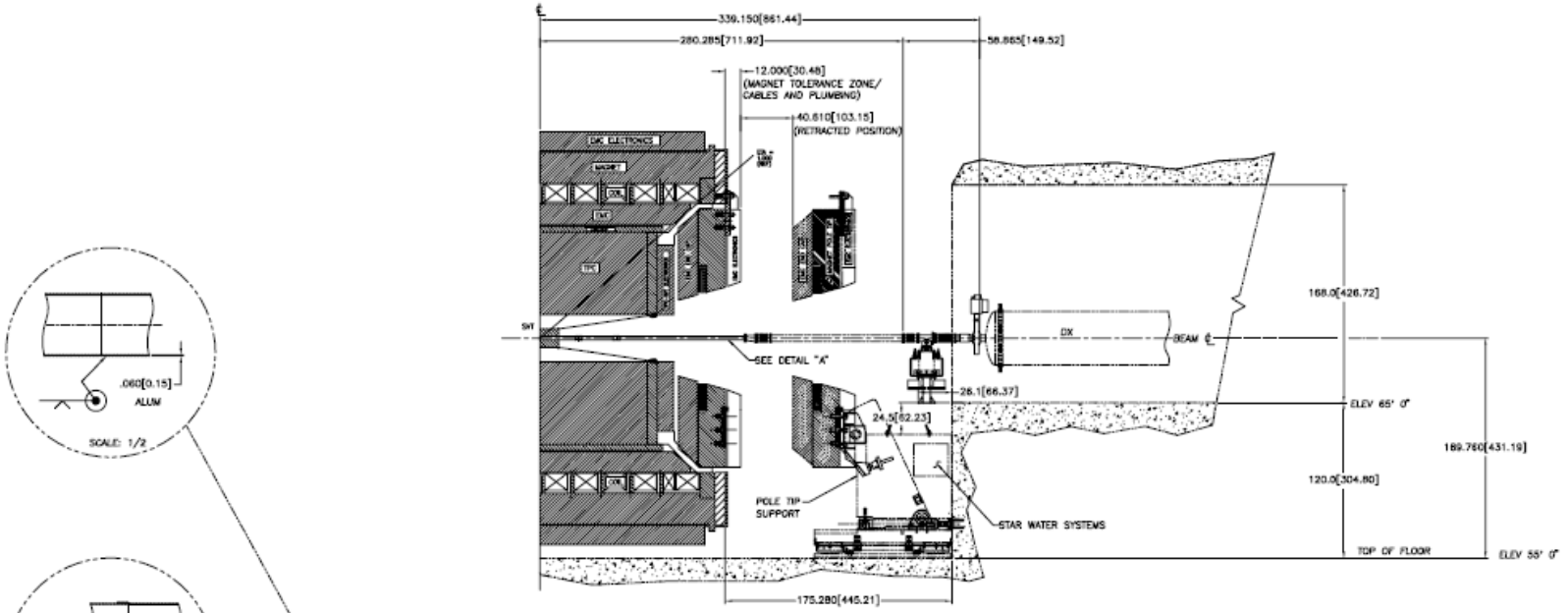
Although STAR is not optimized for fixed-target collisions, it will have coverage from roughly mid-rapidty back to target rapidity.

This coverage is sufficient for some BES studies, although a detailed analysis of the limitations and the required statistics for each observable needs to be done.

An internal fixed target could be used to take beam halo collisions with injection energy gold to acquire a data set at center of mass energy of 4.5 GeV. This results could compliment the existing beam energy scan data.

Results from injection energy fixed-target collisions could help define the need to move the Pelletron from FNAL for implementation in a future BES-II run.

EXTRAS



DETAIL A

[DIMENSIONS ARE IN CENTIMETERS]

