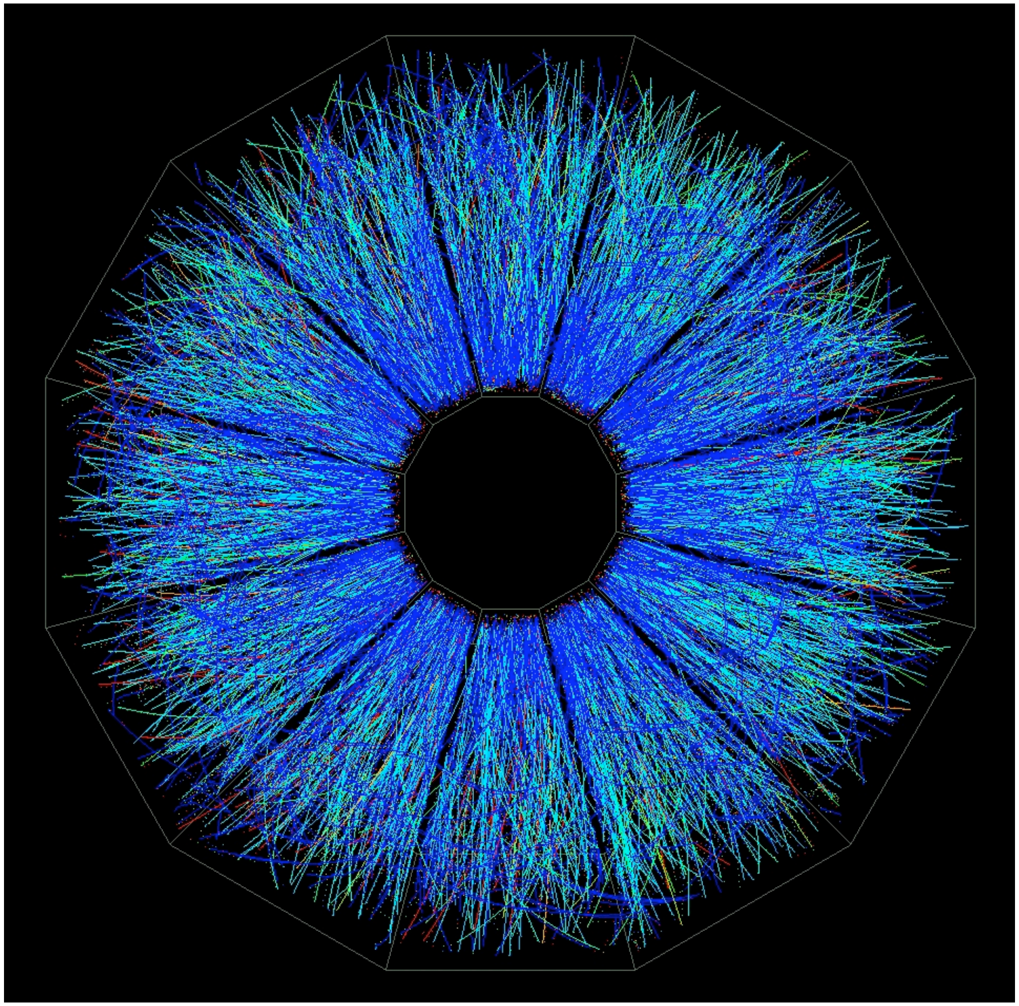
STAR BUR Run 10 and 11



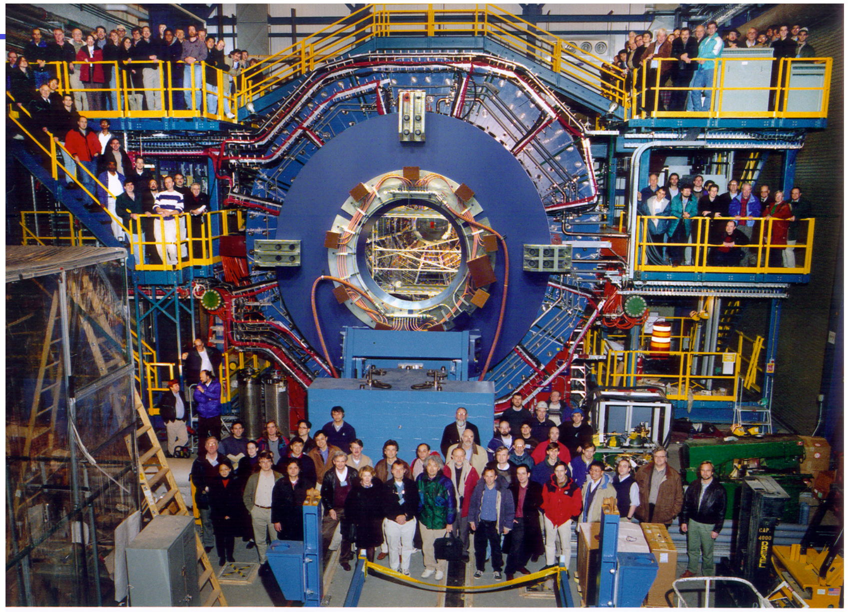
James Dunlop

Brookhaven National Laboratory

Outline

- Performance Run 9
- Run 10 Beam Use Request
  - Search for the QCD Critical Point in Au+Au
  - Quantitative studies Au+Au 200 GeV with DAQ1000 and ToF
- Run 11 Beam Use Request
  - Return to Spin Program
  - U+U collisions for hydrodynamic studies at 200 GeV
  - Studies of gluonic matter with pp2pp

STAR Collaboration Membership



U.S. Labs: Argonne, Lawrence Berkeley, and Brookhaven
U.S. Universities: UC Berkeley, UC Davis, UCLA, Carnegie Mellon, Creighton, CCNY, Indiana, Kent State, MSU, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT, Kentucky, Old Dominion U
Brazil: Universidade de Sao Paulo, Universidade Estadual de Campinas
China: IHEP, IOPP, USTC, Tsinghua U., SINAP, IMP, ShanDong U
Croatia: Zagreb University
Czech Republic: Institute of Nuclear Physics, Czech Technical U.
England: U. of Birmingham
France: SUBATECH
Germany: Max Planck Institute, Frankfurt (BES)
India: IOP, Bhubaneswar, Jammu U., IIT-Mumbai, Panjab U., Rajasthan U., VECC
Netherlands: NIKHEF
Poland: Warsaw University of Technology
Russia: MEPHI, LPP/LHE JINR – Dubna, IHEP – Protvino, ITEP
South Korea: Pusan National U., KISTI

Six new institutes joined in 08-09

New institute has applied for the membership:
- HIT, China: two-particle correlation

12 countries
56 institutes
~ *620* scientists and engineers

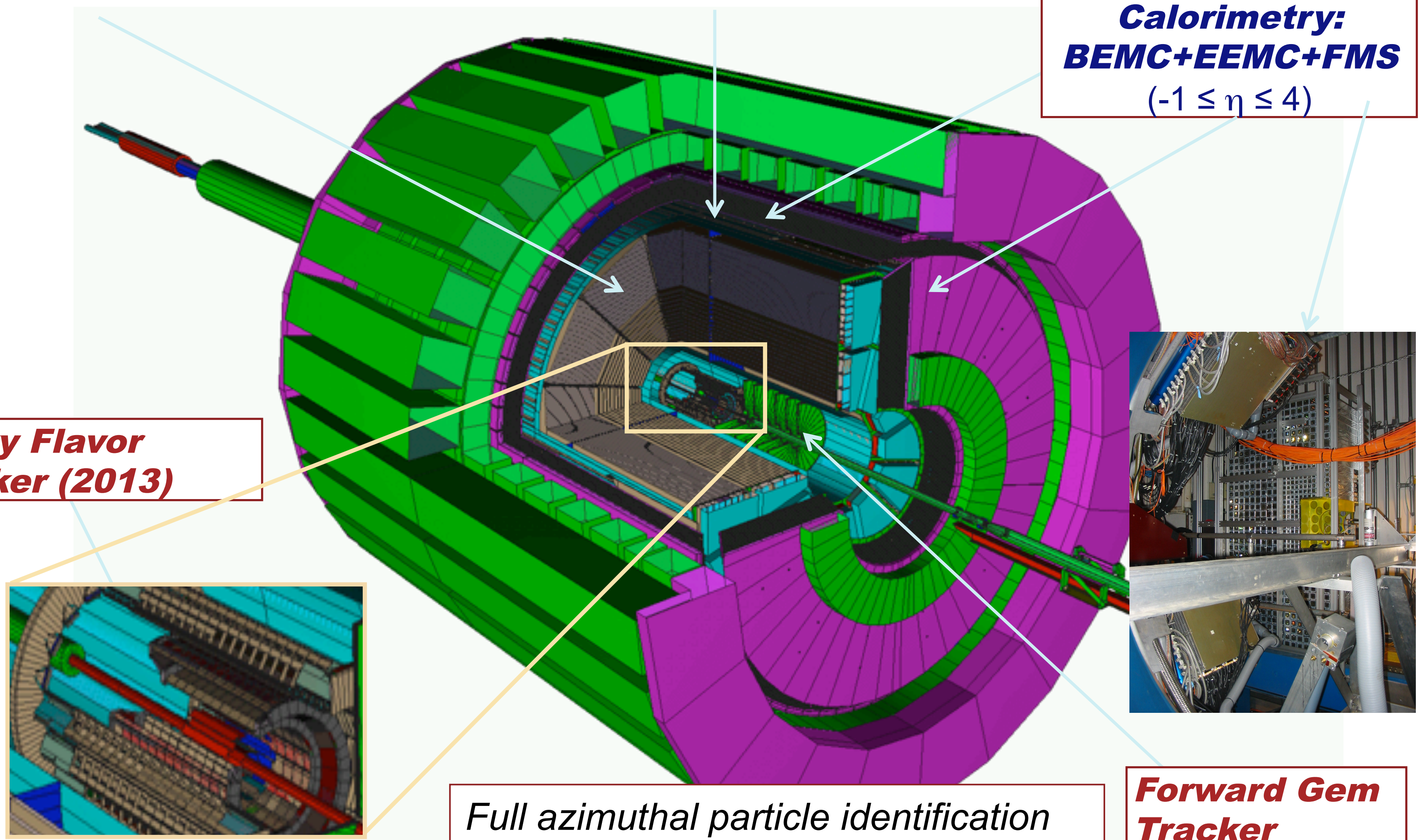
Research topics at the QCD Lab:
- properties of strongly interacting matter
- proton spin structure
- gluonic matter

