STAR Heavy-Ion Program Runs:12-14

Lokesh Kumar (for STAR Collaboration)

Outline:

- STAR Physics program for heavy-ions
- Run 12 heavy-ion data taking
  - U+U 193 GeV and Cu+Au 200 GeV
- STAR proposals: Run13-14
- BES Phase-II
  - STAR in Fixed Target Mode
- Summary

RHIC & AGS Annual Users' Meeting

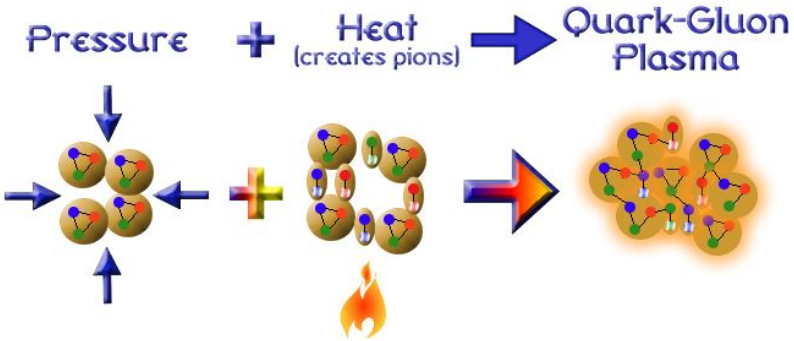
June 12-15, 2012, Brookhaven National Laboratory

STAR Heavy-Ion Program

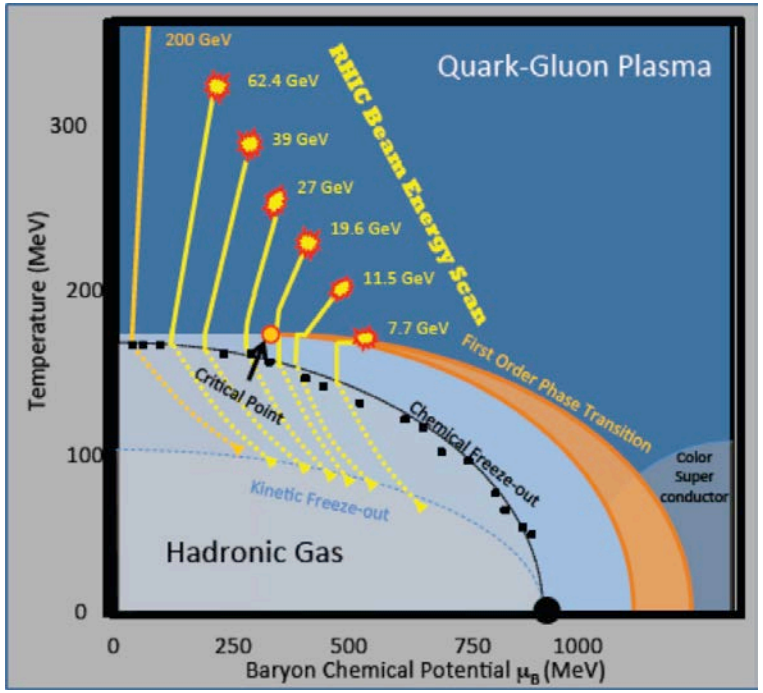
Main goals:

1. Study QGP and its properties

STAR: Nucl. Phys. A 757, 102 (2005)



QCD Phase Diagram:



2. Study the QCD phase diagram:

- Search for the signals of possible phase boundary

- Search for the possible QCD Critical Point

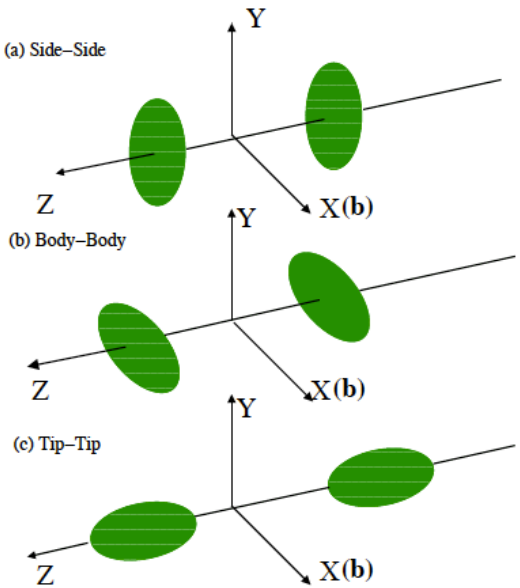
http://drupal.star.bnl.gov/STAR/starnotes/public/sn0493: arXiv:1007.2613

Motivation: U+U

Uranium ion is a deformed nuclei:

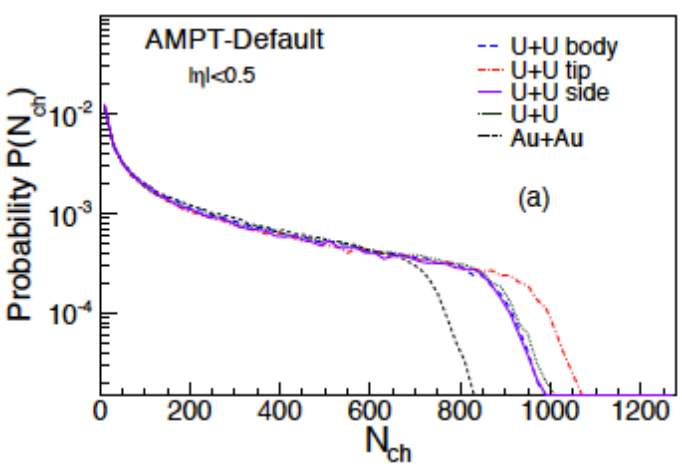
$$\rho = \frac{\rho_0}{1+\exp([r-R']/a)}$$

$$R' = R[1+\beta_2 Y_2^0(\theta)+\beta_4 Y_4^0(\theta)]$$

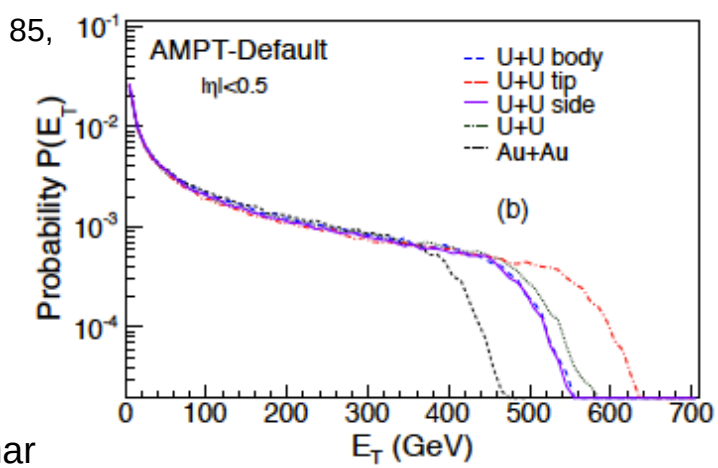


ρ_0= normal nuclear density,
R = radius of nucleus = 6.81 fm,
a=surface diffusion parameter = 0.55 fm,
$Y_l^m(\theta)$=spherical harmonics,
θ=polar angle with symmetry axis,
β_2, β_4=deformation parameters = 0.28, 0.093

Higher multiplicity and energy density compared to Au+Au:



R. Haque et al. PRC 85, 034905 (2012)

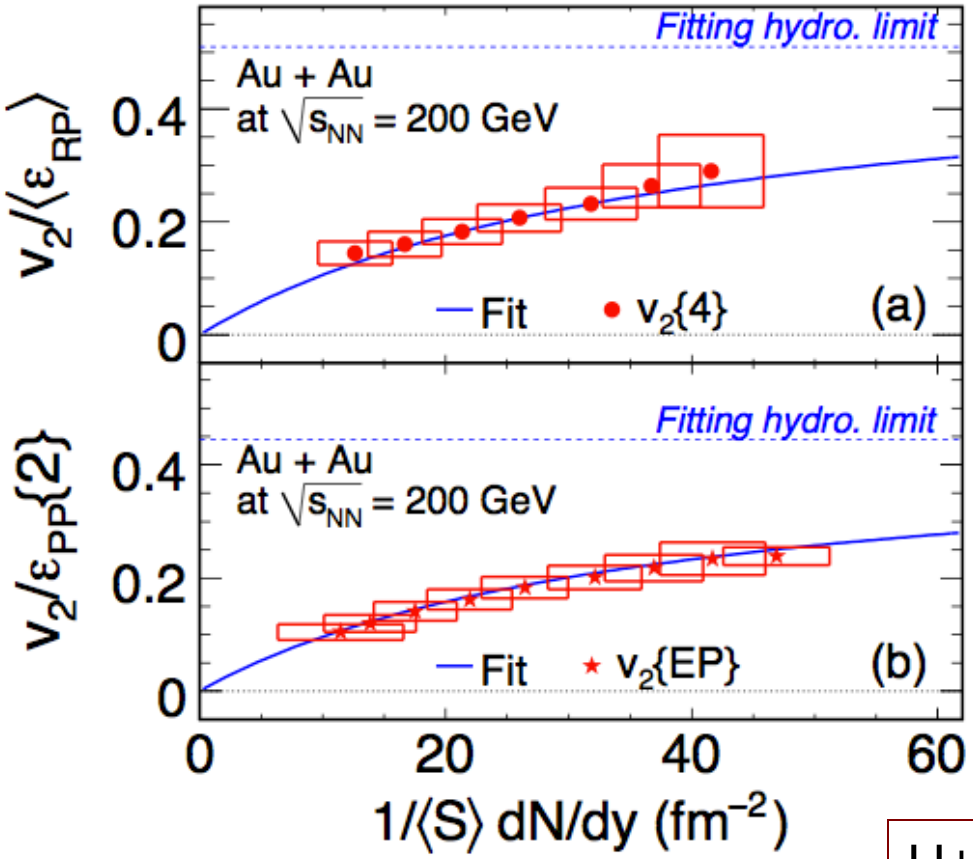


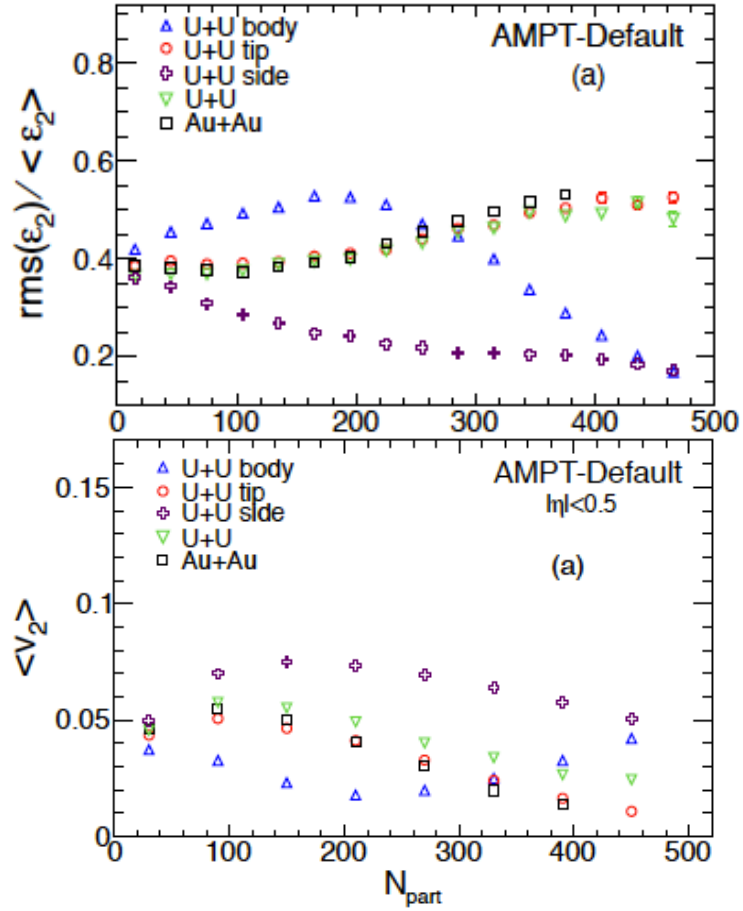
Motivation: U+U

R. Haque et al., PRC 85, 034905 (2012)

Elliptic flow:

H. Masui et al., PLB 679, 440 (2009)





(1/<s>)dN/dy:

U+U ~ LHC > RHIC (Au+Au)

U+U provides interesting possibilities to understand effect of initial geometry on v_2 and fluctuations

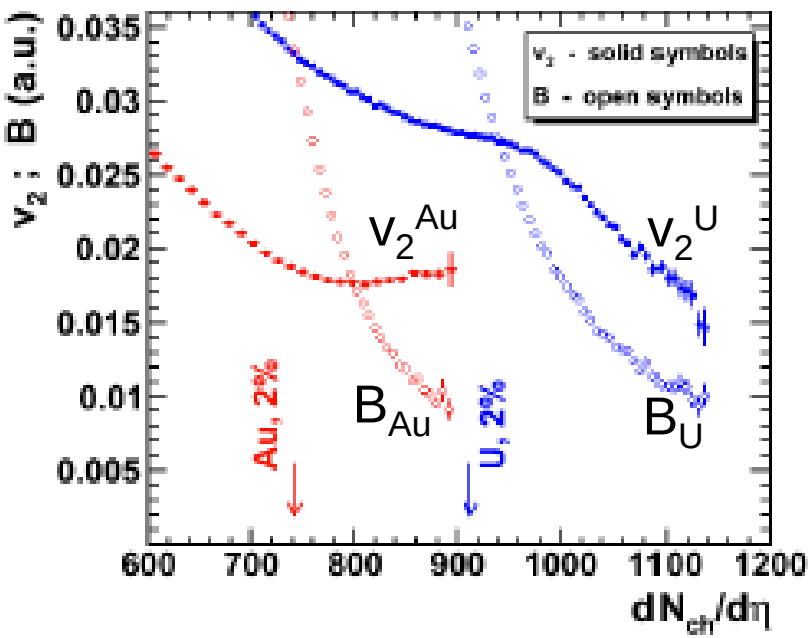
Motivation: U+U

Chiral Magnetic Effect (CME):

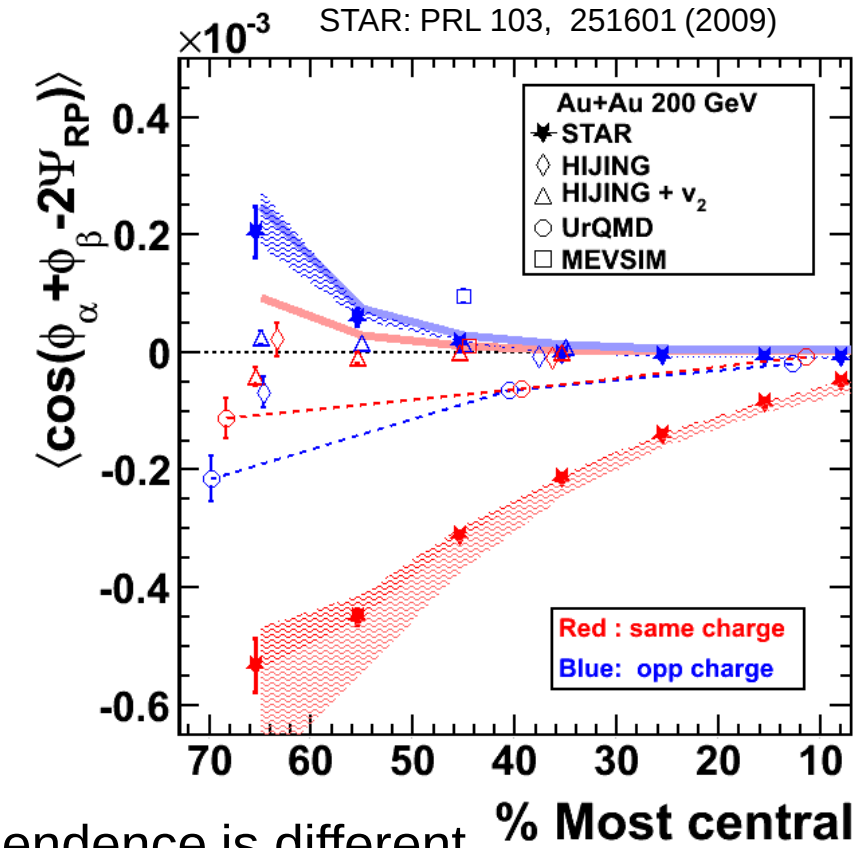
- Correlation due to v_2 is one of the main background
- Strong magnetic field is desired

Understand CME signal: change the relative strengths of magnetic field and v_2 - U+U helps

S. Voloshin, PRL 105, 172301 (2010)



STAR: PRL 103, 251601 (2009)

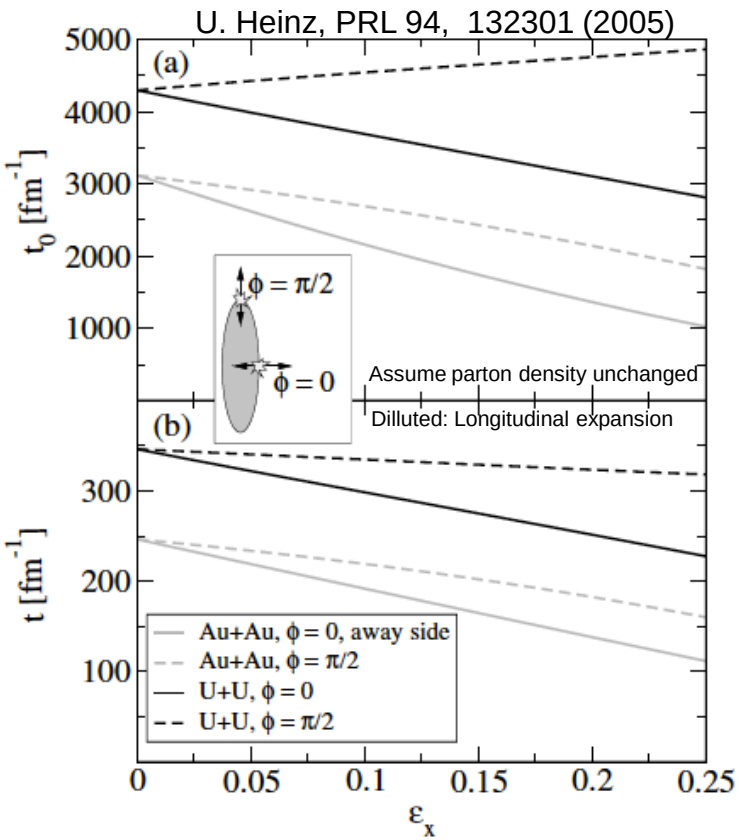


- v_2 dependence is different
- B dependence is similar

U+U could help to understand background effect for CME

Motivation: U+U

Path length dependence of energy loss:



✧ Path Length (<L>):
U+U > Au+Au (~3% in central, ~5% in peri.)
- R_{AA} to be suppressed more at a given N_{part}

✧ Au+Au collisions: difficult to distinguish between types of path length dependence

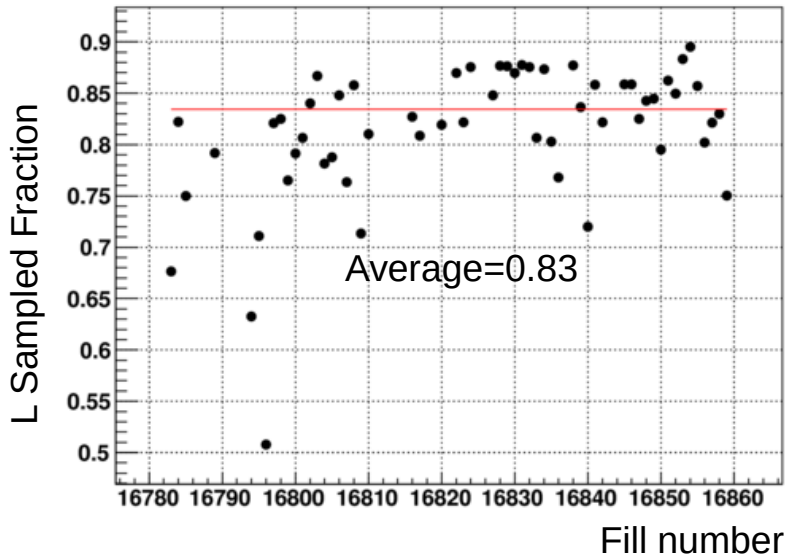
t ∝ energy loss (roughly)

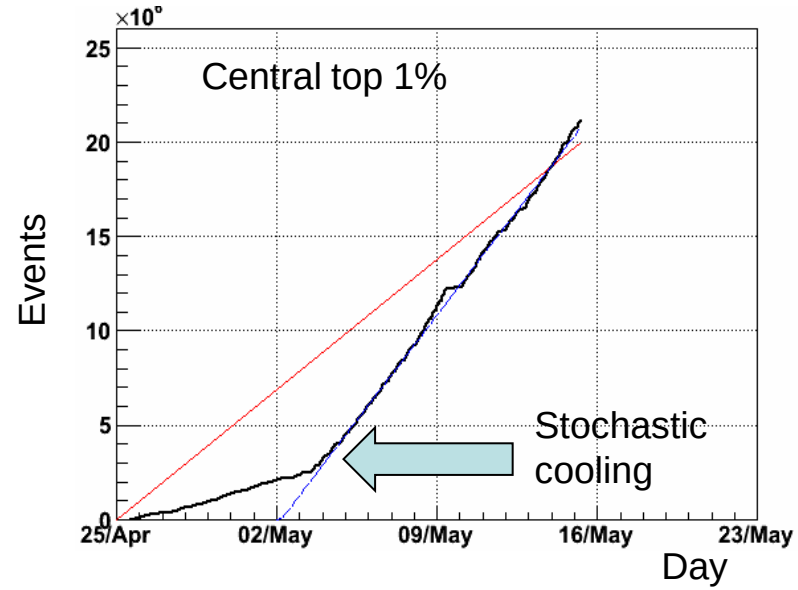
- E_{loss} (out-of-plane) - E_{loss} (in-plane): U+U > 2 (Au+Au) [for largest eccentricity]

- Total energy loss: U+U ~ 2 (Au+Au)

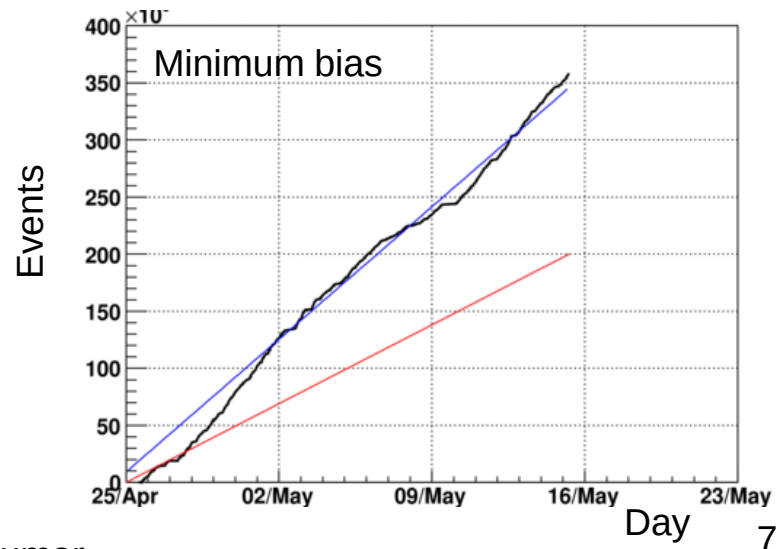
U+U provides more understanding on energy loss and it's path length dependence