REVISIONS

REV	ZONE	ECN NO.	BY	DATE	CHECKED	APPROVED

BROOKHAVEN NATIONAL LABORATORY
UPTON, N.Y. 11973

RHIC–STAR SOLENOID MAGNET
BEAM PIPE
LAYOUT

SIZE	DWG NO.	REV
E	CNV005–E–1	A

SCALE 1/32 | SHEET 1 of 1

STAR DWG NO. CNV005–E–1 | SHEET 1 of 1 | A3

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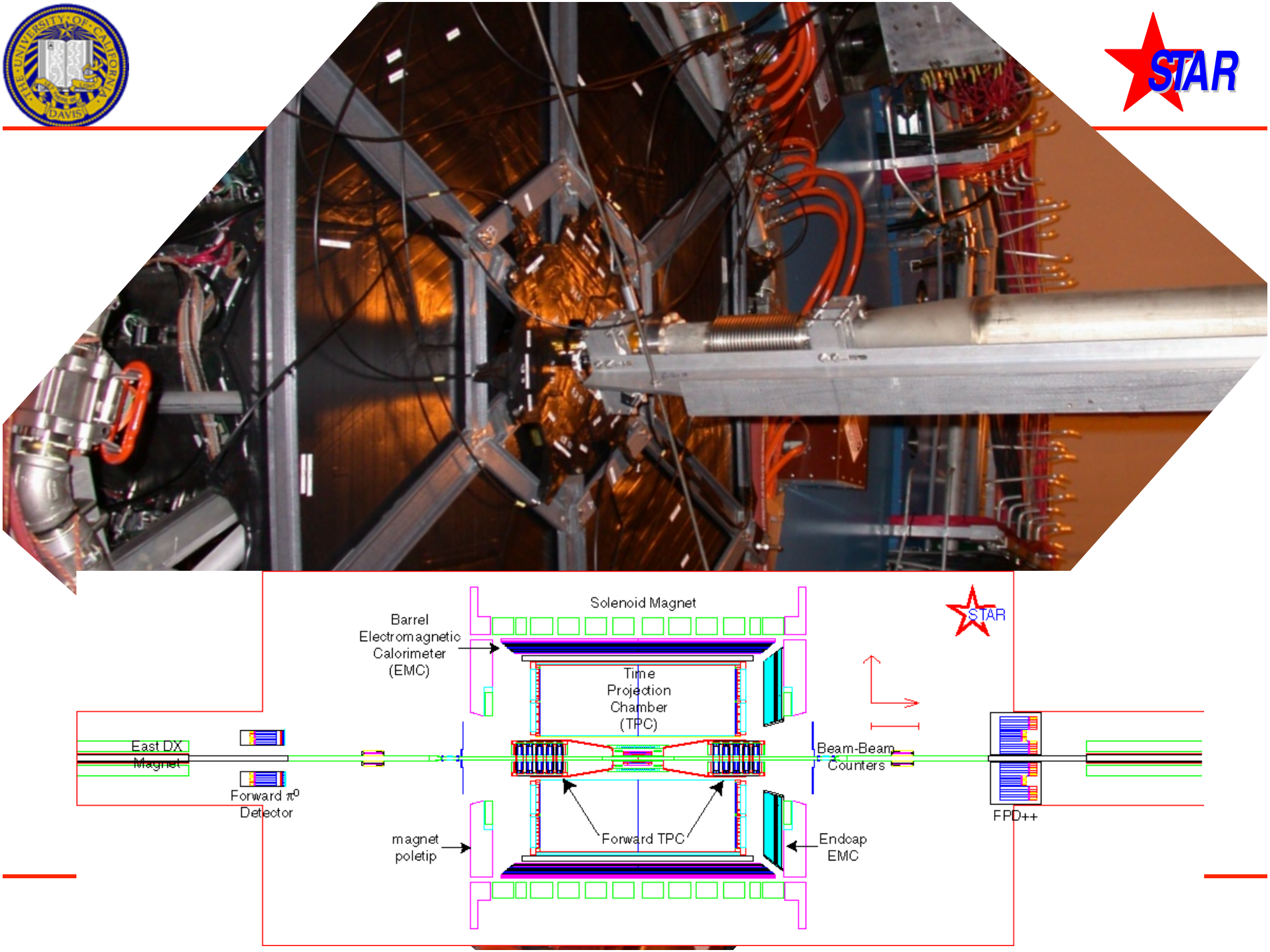
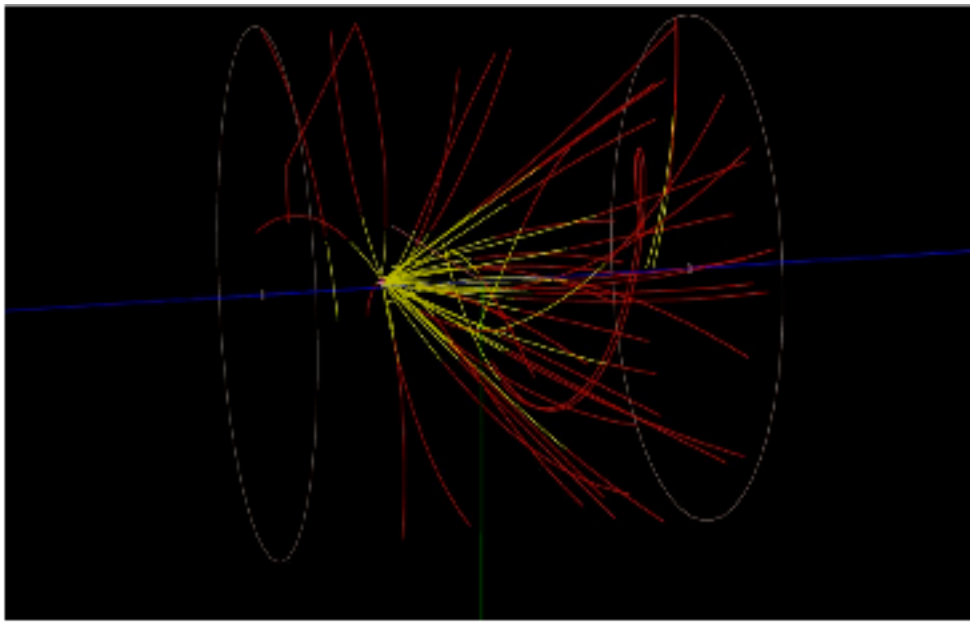
Plotted 02-15-00 08:58