STAR: A Correlation Machine

Tracking: TPC

Particle ID: TOF

Electromagnetic Calorimetry: BEMC+EEMC+FMS
$(-1 \leq \eta \leq 4)$



Heavy Flavor Tracker (2013)

Forward Gem Tracker (2011)

Full azimuthal particle identification over a broad range in pseudorapidity

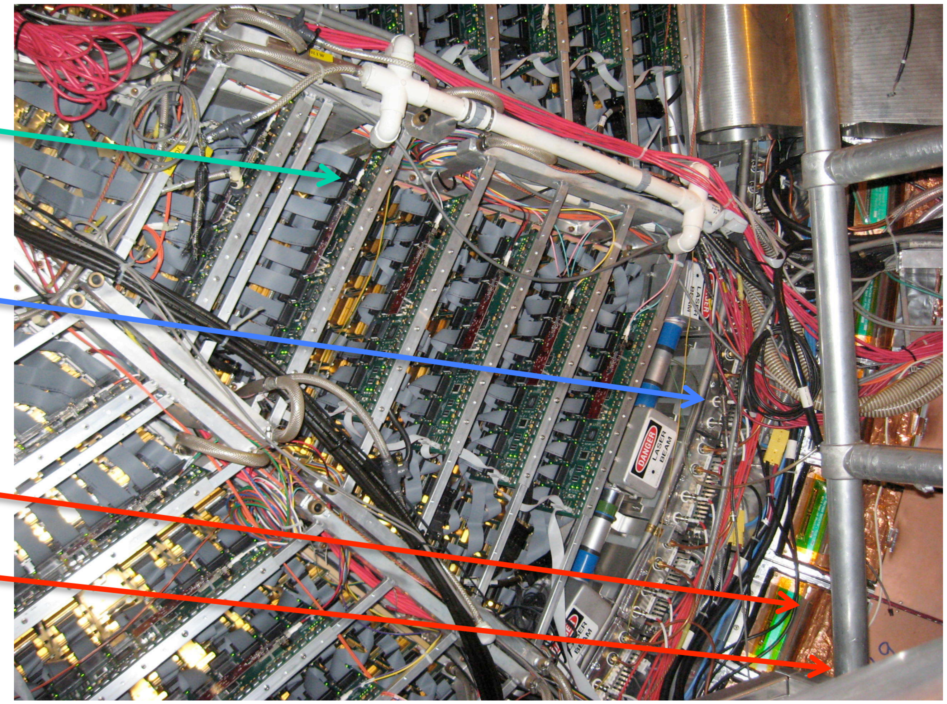
Changes for Run 9

- Major changes in the detector: Fully commissioned

Time Projection Chamber DAQ1000:
replacement of entire electronics chain

Time of Flight: 75% of trays in place
First run with more than ~few trays

Electromagnetic Calorimeter:
- Shower Max: modification of electronics to decrease deadtime
- Towers: rewire trigger to increase jet efficiency

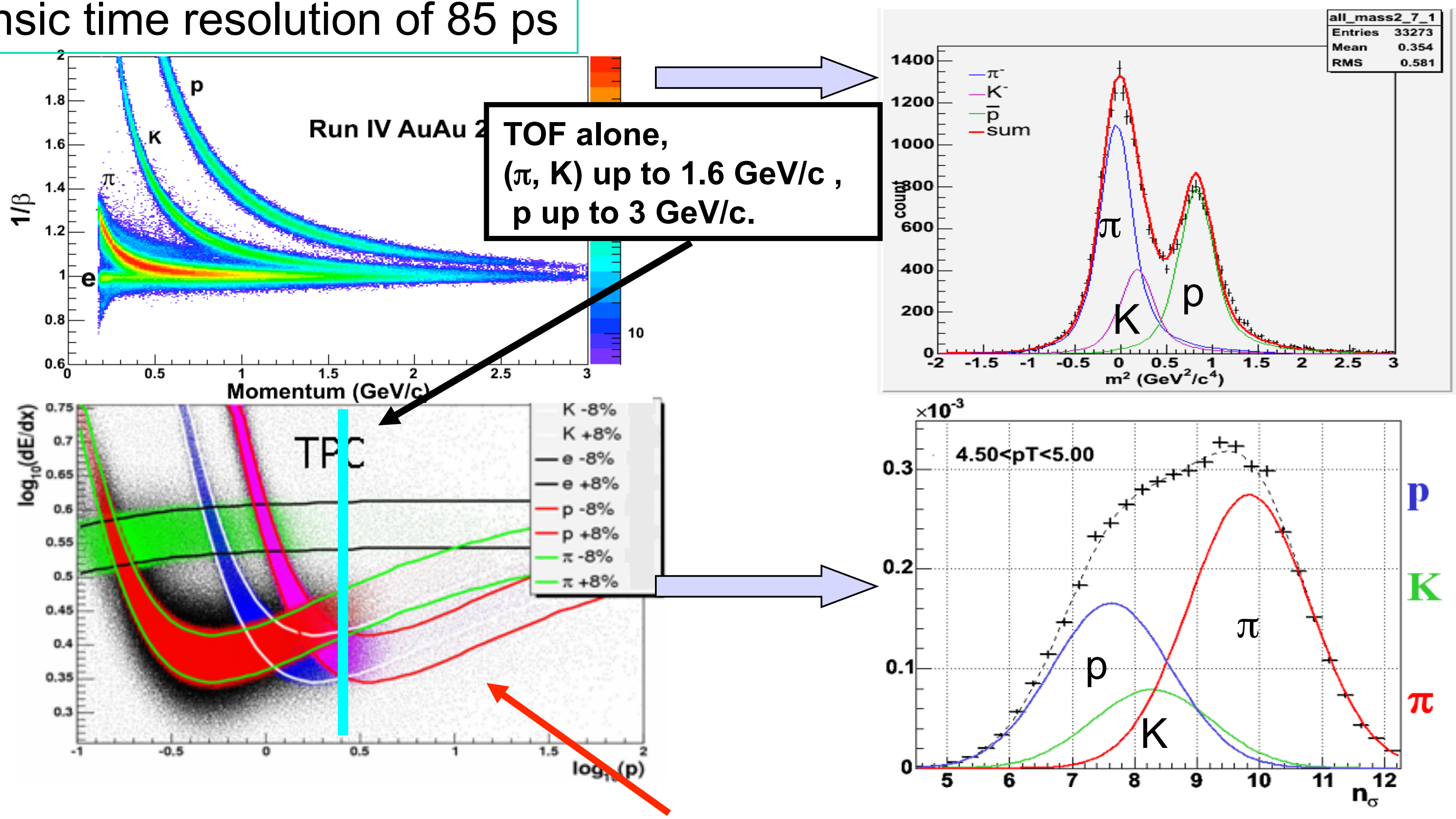


Trigger: New electronics (QT boards) for basic detector systems (BBC, ZDC, etc.)
- New Trigger Control Unit for greater flexibility (not fully commissioned)

Overall goal: increase sampled/delivered ratio by lower deadtime
Largely successful: >90% livetime, best fills ~70% efficiency
Have sampled 50% of delivered $\mathcal{L}$ since May 7, as projected