U+U 193 GeV Data taking





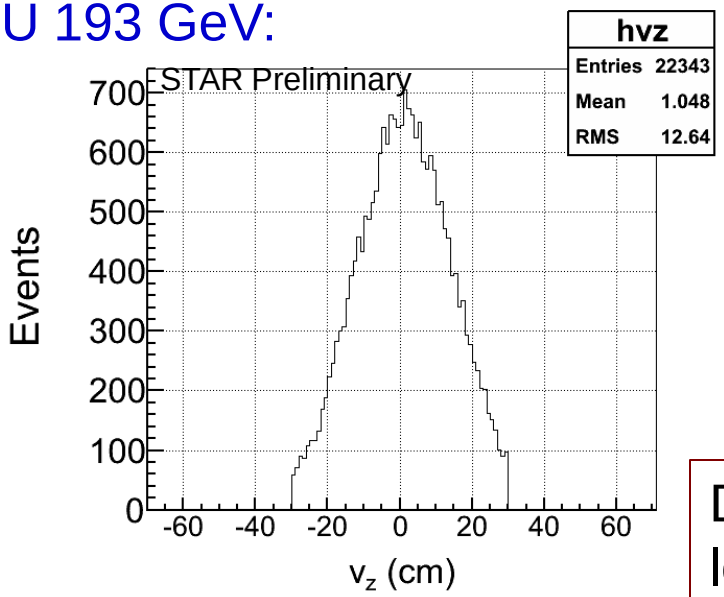
Red: Linear projection to goal from t=0
Blue: Linear projection based on actual performance
Black: Actual Performance

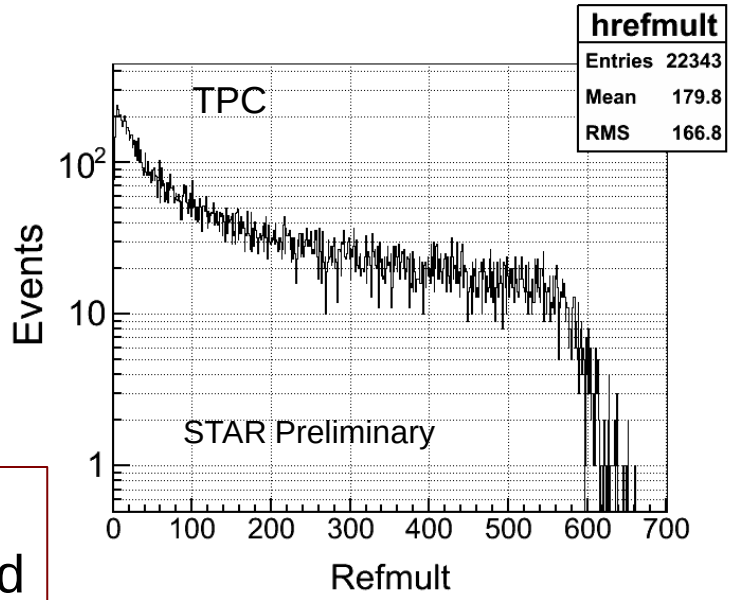


- ✓ 3 weeks running
- ✓ Central (top1%): 21M events
- ✓ Minbias: 352M events
- ✓ All data goals are achieved

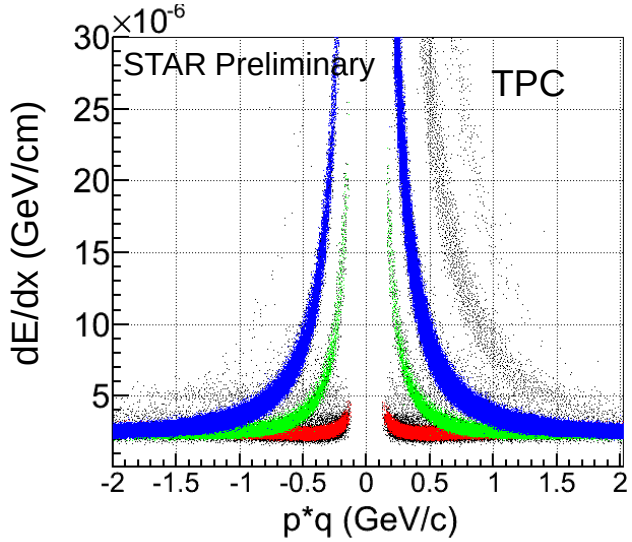
First Look (fast offline)

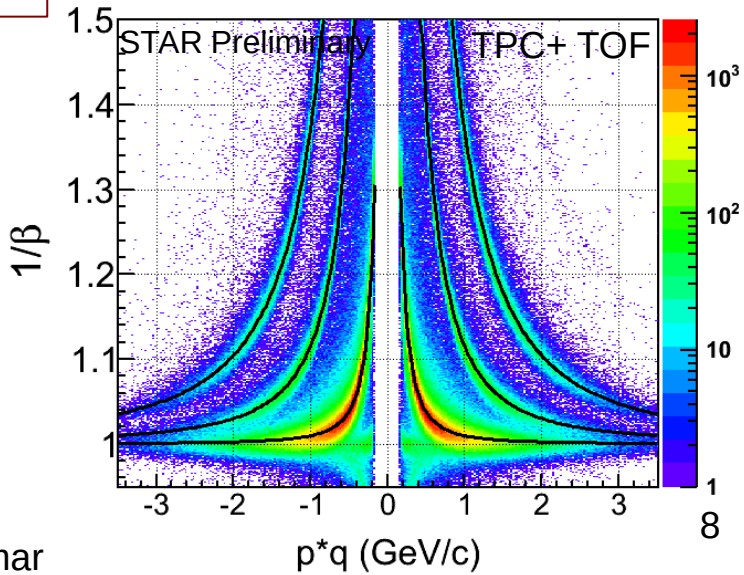
U+U 193 GeV:



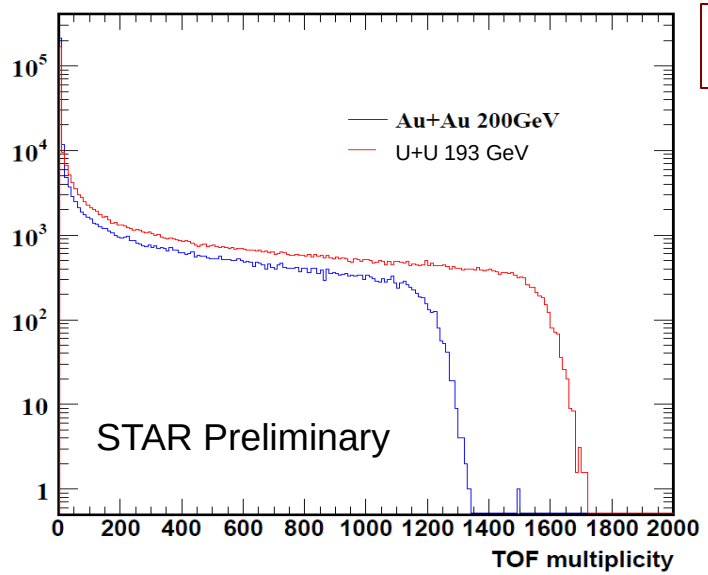


Data:
looks good



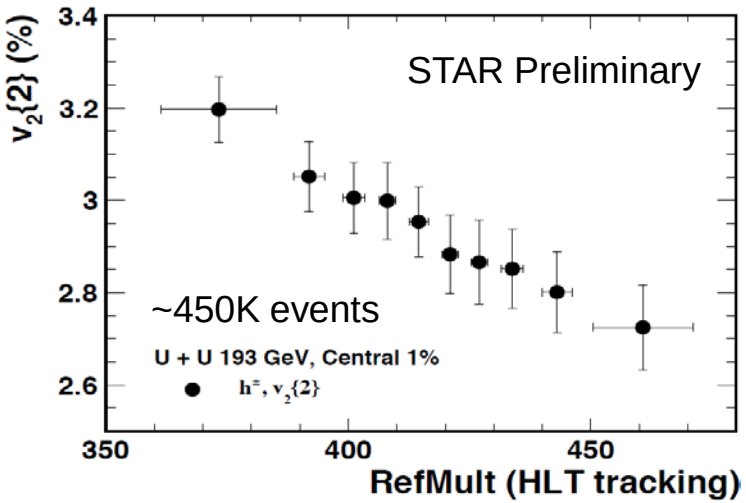


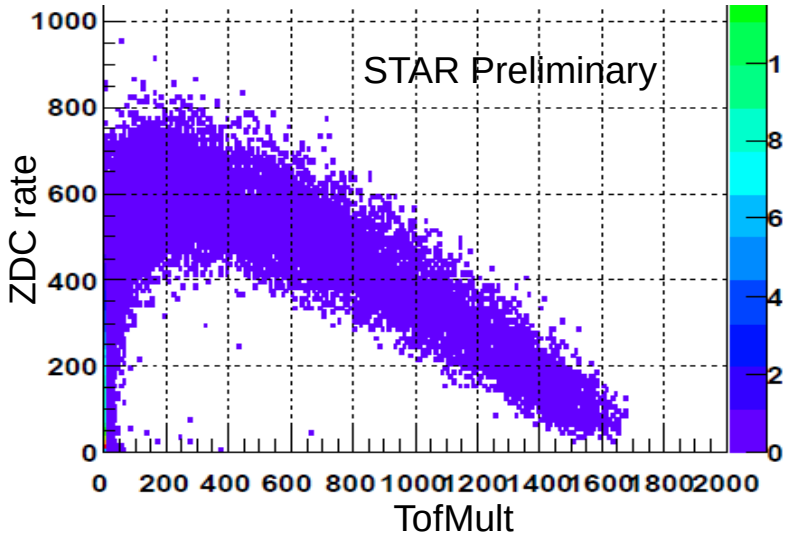
First Look (Online Tracking)

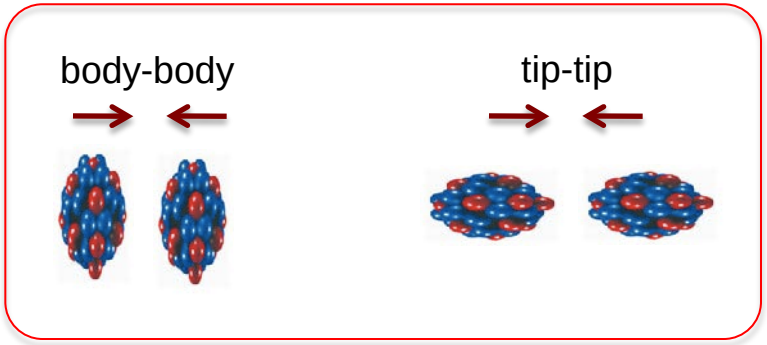


U+U multiplicity (uncorrected): 20-30% higher

Elliptic flow (HLT online):



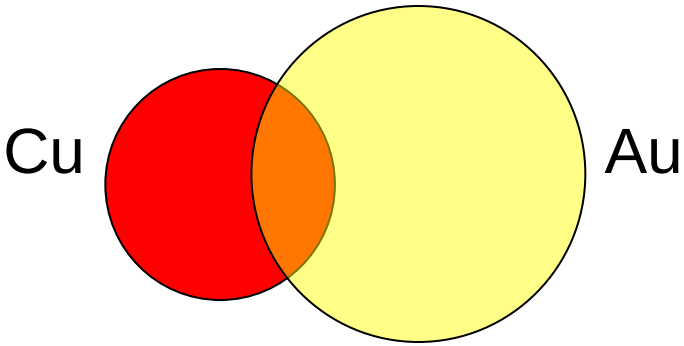




Motivation Cu+Au

Advantages using asymmetric species:

✧ Could vary collision geometry and density profile of produced matter



✧ Cause initial state fluctuations

✧ Mid-central collisions break left-right symmetry giving non-zero odd-harmonics of flow from geometry