Solenoid Magnet
Barrel
Electromagnetic
Calorimeter
(EMC)
Time
Projection
Chamber
(TPC)
East DX
Magnet
Forward π0
Detector
Beam-Beam
Counters
FPD++
magnet
poletip
Forward TPC
Endcap
EMC
STAR

Beam-Pipe Collisions

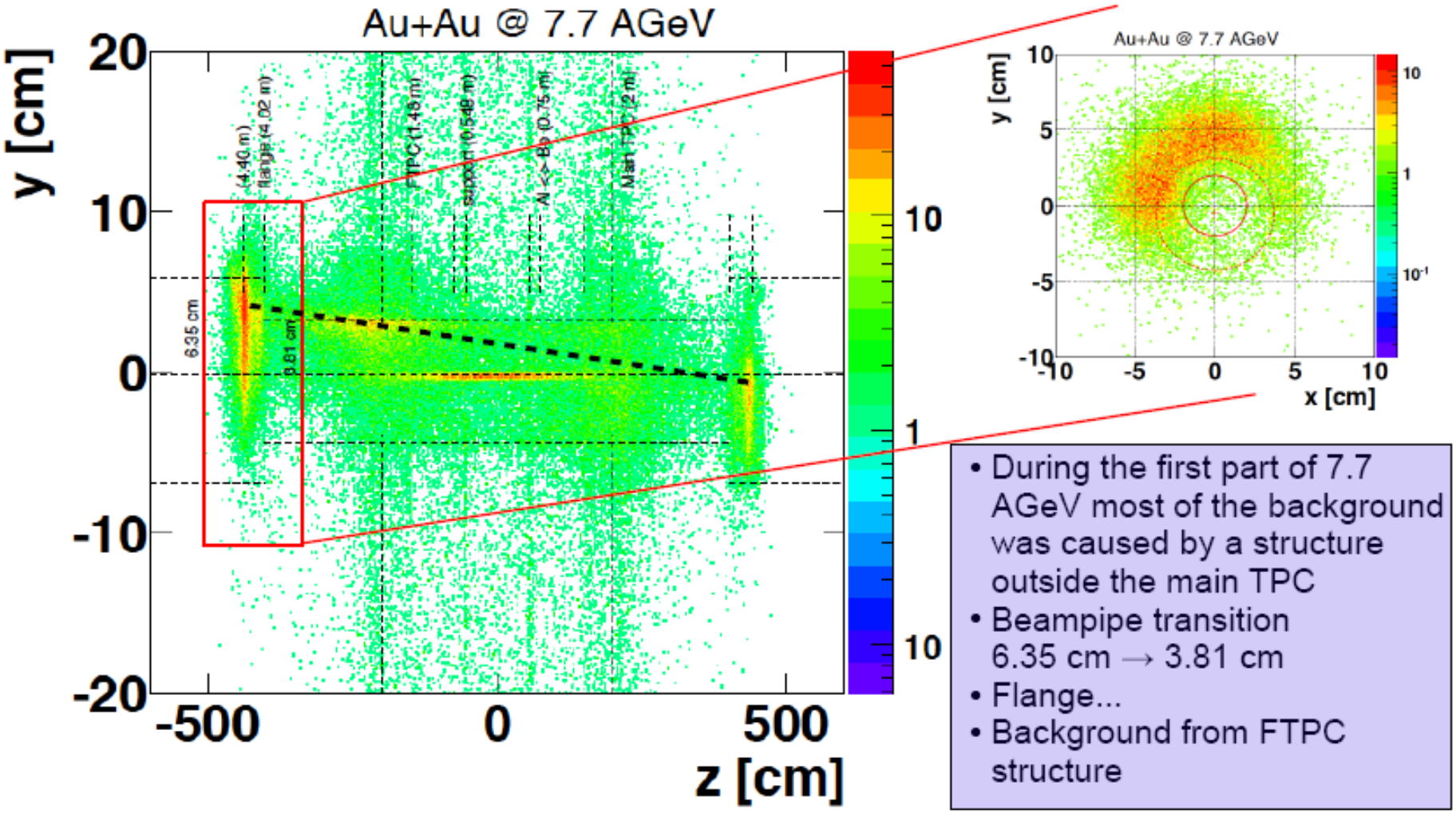
- Au ions in the beam collide with Al nuclei in the beam pipe
- STAR detector obtains useful data from these collisions



At the end of the 7.7 GeV Run, only 17% of all triggers were Au+Au. Most of the rest were collisions with some piece of beam pipe.