Performance of STAR ToF

Intrinsic time resolution of 85 ps

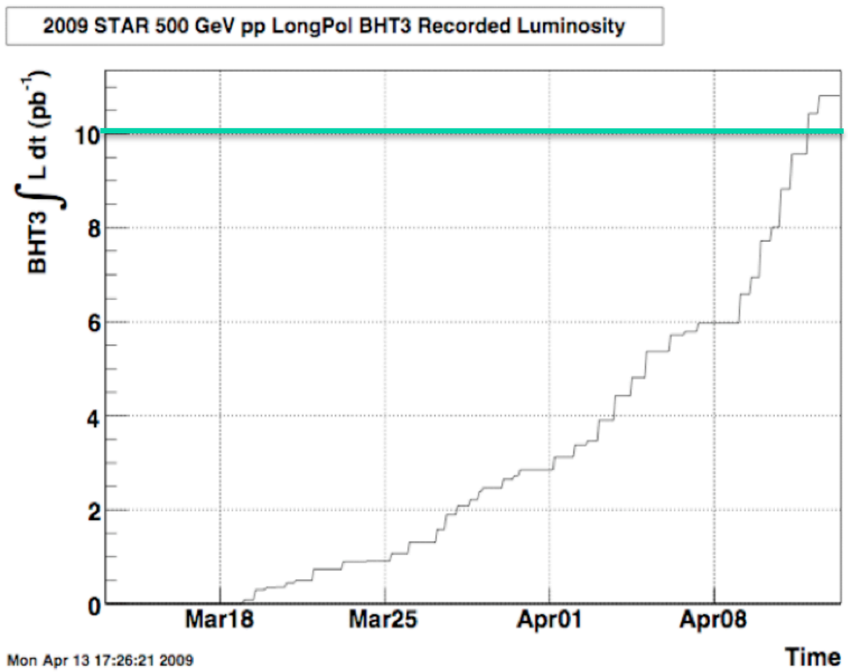


TOF+dE/dx+relativistic dE/dx (π ,p) from 0.2 up to 12 GeV/c

M. Shao et al., NIMA **558**, (419) 2006

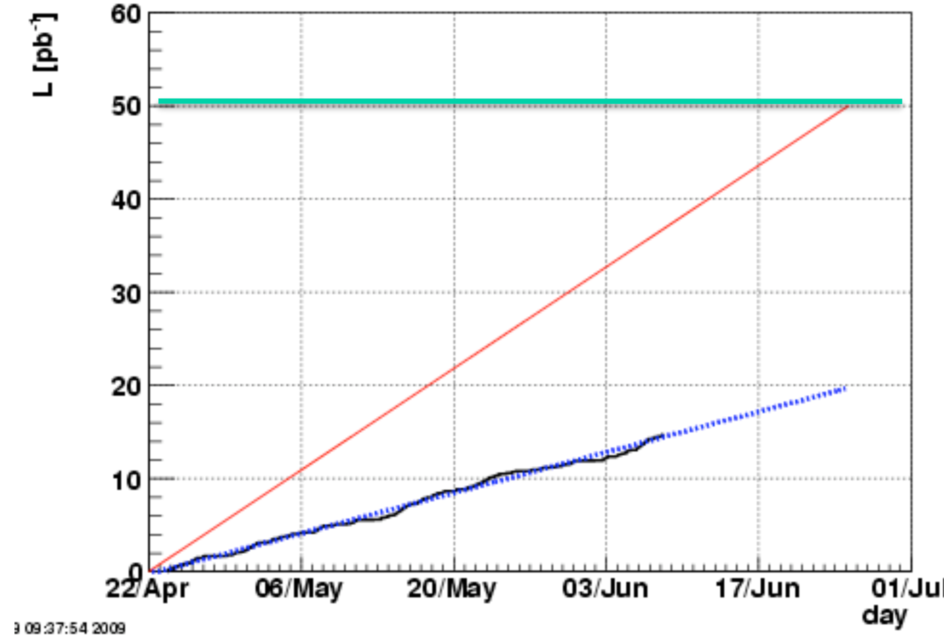
Datasets in Run 9

$\sqrt{s}$ = 500 GeV



- Goal: $\mathcal{L}$:10 pb^{-1}, $P^2\mathcal{L}$: 2.5 pb^{-1}
- $\mathcal{L}$ goal reached
  - expect W Jacobian peak
- Polarization an issue
  - No significant A_L expected

$\sqrt{s}$ = 200 GeV



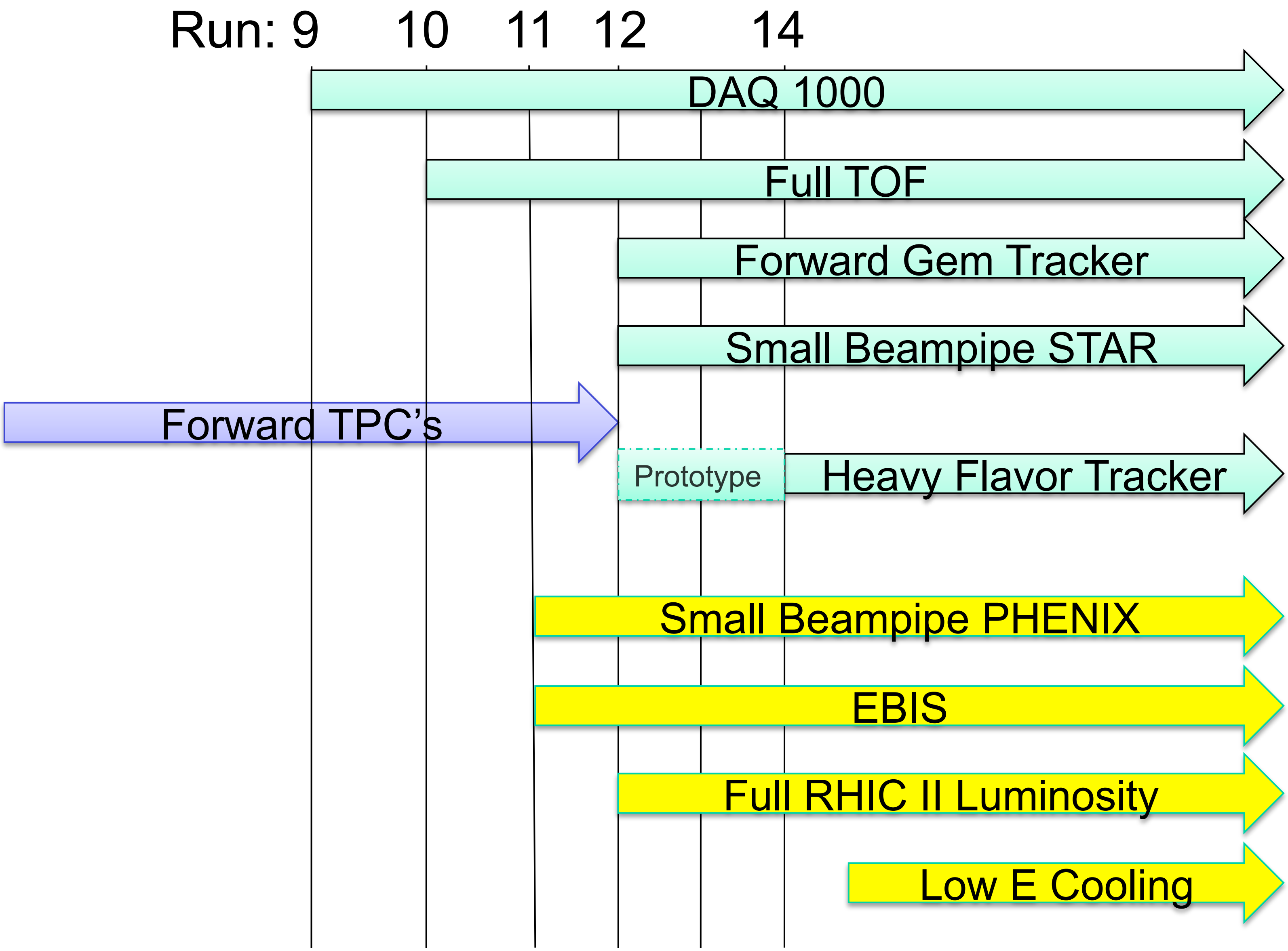
- Goal: $\mathcal{L}$: 50 pb^{-1}, $P^4\mathcal{L}$: 6.5 pb^{-1}
- Expect: $\mathcal{L}$ ~40%, $P^4\mathcal{L}$ ~30%
- Minbias reference: x10
- Will need to return in Run 11

500 GeV: Lessons learned

- Higher Luminosity → Stress on TPC
  - Acute aging: high voltage trips
    - Largely alleviated by decreasing gain: made possible by DAQ1000
  - Chronic aging: total integrated charge on wires
    - Studies ongoing to project from Run 9 into the future

- TPC Review on June 4-5 2009 with outside experts
  - 500 GeV: no showstoppers, but careful study and plans needed
  - Detailed recommendations for study and possible alleviation scenarios will come from the review