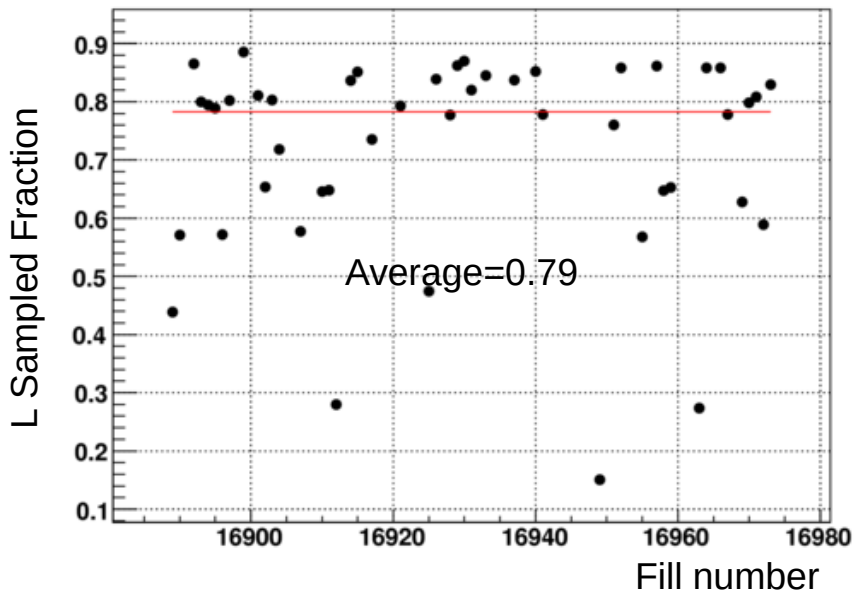
Physics:

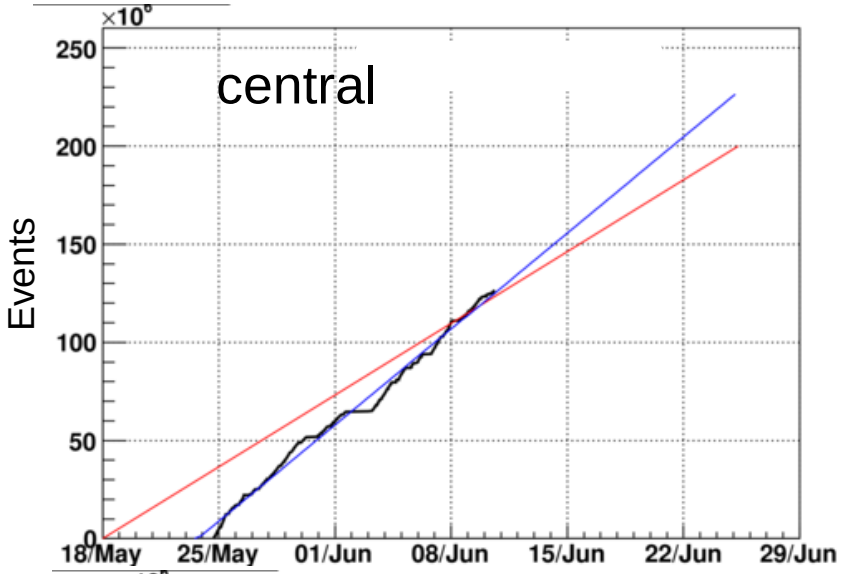
✓ Study initial geometry and fluctuations

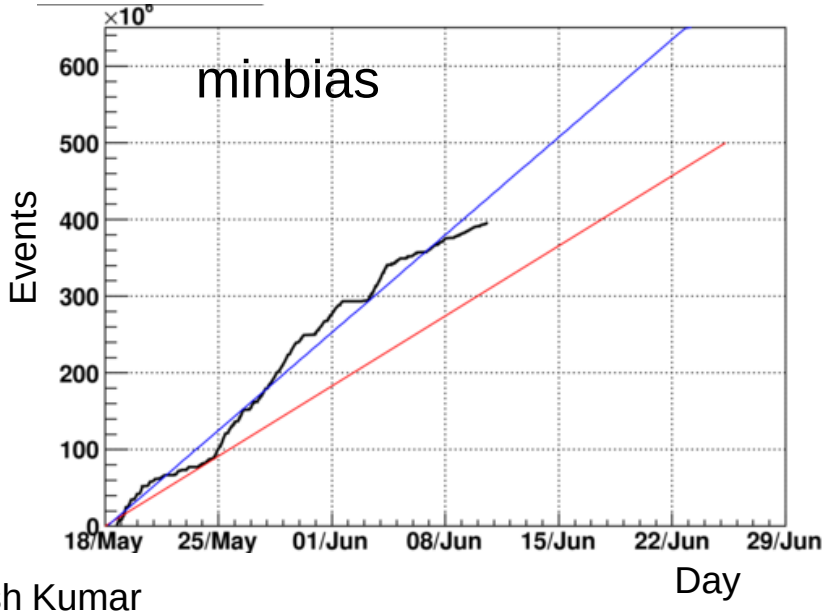
✓ Most of the studies mentioned for U+U

✓ Comparison to U+U, Au+Au and Cu+Cu data

Cu+Au 200 GeV Data Taking







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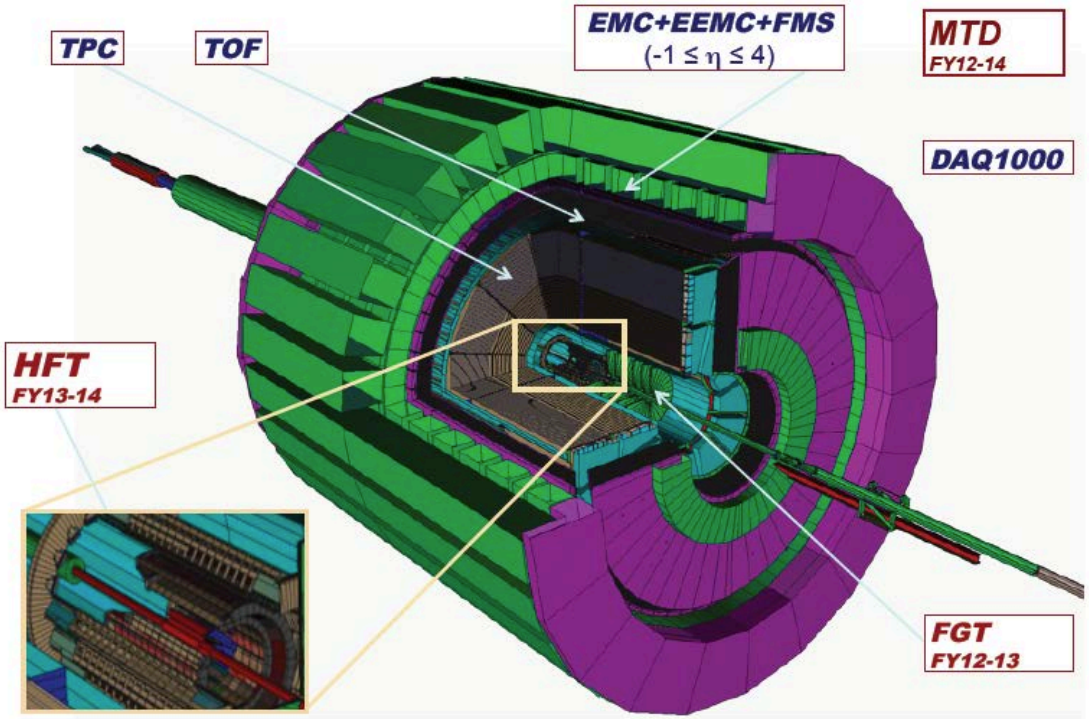
Black: Actual Performance

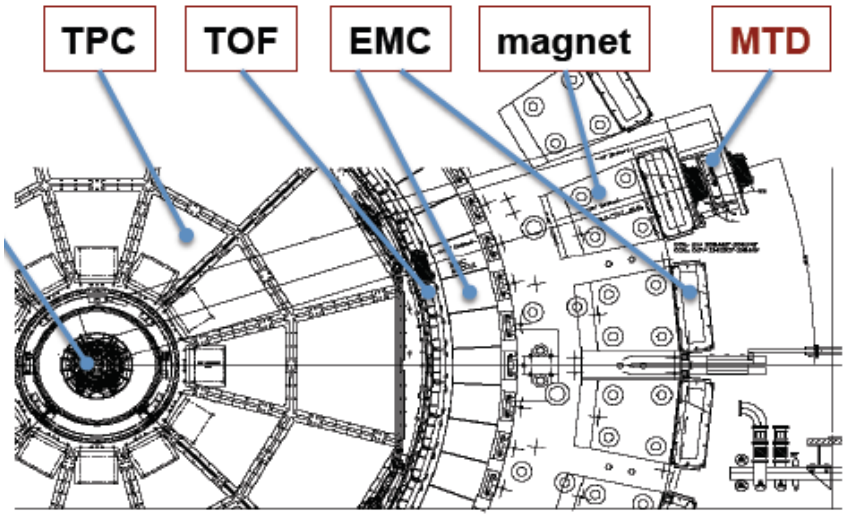
Data taking going on….

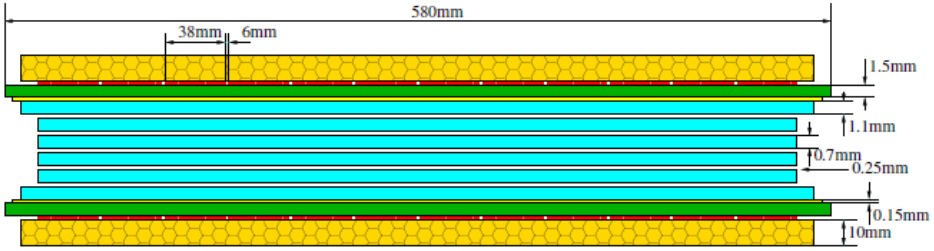
STAR Proposals: (Heavy-Ion) Run 13-14

- Two new detectors: For precise study of dileptons and heavy flavor physics – Muon Telescope Detector (MTD) and Heavy Flavor Tracker (HFT)
- Fixed Target Proposal: To extend μ_B range up to 800 MeV
- Main Goal: 200 GeV Au+Au and 200 GeV p+p (reference)



Muon Telescope Detector (MTD)