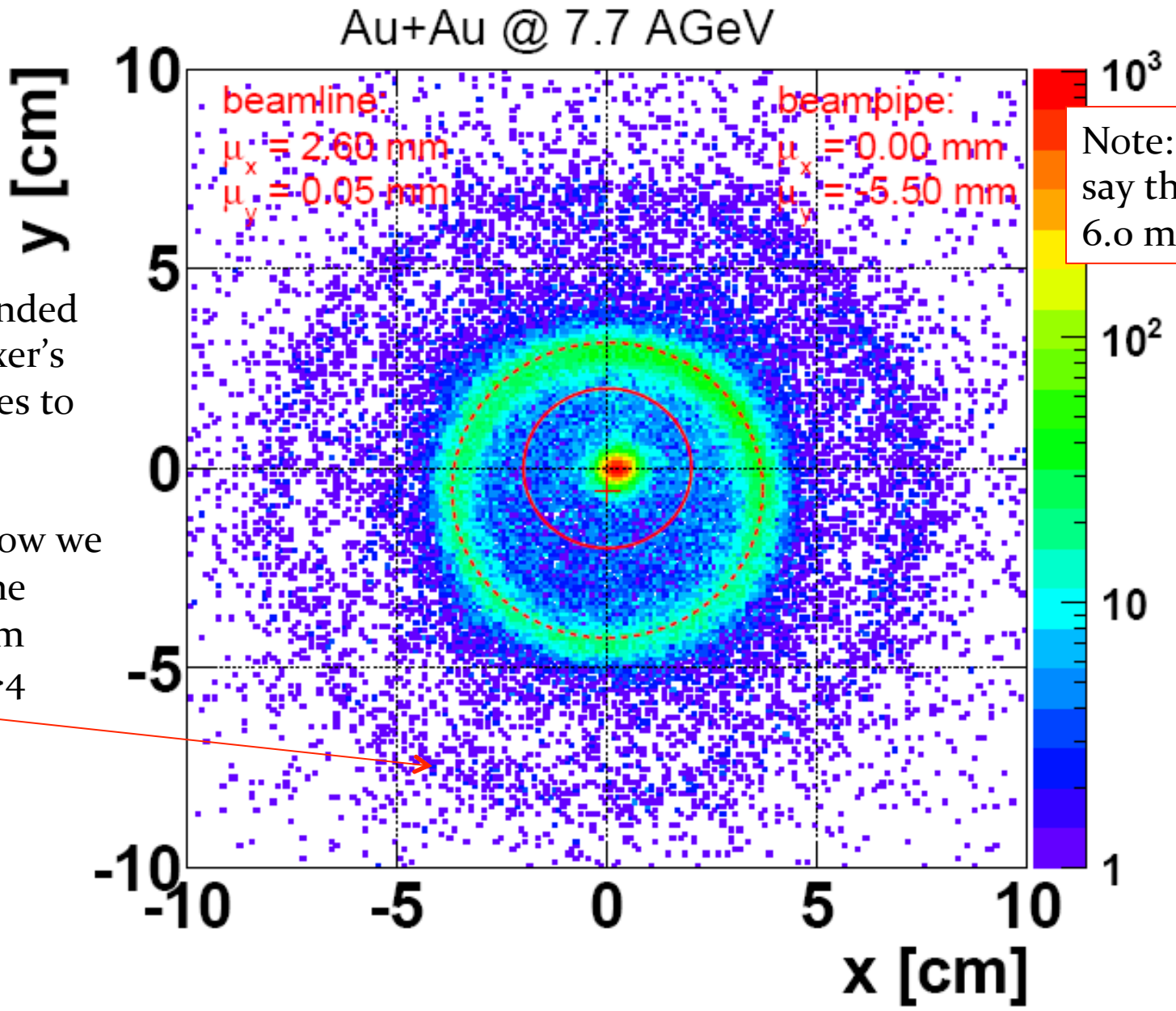
- Au+Al not the normal events analyzed at STAR
- One-sided collisions, not on the beam axis
- Must think carefully about the geometry

Beam-Pipe Collisions



- During the first part of 7.7 AGeV most of the background was caused by a structure outside the main TPC
- Beampipe transition 6.35 cm → 3.81 cm
- Flange...
- Background from FTPC structure

Figure from Alex Schmah



Note: I would say the pipe is 6.0 mm low

Alex extended the vertexer's capabilities to analyze upstream events. Now we can see the large beam pipe at z>4 meters

19.6 GeV Run