Timeline for upgrades



Run 10: Critical Point Search

Run	Energy	System	Time	Goal
10[1]	$\sqrt{s_{NN}}$=7.7-39 GeV	Au + Au	16 weeks	Critical Point search
	$\sqrt{s_{NN}}$ = 5 GeV	Au + Au	1 week[a]	Commissioning and first look at data
	$\sqrt{s_{NN}}$ = 200 GeV	Au + Au	8 weeks	250M central 300M minbias 2 nb^{-1} sampled
11[2]	$\sqrt{s}$ = 200 GeV[b]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$	13 weeks	~30 pb^{-1} long.[d] 15 pb^{-1} transverse
	$\sqrt{s}$ = 500 GeV[c]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$		15 pb^{-1} longitudinal 6.5 pb^{-1} transverse
	$\sqrt{s}$ = 200 GeV	$p_{\rightarrow} p_{\rightarrow}$	5 days	pp2pp at high β*
	$\sqrt{s_{NN}}$ =200 GeV	U + U	4 weeks[e]	400M events

(1) 30 cryo weeks, 25 weeks production with one species
(2) 25 cryo weeks, 18 weeks production with two species.
(a) C-AD test for higher luminosity at the lower energy
(b) 60% or higher polarization in both yellow and blue rings is needed.
(c) 50% or higher polarization in both yellow and blue ring is needed.
(d) Request is to finish the minimum 50 pb^{-1} goal and make progress towards the portion of the long-term goal of 80 pb^{-1} at 60% polarization remaining after Run 9 is completed
(e) Contingent on EBIS operation at moderate rates (5-10 kHz)

Critical Point Search

RHIC Flagship

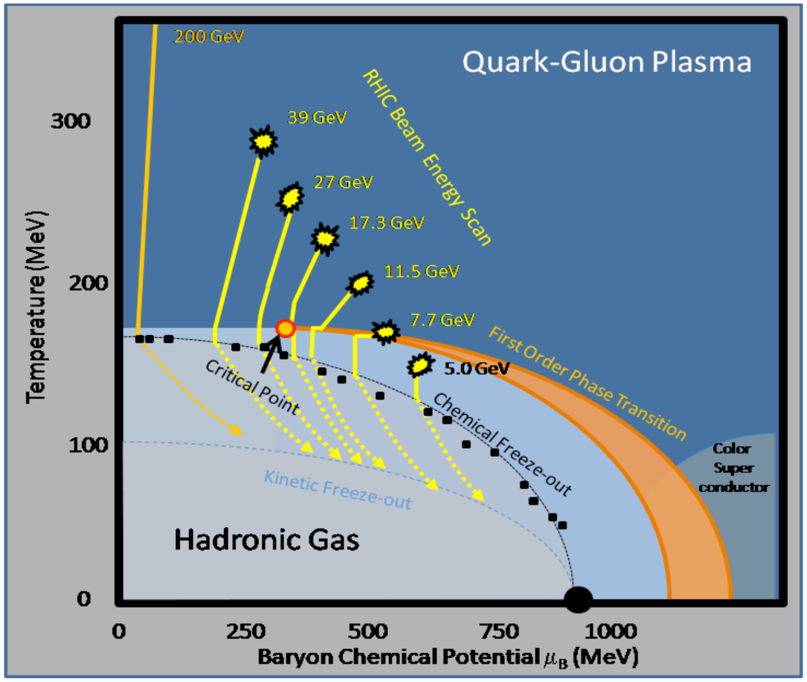
Time is now

Fall 2008

Collaborating for a "Perfect" Scan of Nuclear Matter

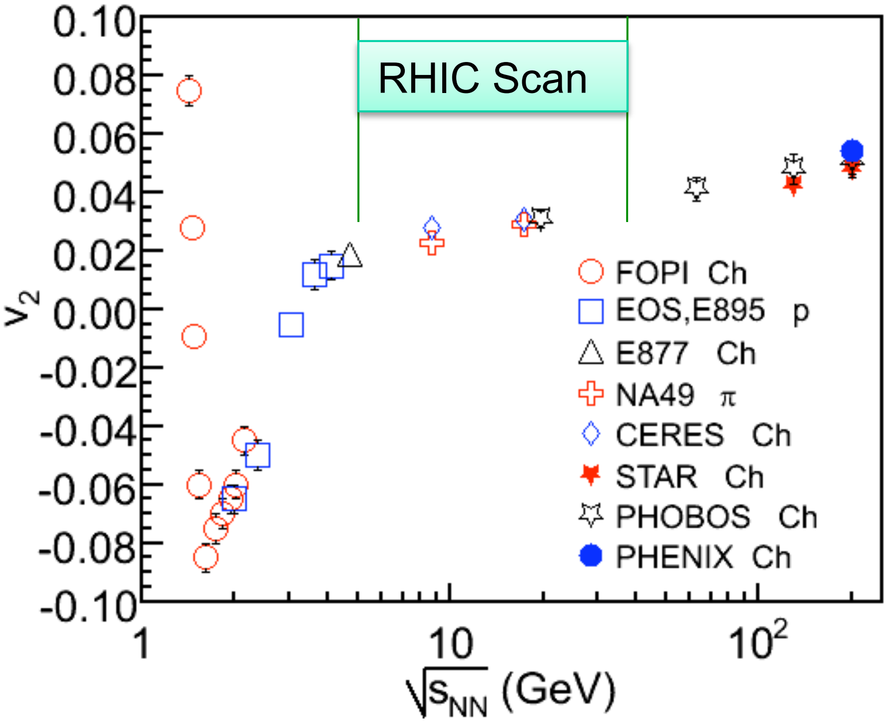
COLLABORATING FOR A "PERFECT" SCAN OF NUCLEAR MATTER

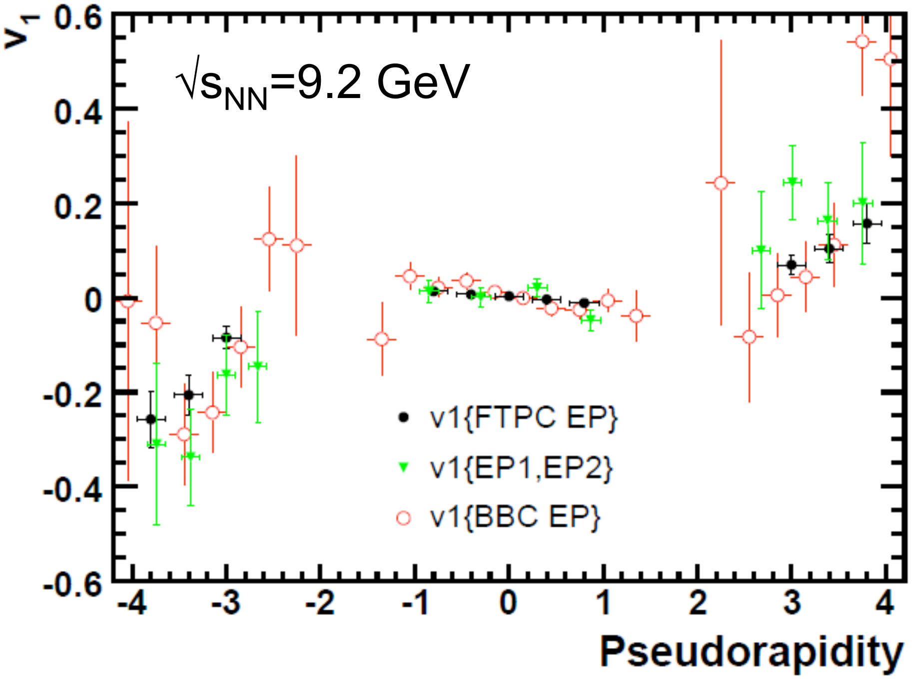
Strategy: Critical Point Search in Run 10



- 1^{st} order phase transition: bracket location of the Critical Point
  - Hydrodynamics: v_1, v_2, azimuthally sensitive HBT for EOS softest point
- Direct signatures of Critical Point via enhanced fluctuations
  - Large-acceptance identified particle fluctuations and correlations
- Need data samples sufficient for definitive measurements