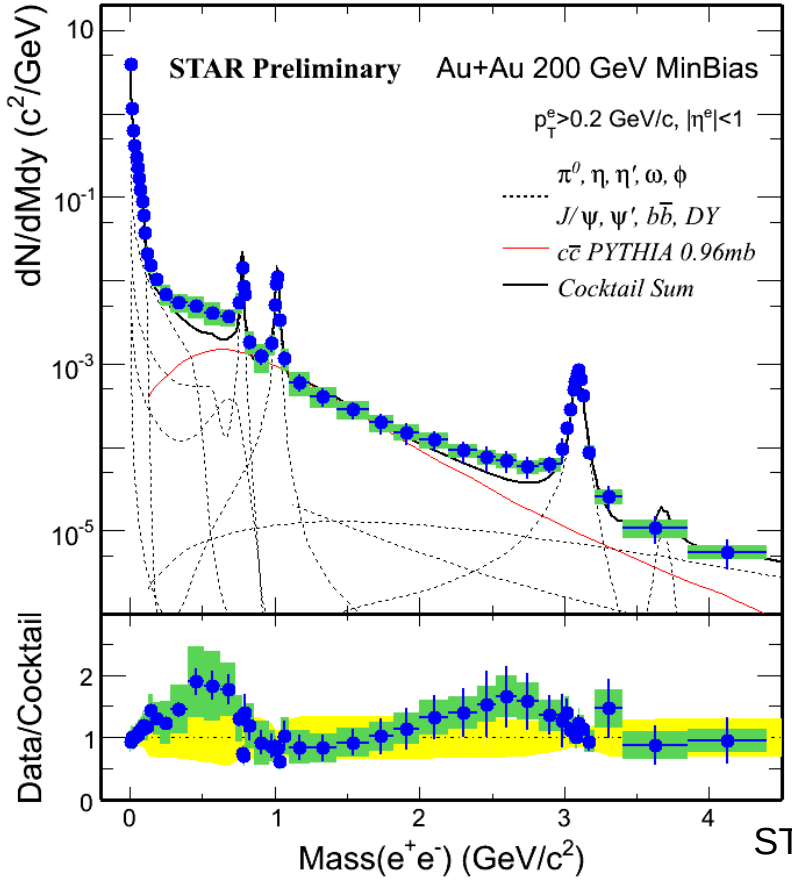


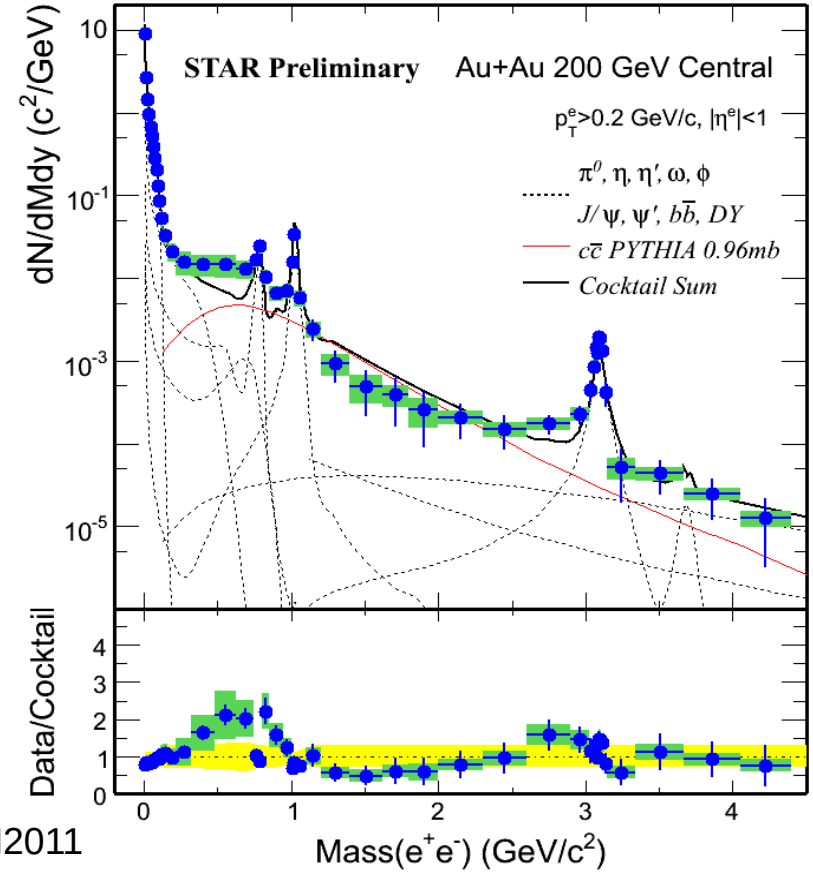
- ✧ Long Multi-gap Resistive Plate Chamber (MRPC) technology
- ✧ Electronics same as STAR-TOF

- ✧ MRPCs covers the whole iron bars and leave the gaps in between uncovered.
- ✧ Acceptance: 45% in azimuth and $|\eta|<0.5$
- ✧ 118 modules, 1416 readout strips, 2832 readout channels

12/118 modules this year
Complete in FY2014

Current Di-lepton Results from STAR



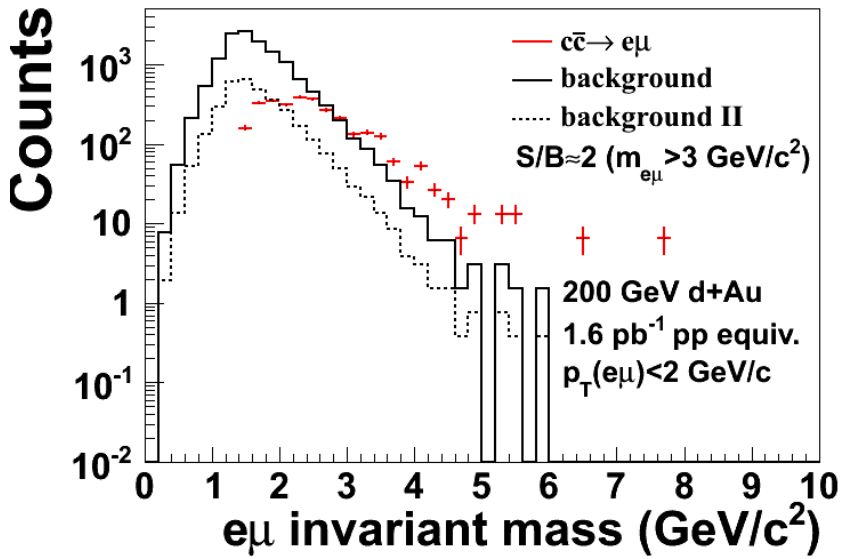


STAR: QM2011

Charm contribution dominates intermediate mass region
Current estimates are using PYTHIA

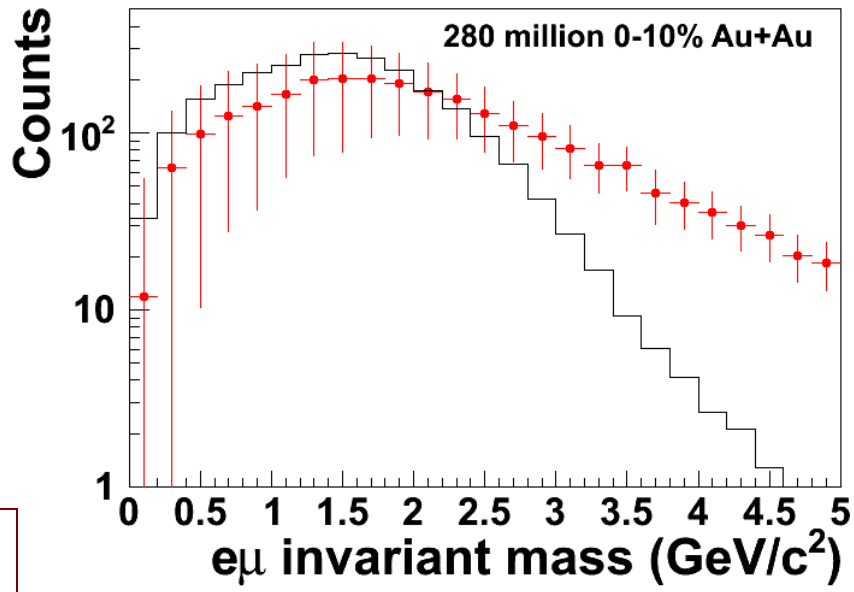
Charm Correlations with MTD

Simulation



Black: de-correlation + charm suppression

Red: PYTHIA fully correlated charm



Run-13 set-up, MTD 43%

Measure eμ correlation from ccbar using MTD:

- S/B=2 ($M_{e\mu}$ > 3 GeV/c^2 and $p_T(e\mu)$ < 2 GeV/c)
- S/B=8 with electron pairing and TOF association

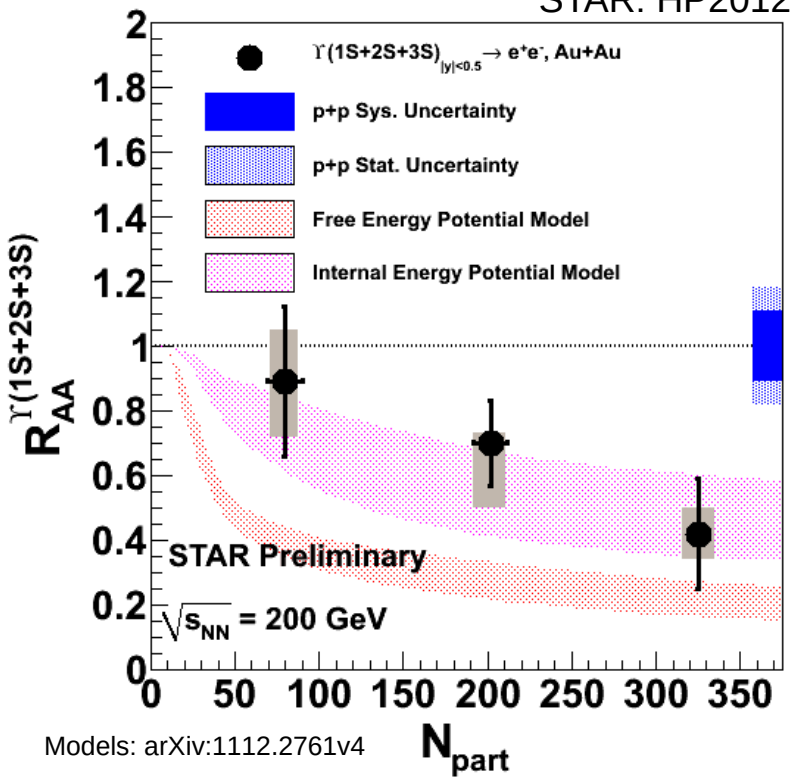
Different shape for two cases

ϒ Measurements

- ϒ is a cleaner probe compared to J/ψ
- Different states suppressed differently in QGP

Current status: Combined measurement of 1S+2S+3S states

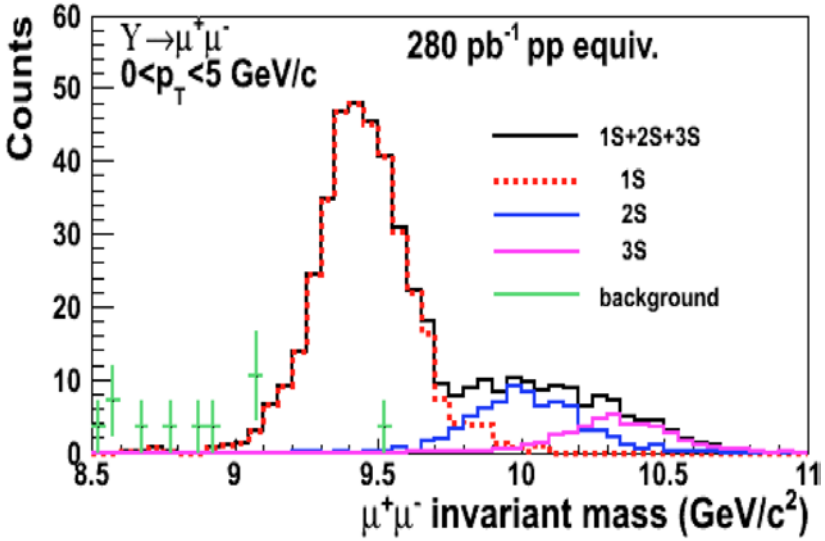
STAR: HP2012



Models: arXiv:1112.2761v4

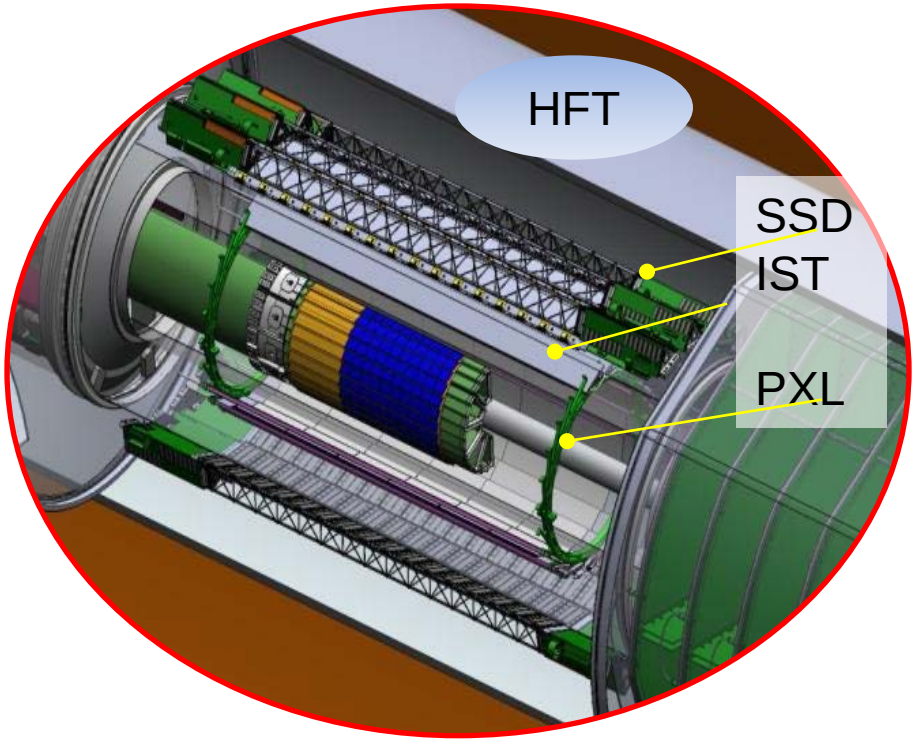
ϒ(1S+2S+3S) is suppressed

Simulation:



Possible with MTD to separate 1S from 2S+3S states

Heavy Flavor Tracker (HFT)



Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Radiation length
SSD	22	20 / 740	1% X_0
IST	14	170 / 1800	<1.5 %X_0
PIXEL	8	12/ 12	~0.4 %X_0
	2.5	12 / 12	~0.4% X_0

Four layers of silicon:

Pixels: Double layers, 10 sectors delivering good pointing resolution

SSD: existing single layer detector, double side strips

IST: one layer of silicon strips along beam direction, guiding tracks from the SSD through PIXEL detector

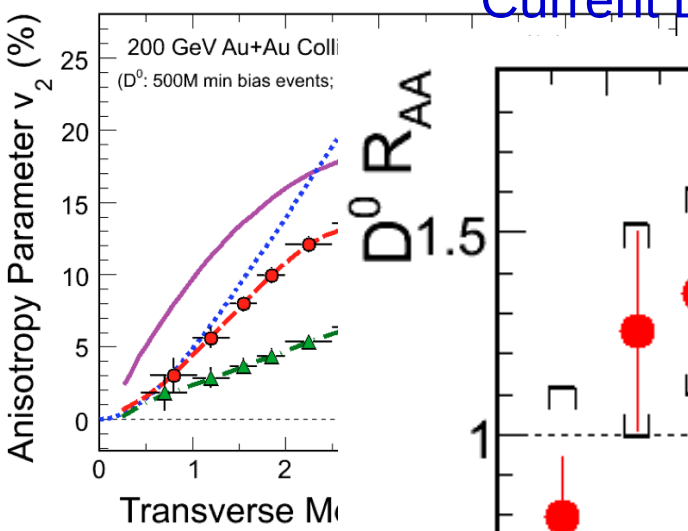
- About ~20μm dca resolution at high-p_T
- Works at high rate (800Hz-1KHz)
- Topological reconstruction of open charm

Prototype for year 2013 (only Pixel and beam pipe)

Complete for year 2014

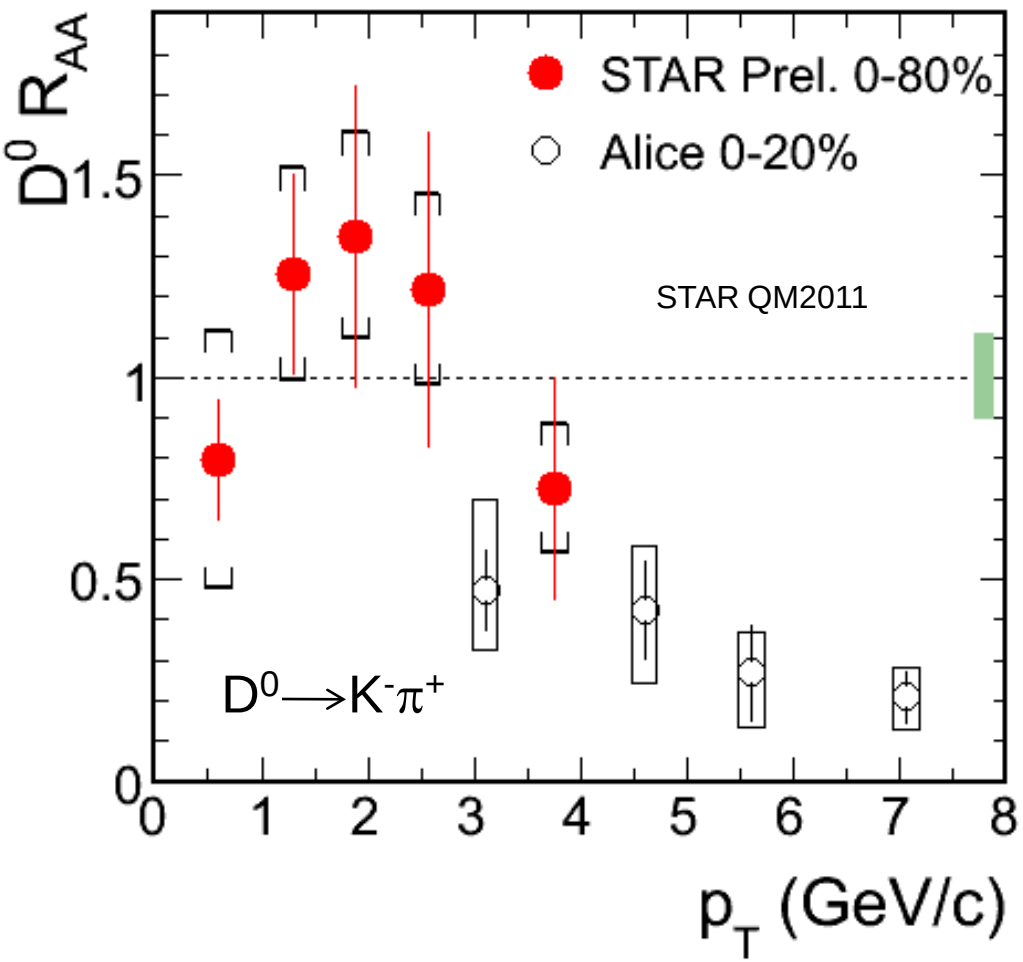
Physics using STAR HFT

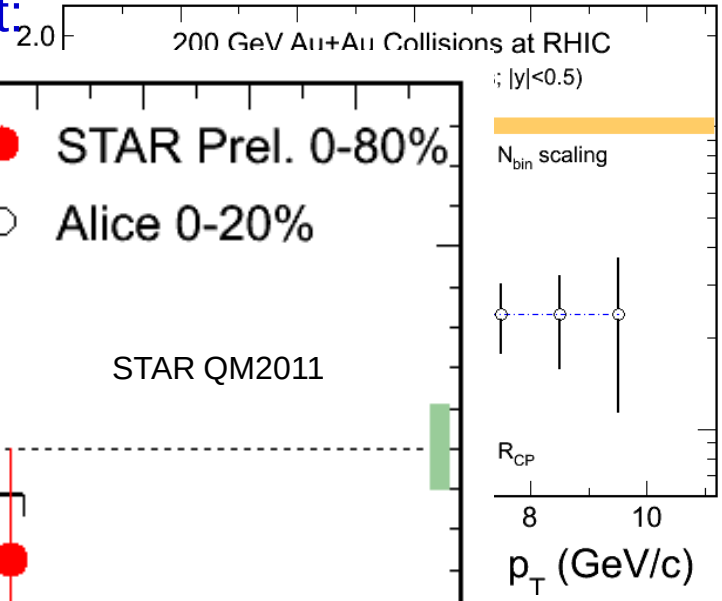
Elliptic flow:



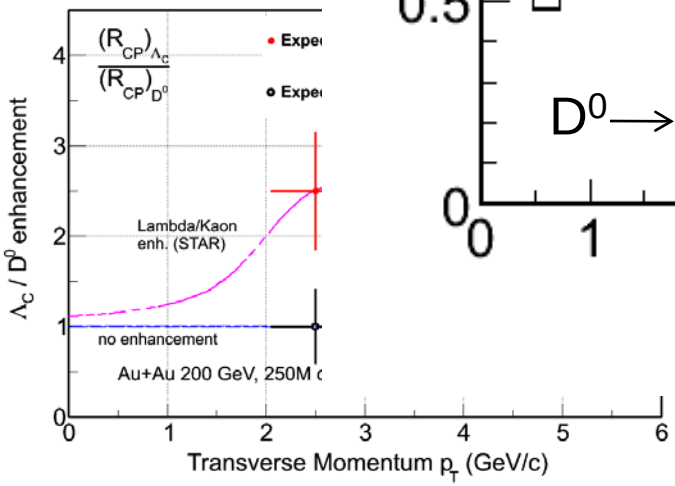
R_{cp}:

Current D^0 Result:





Baryon/Mesc



dy measured in
ge sector (Λ/K^0_s)
ce mechanism
?

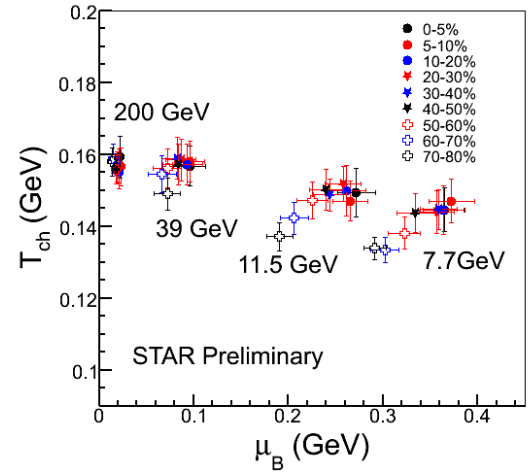
Lokesh Kumar

Beam Energy Scan Phase- II

Beam Energy Scan Phase-I

Runs	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Events(10^6)
10	39	112	130
11	27	156	70
11	19.6	206	36
10	11.5	316	12
10	7.7	420	5
12*	**5**	550	Test Run

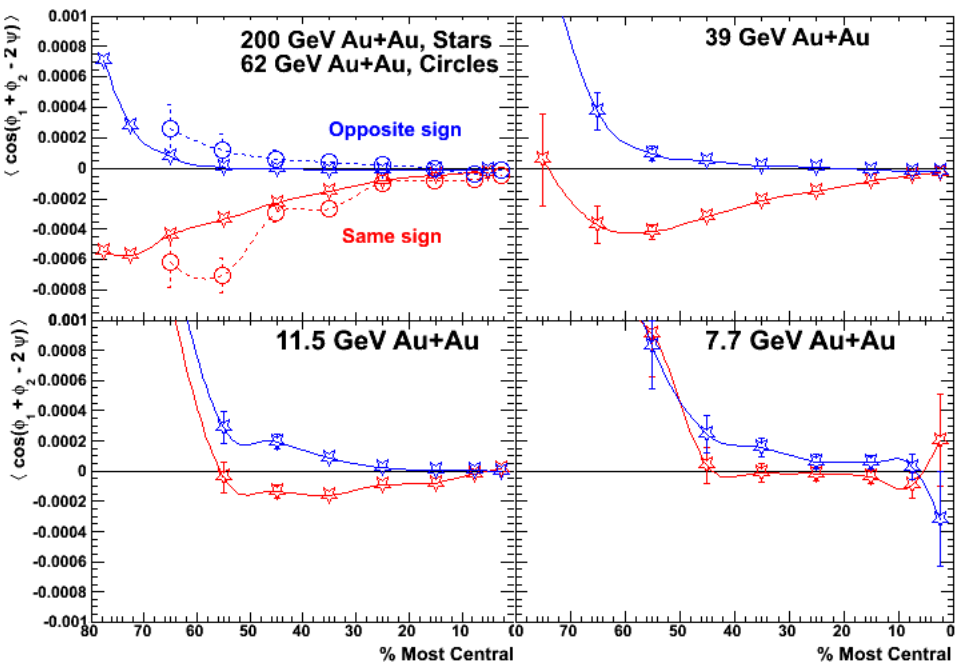
Centrality dependence of T_{ch}-μ_B:



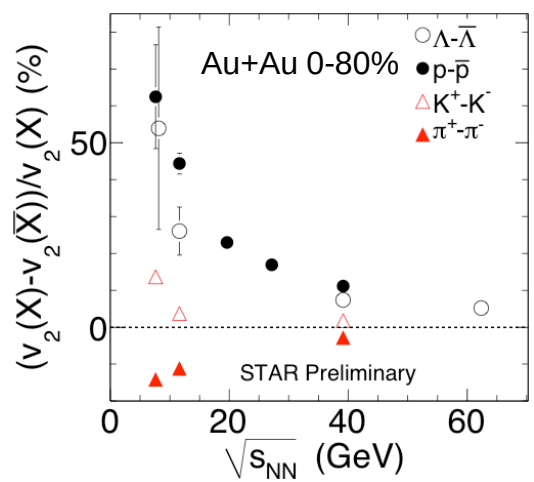
Using π,K,p ratios

STAR: CPOD2011

Dynamical charge correlations: STAR: QM2011



Particle and anti-particle v_2:



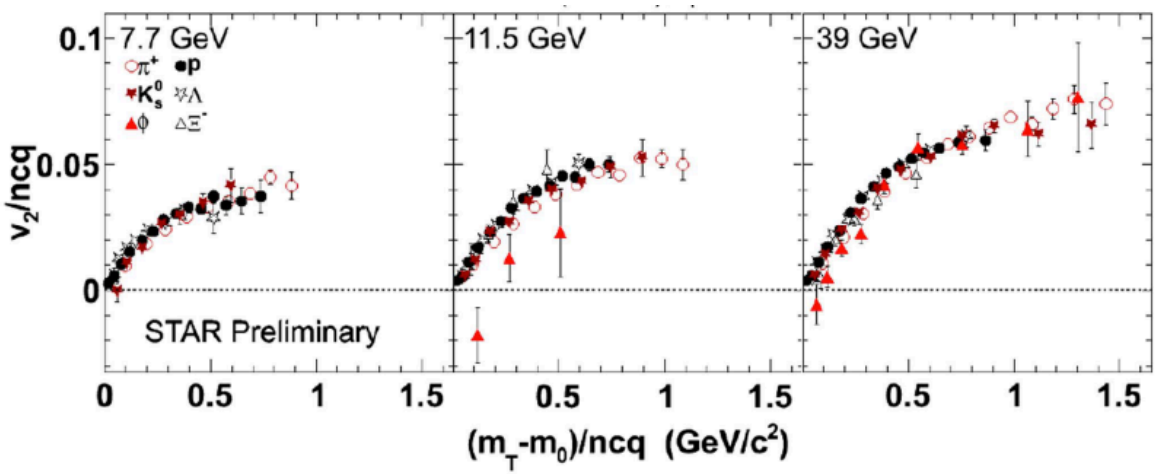
STAR: CPOD2011

Hadronic interactions dominate: low $\sqrt{s_{NN}}$

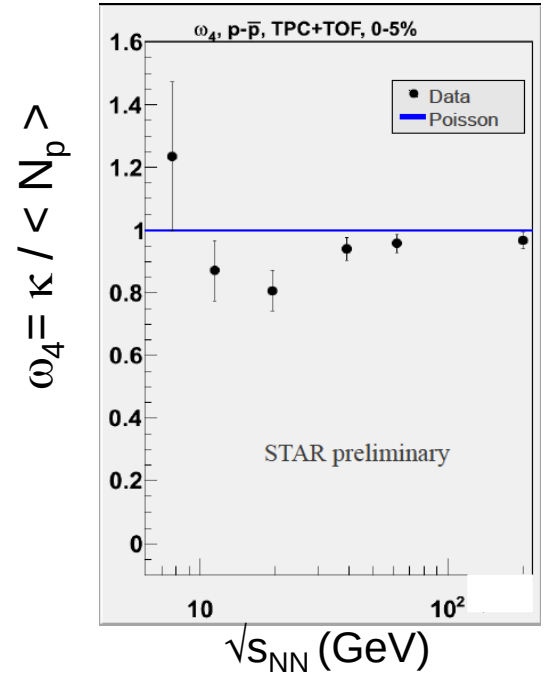
Motivation of BES-II

NCQ- scaling:

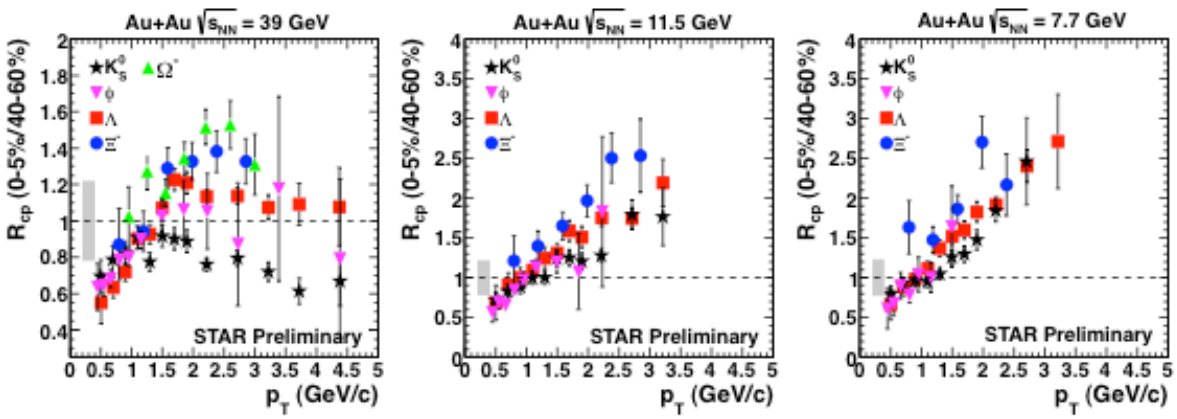
STAR:CPOD2011



Higher moments: STAR:DNP2011



R_{cp} measurements: STAR:CPOD2011



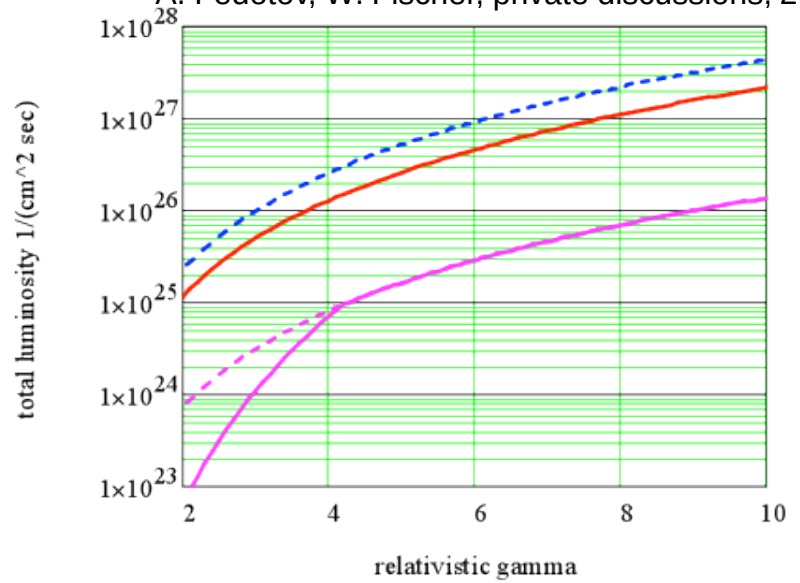
- Need higher statistics for strong conclusions at 11.5 and 7.7 GeV
- New energy point ~15GeV

➡ BES-II

BES Phase-II proposal

- ✧ Electron cooling will provide increased luminosity ~ 10 times
- ✧ Enables increased statistics for the BES energies
- ✧ Statistics enriched data for rare probes e.g. di-lepton, hypernuclei measurements

A. Fedotov, W. Fischer, private discussions, 2012.



Proposed energies for BES-II (Years 2015-2017):

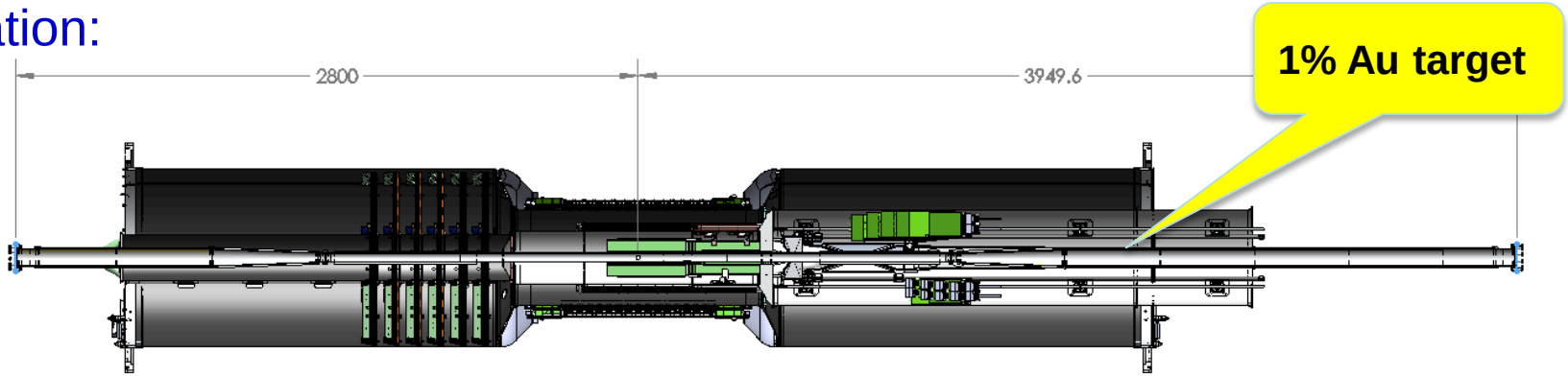
$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Requested Events(10^6)
Au+Au 19.6	206	150
Au+Au 15	256	150
Au+Au 11.5	316	50
Au+Au 7.7	420	70
U+U: ~20	~200	100

STAR in Fixed Target Mode

Details:

Means	Motivation	Advantage
Au beam hitting the fixed Au target	Compliment BES program by extending μ_B up to 800 MeV (corresponds to $\sqrt{s_{NN}}$=2.5 GeV)	No disturbance to normal RHIC operations

Configuration:



- Annular 1% gold target inside the STAR beam pipe : Need CAD help
- 2m away from the center of STAR
- Data taking concurrently with collider mode at beginning of each fill