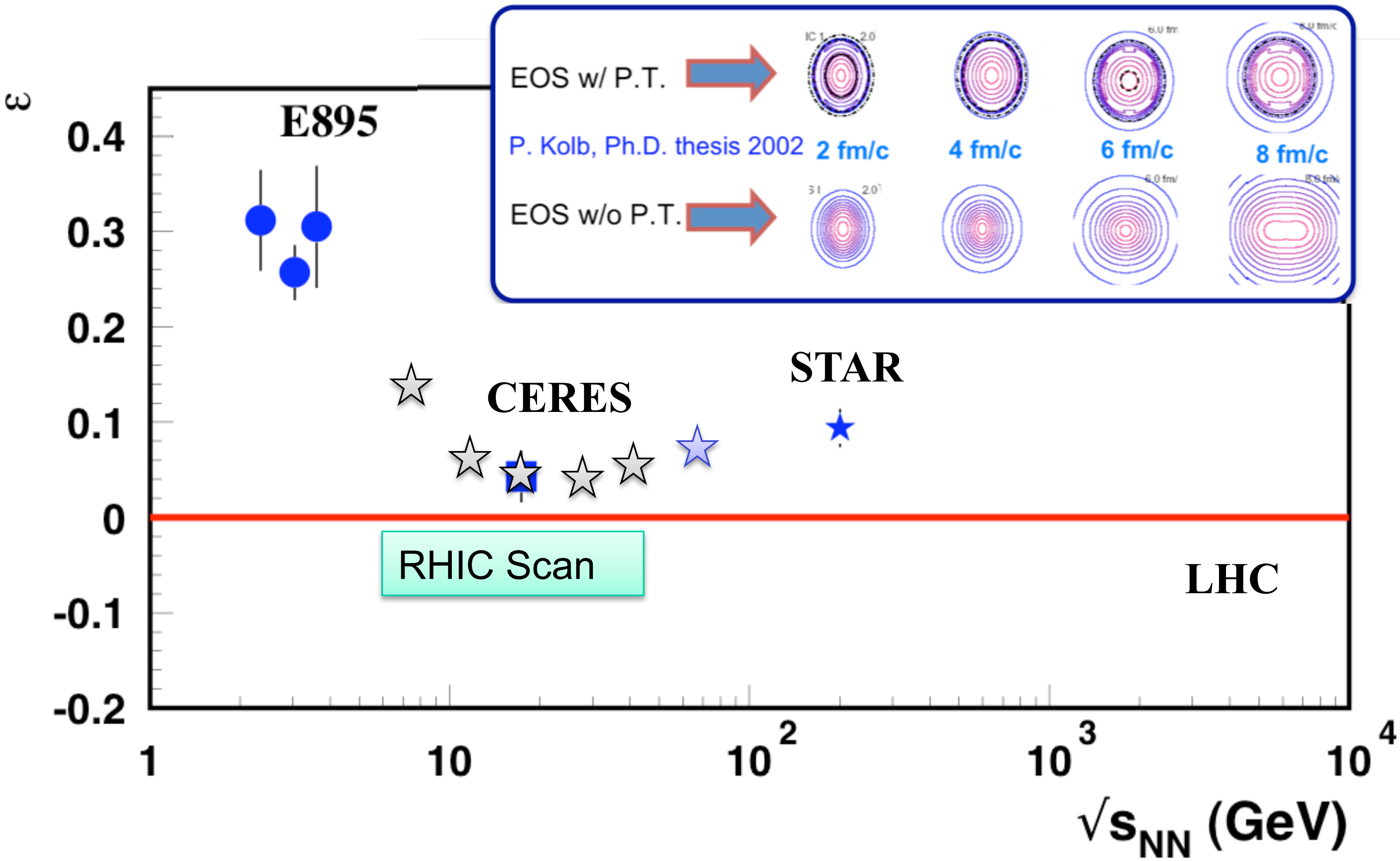
1st order: Elliptic and Directed Flow





- Search for flow signatures of softest point in EOS
  - v_2: no gross signature, but possibility in more differential measurements
    - e.g. collapse of proton elliptic flow [SPS]
  - v_1: shape vs. rapidity. "Wiggle" a phase transition signature

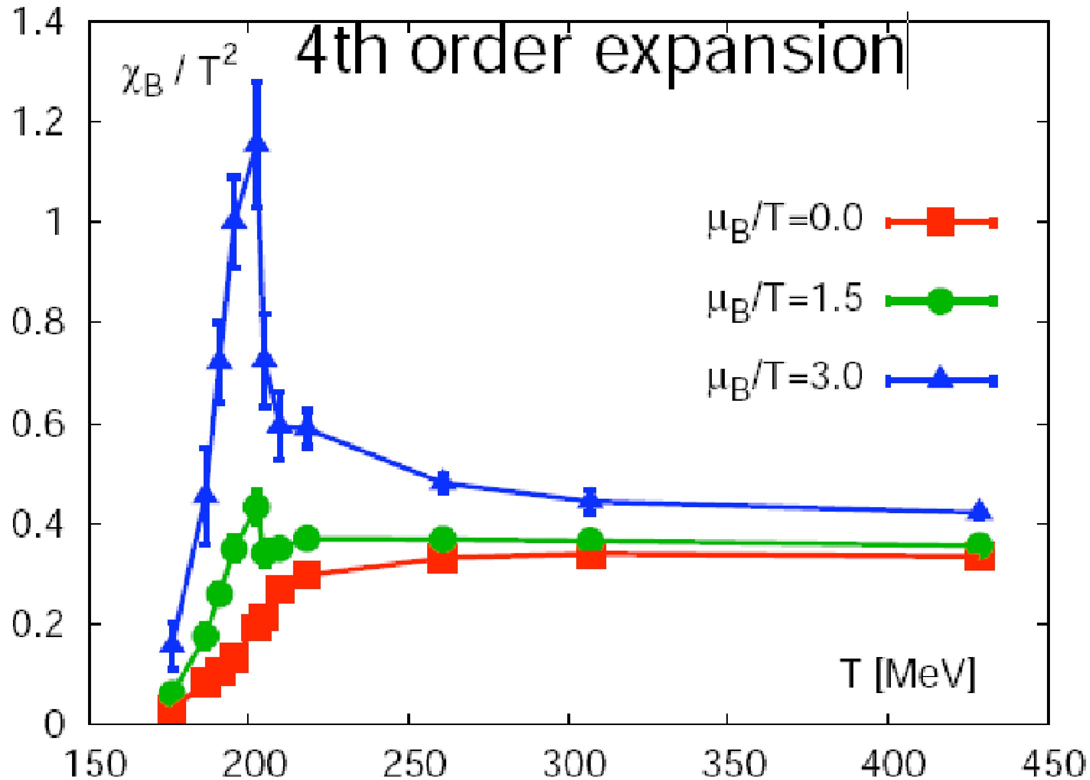
1st order: HBT vs Reaction Plane



Non-monotonic behavior would indicate a softest point: 1st order

Need: 4M events at each energy (e.g. ~3σ STAR-CERES)

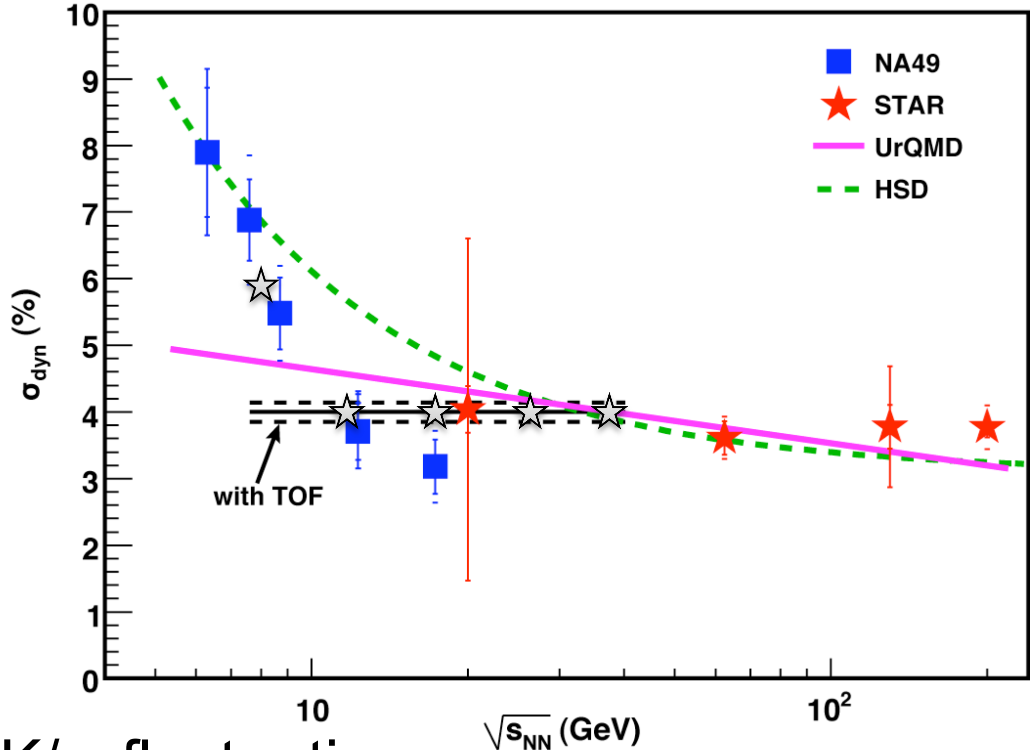
Fluctuations: direct signature of Critical Point



- Critical point in Lattice QCD: divergence of susceptibilities
- Divergence of susceptibilities → large fluctuations
- Search for non-monotonic behavior in fluctuation measures

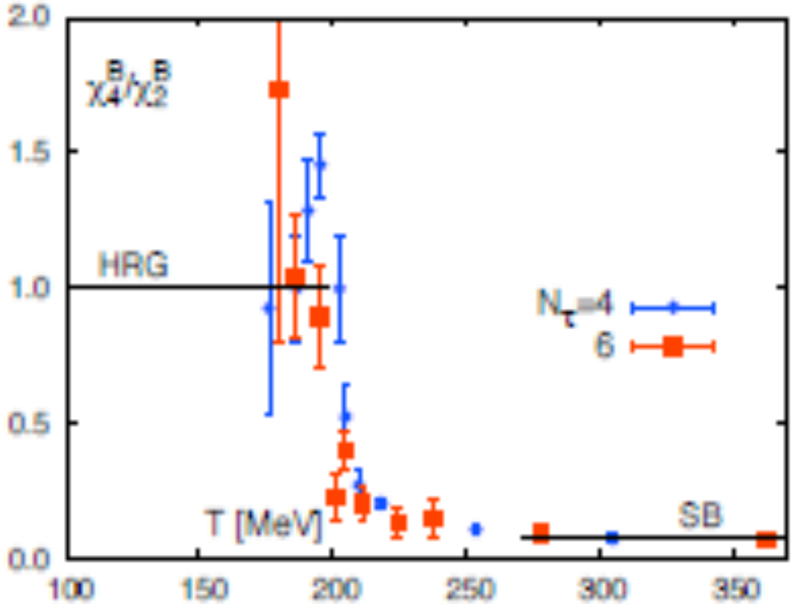
Identified particle fluctuations

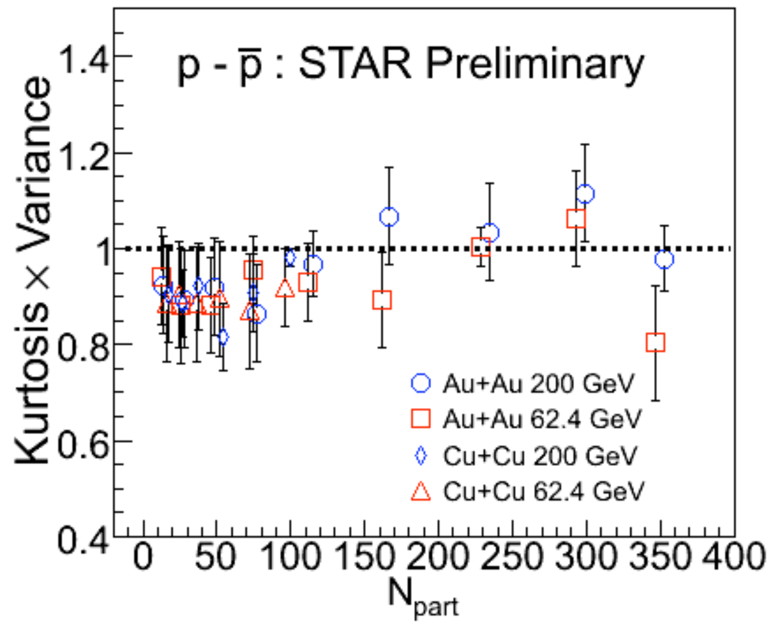
$(K^{+}+K^{-})/$
$(\pi^{+}+\pi^{-})$



- Example: K/π fluctuations
  - Rise in NA49 data not explained by models
- STAR: Full PID, large acceptance uniform over $\sqrt{s_{NN}}$
- Unprecedentedly accurate and differential measurements possible
- Need 5M events: lowest energy most promising

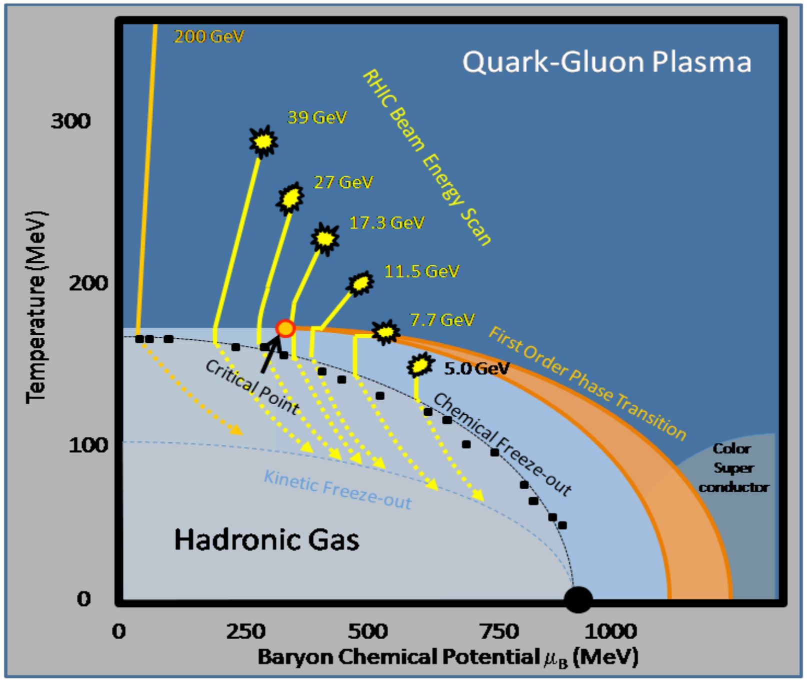
Higher orders: Kurtosis





- Higher order moments: potentially more sensitive
  - Sensitive to the 7th power of correlation length
- Studies in current data establish baseline for interpretation
- Need: 5M events at each energy (Kurtosis*Variance ±0.1)

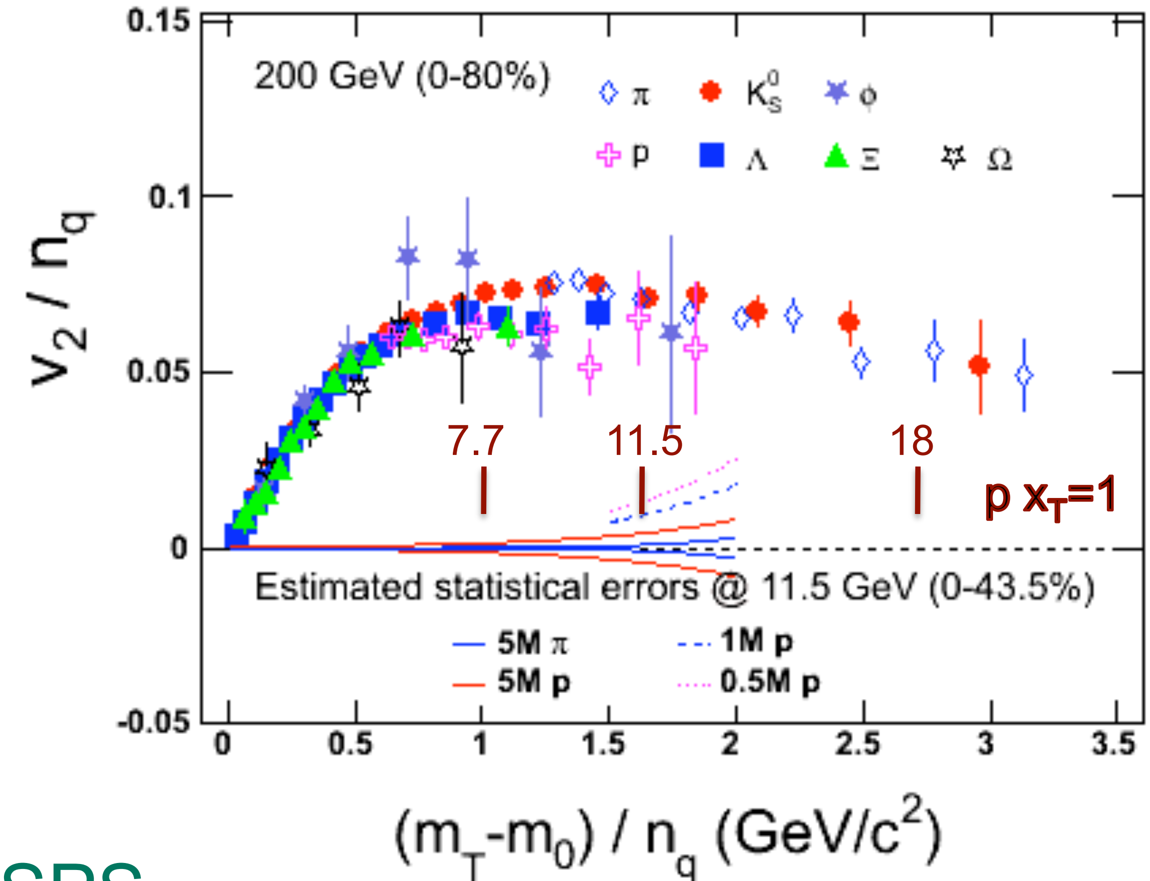
Turn-off of QGP Signatures



- Search for onset of signatures of new phenomena discovered at highest RHIC energy
  - Number of constituent quark scaling in v_2: partonic collectivity
  - Hadron suppression: opacity
  - “Ridge”: pair correlations extended in pseudorapidity
  - Local parity violation

Partonic collectivity

- v_2 scales as $n_q \rightarrow$ partonic degrees of freedom
- Where does partonic collectivity break down?