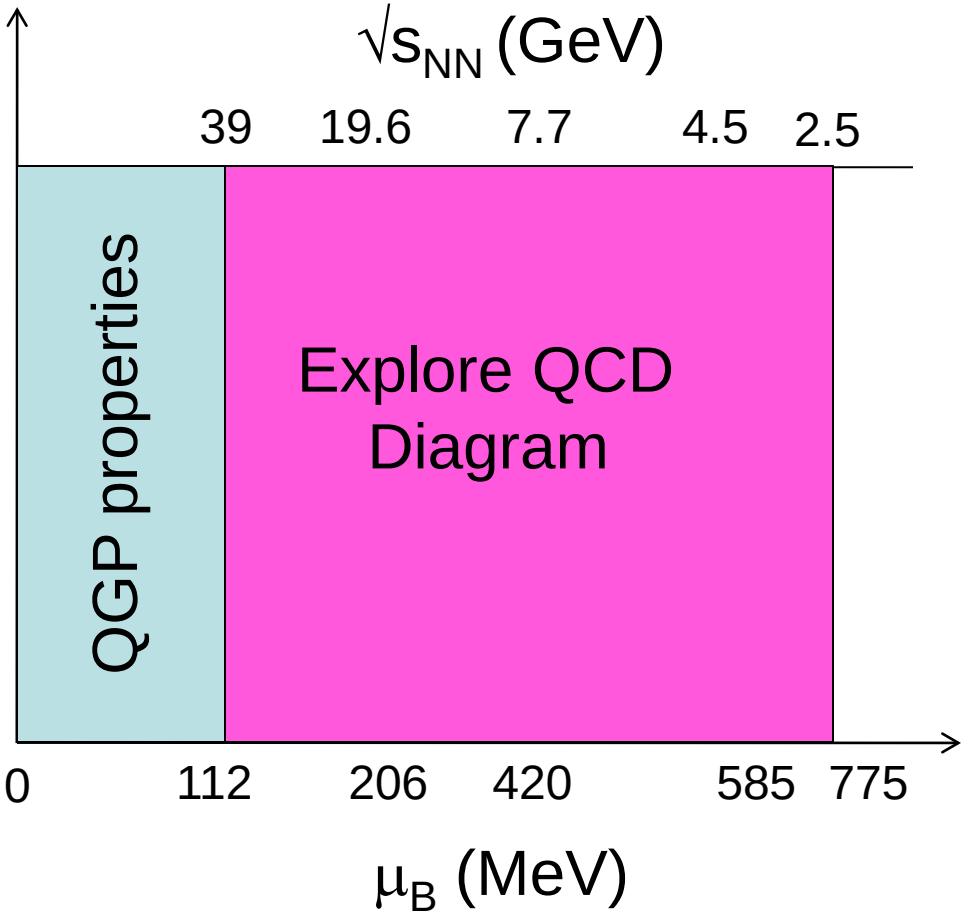
: No disturbance to normal RHIC running

Fixed Target Proposal

Energies, analyses, corresponding statistics:

Collider mode Energies (GeV)	5	7.7	11.5	*15*	19.6
Fixed Target sqrt(S_{NN}) (GeV)	*2.5*	*3.0*	*3.5*	*4.0*	*4.5*
Fixed Target μ_B (MeV)	*775*	*720*	*670*	*625*	*585*
Fixed Target y_{CM} (Acceptance 0.0 to 1.7)	*0.82*	*1.05*	*1.25*	*1.39*	*1.52*
Observables (1st order phase transition)	*Required Statistics (Mevents)*				
v_2 (up to ~1.5 GeV/c)	1.1	0.9	0.8	0.7	0.6
v_1 (Protons and Pions)	1.0	0.8	0.7	0.6	0.5
Azimuthally sensitive HBT (pions)	20	15	13	11	10

STAR Heavy-Ion Program Summary



Summary

- STAR collected about 350M minimum bias and 20M central top 1% data for U+U 193 GeV:
  - Study v_2, jet-quenching, and Chiral magnetic effect

- In addition, Cu+Au collisions at 200 GeV:
  - Study initial conditions, and jet-quenching effects

- STAR focus in Run13-14: ***Study QGP Properties***
  - Dilepton and heavy-flavor physics with fully installed MTD and HFT
  - Plan: Measure charm correlation, quarkonia, D^0-meson v_2, R_{cp} and $\Lambda_c/D^0(p_T)$

- BES-II: ***Explore QCD Phase Diagram***
  - With e-cooling, propose high statistics data below 20 GeV
  - Consolidate the BES phase-I findings

- Fixed Traget Mode: ***Concurrent Running with Collider***
  - Extend μ_B coverage up to 800 MeV (No separate request !)

Thanks

Thanks to STAR Collaboration

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Thank You
CAD

Back up

STAR Request Run-12

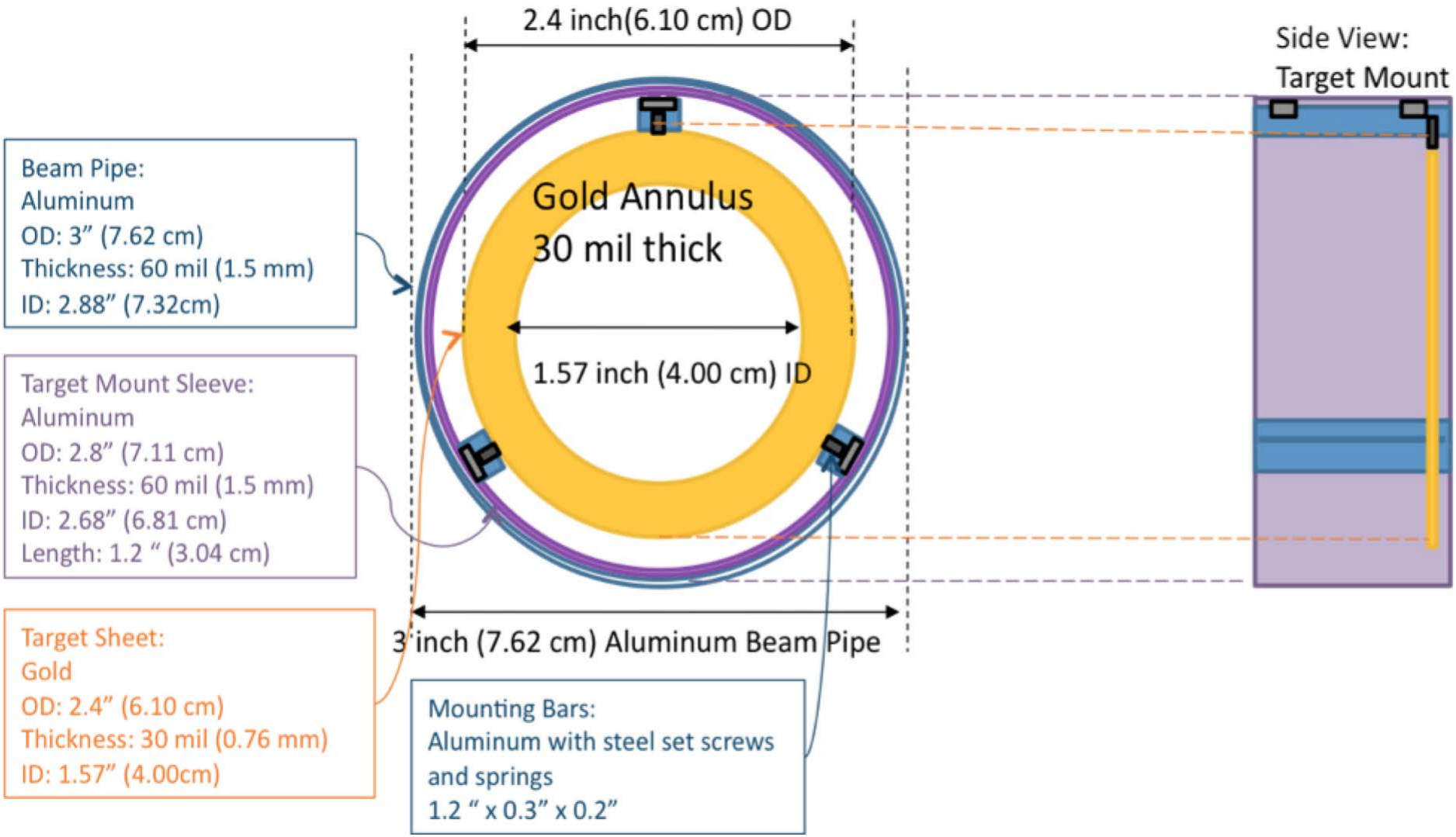
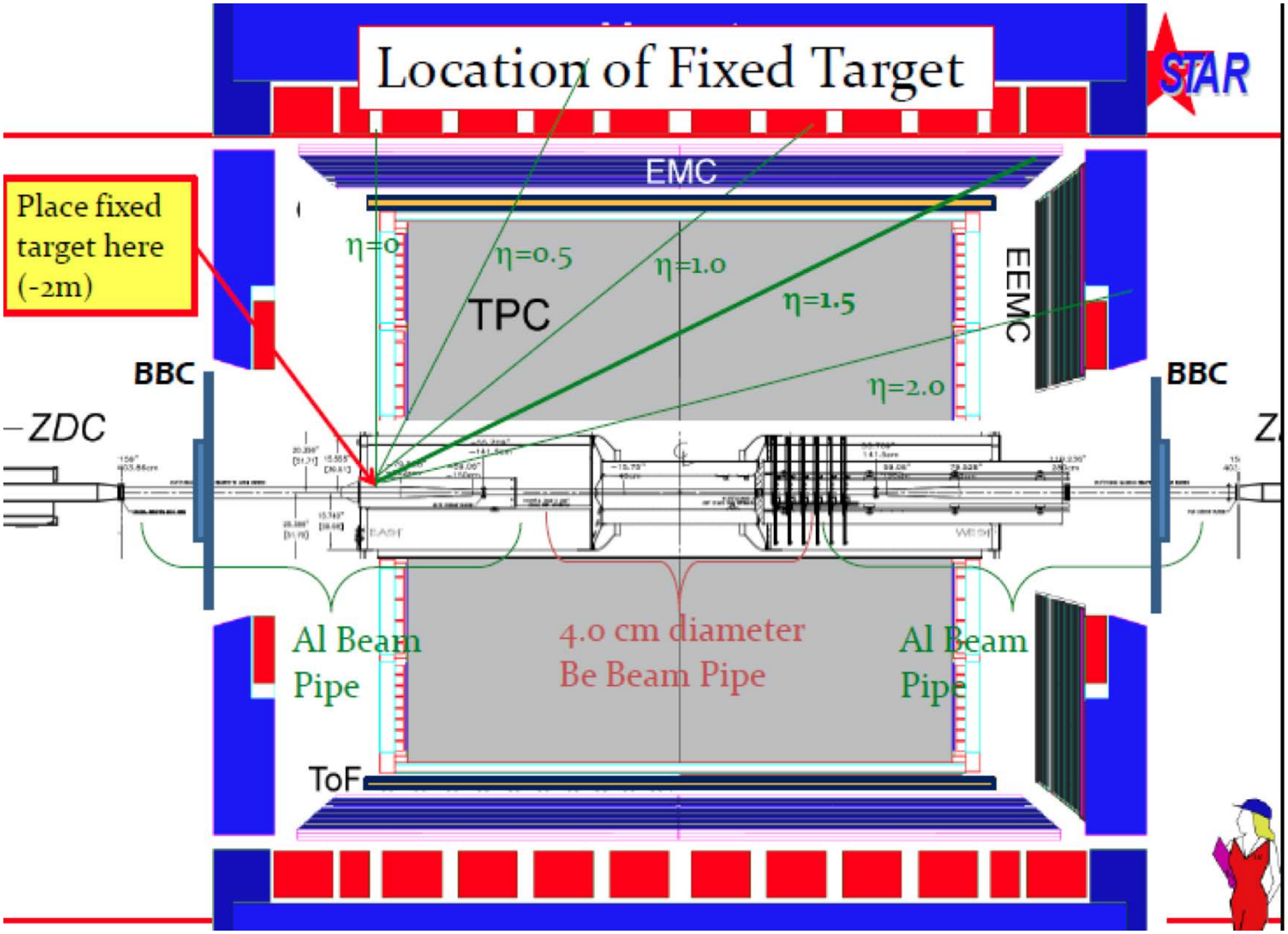
STAR Request:

Run	Energy	System	Time	Goal
12[2]	$\sqrt{s}$ = 500 GeV[b]	$p_{\rightarrow} p_{\rightarrow}$ or $p_{\rightarrow} p_{\rightarrow}$	10 weeks	~30 pb^{-1} long. 15 pb^{-1} transverse
	$\sqrt{s}$ = 200 GeV[c]	$p_{\uparrow} p_{\uparrow}$	10 weeks	40 pb^{-1} longitudinal 30 pb^{-1} transverse
	$\sqrt{s_{NN}}$ =200 GeV	U + U or Au+Au	10 weeks	3.5 nb^{-1} U+U or 5 nb^{-1} Au+Au

PAC Recommendations:

Energy ($\sqrt{s_{NN}}$ GeV)	System	Time
200 GeV	Polarized pp	5 weeks
500 GeV	Polarized pp	7 weeks
200 GeV	Cu+Au	5 weeks
193 GeV	U+U	3 weeks

Fixed Target Specifications



Fixed Target Set-up