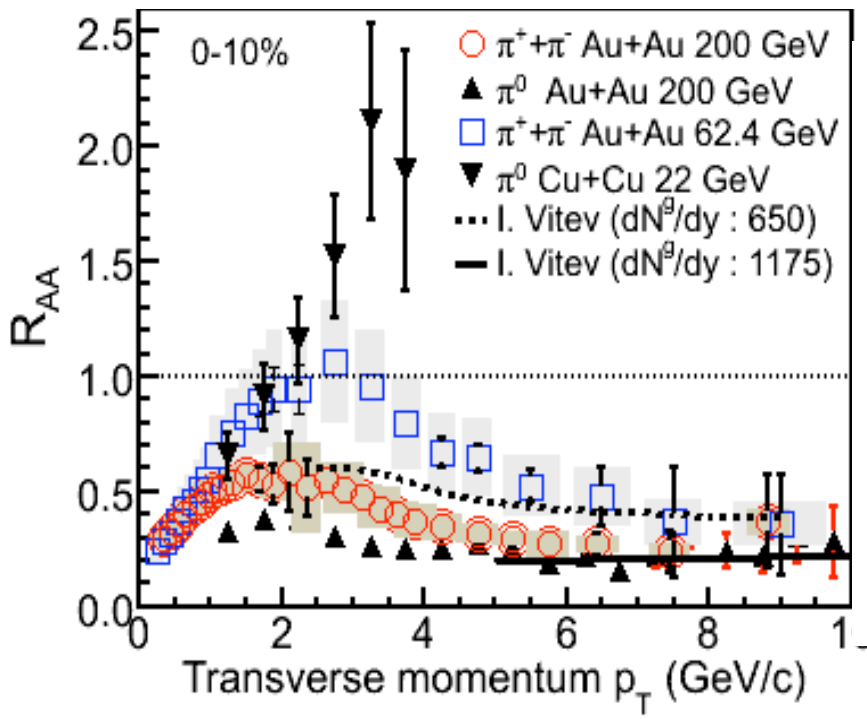


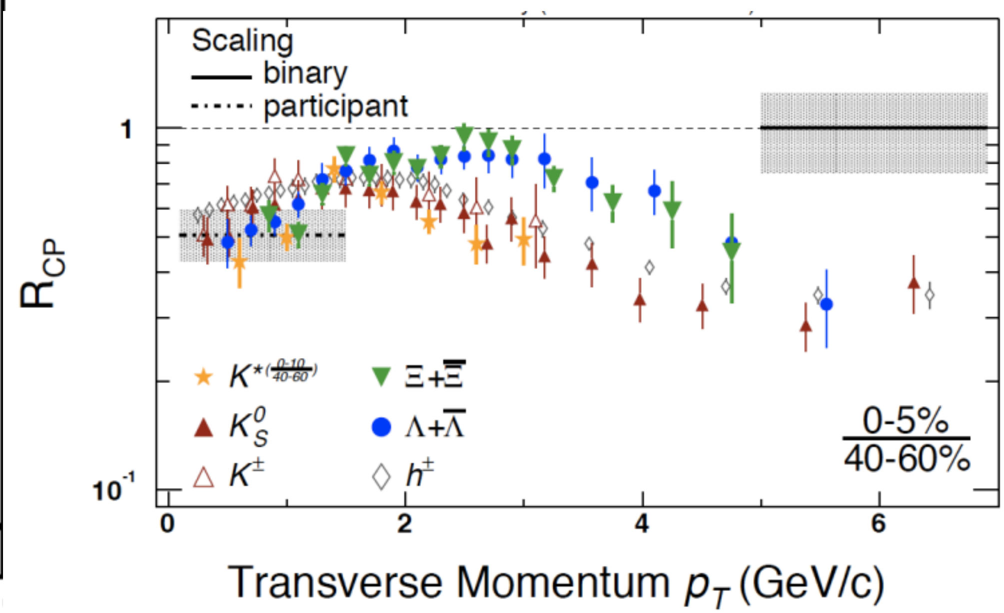
Insufficient reach at SPS

Need: ~5M events at each energy for π, K, p, Λ

φ, Ω need more; only possible for $\sqrt{s_{NN}} \geq 17.3$ GeV

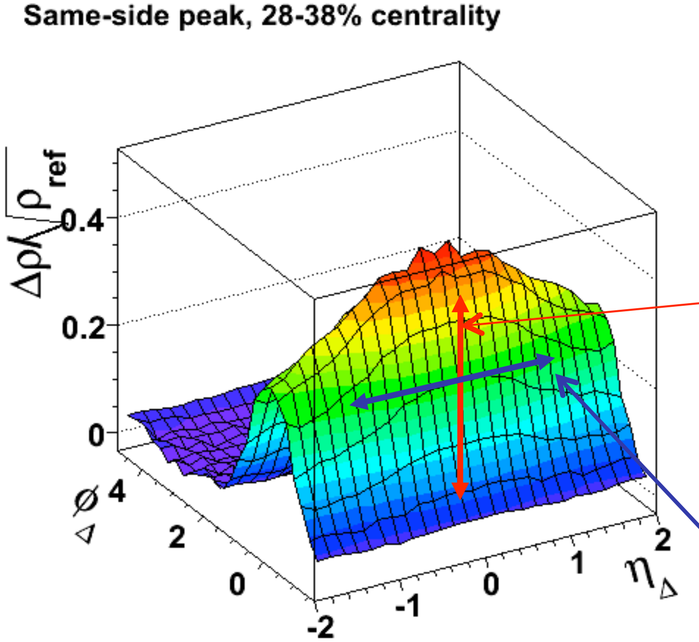
Hadron Suppression

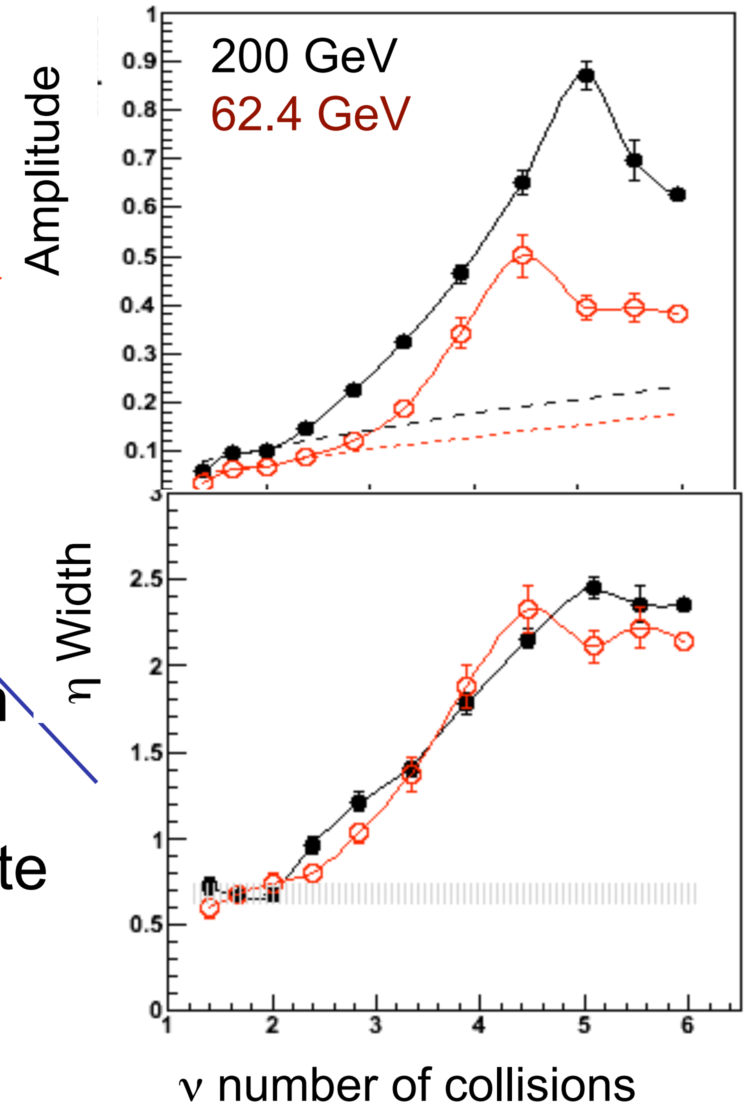




- Factor 5 suppression at 200 GeV → opacity to fast partons
- Interpretation complicated by two effects
  - Initial state effects large at low energies (Cronin)→ R_{CP} preferred
  - n_q grouping at intermediate p_T: fragmentation not dominant origin
- Drives statistical needs for $\sqrt{s_{NN}} \geq 17.3$ GeV

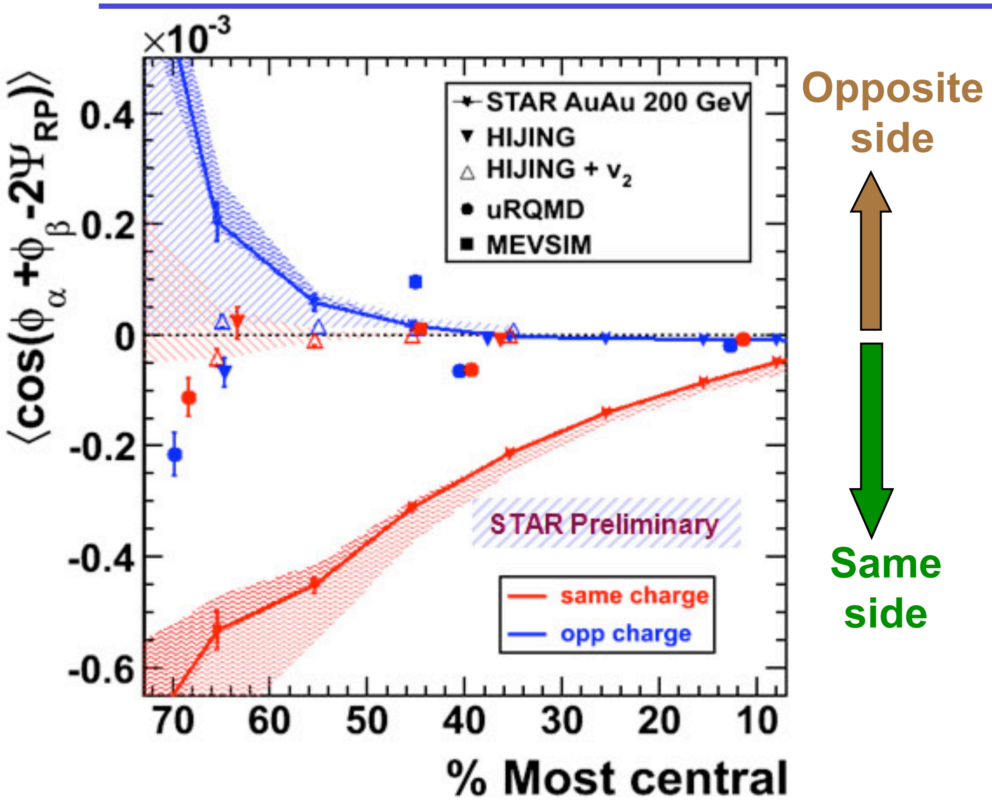
Ridge: pair correlations

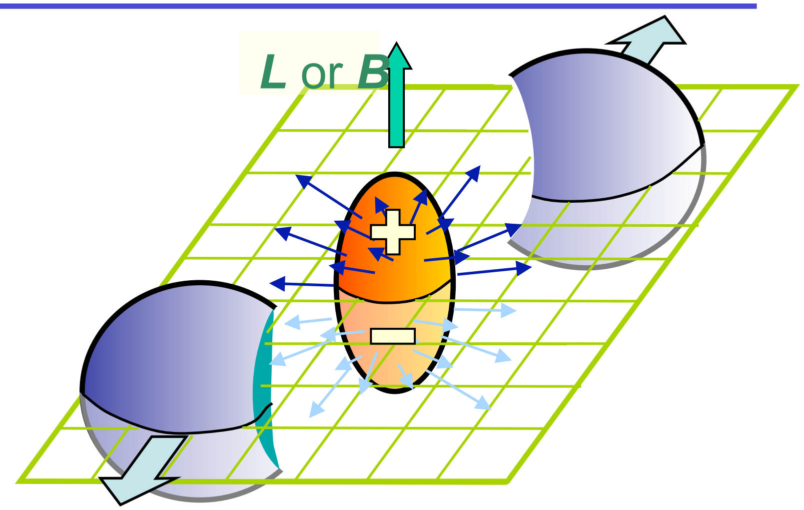




- Dramatic elongation of correlation structure at high energies
- Interpretation: imprint of initial state
  - Glasma flux tubes? Testable predictions for energy dependence
- Focus on $\sqrt{s_{NN}} \geq 17.3$ GeV

Local Parity Violation





Requirements:

Large Magnetic Field from initial L

Chiral symmetry restoration

Deconfinement

- Signature consistent with local parity violation at 200, 62 GeV
  - Measure Parity Even so potential contamination
    - No background found to date that can mimic effect
    - Background (and magnetic field) expected to change with energy
- Need: 5M events at all energies

Specific Critical Point Search Program

Beam Energy	μ_B (MeV)	Event Rate	8-hr Days/1M Events	Events proposed	8-hr days proposed
5	550	0.8	45	(100 k)	5
7.7	410	3	11	5M	56
11.5	300	10	3.7	5M	19
18	220	33	1.1	15M	16
27	150	92	0.4	33M	12
39	110	190	0.2	24M	5

Conservative estimate of rates and hours/day

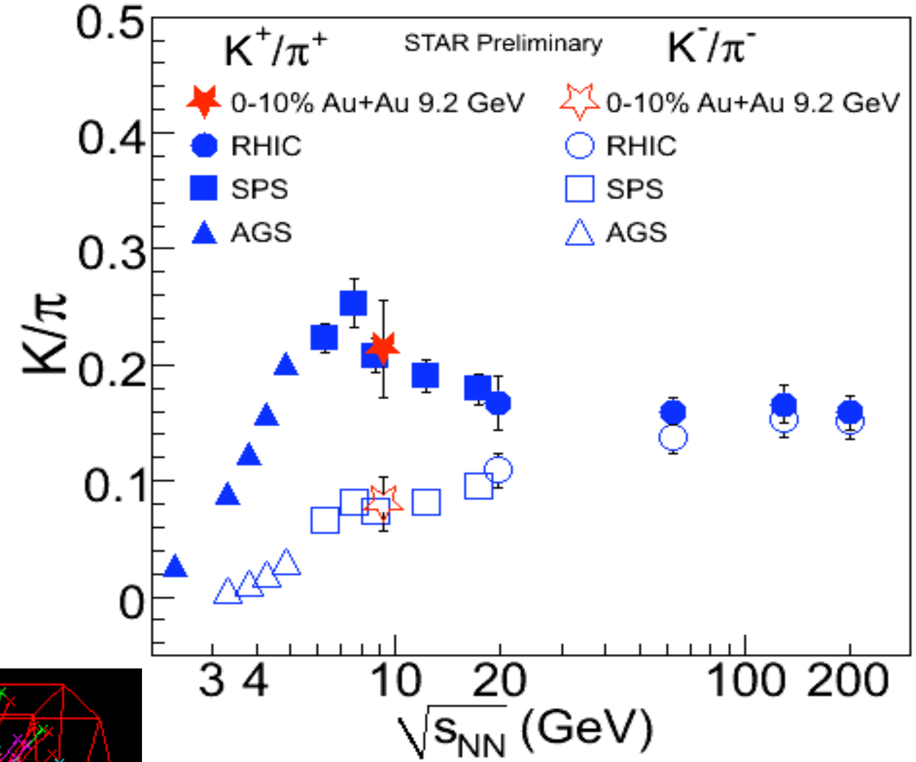
Expected range of Critical Point: μ_B = 150-600 MeV

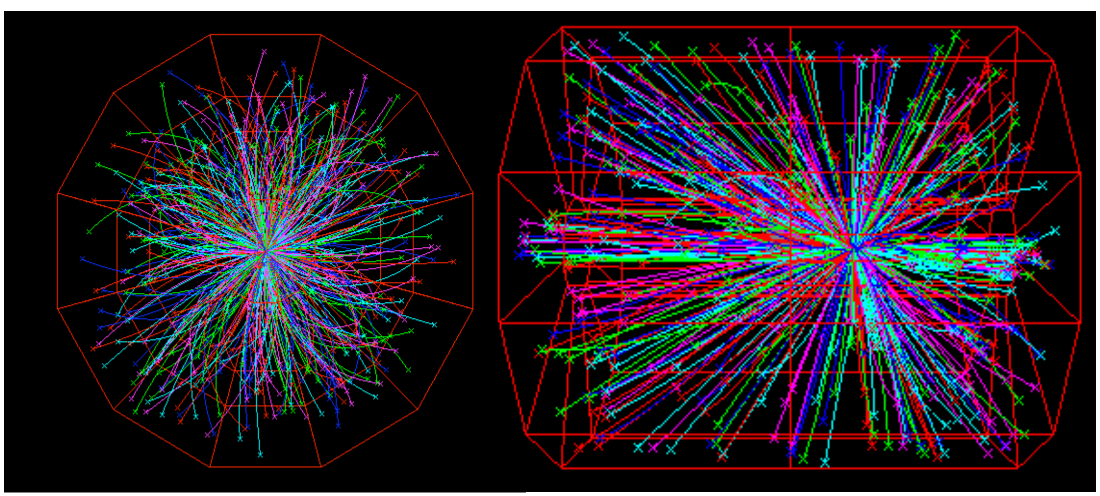
Physics drivers of the program

	Collision Energies (GeV)	5	7.7	11.5	17.3	27	39
Section	Observables	Millions of Events Needed					
A1	v_2 (up to ~1.5 GeV/c)	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
A1	v_1	0.5	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
A2	Azimuthally sensitive HBT	4	**4**	**3.5**	**3.5**	**3**	**3**
A3	PID fluctuations (K/π)	1	**1**	**1**	**1**	**1**	**1**
A3	net-proton kurtosis	5	**5**	**5**	**5**	**5**	**5**
A3	differential corr & fluct vs. centrality	4	**5**	**5**	**5**	**5**	**5**
A3	integrated p_T fluct (T fluct)						
B1	n_q scaling π/K/p/Λ $(m_T-m_0)/n<2$GeV		**6**	**5**	**5**	**4.5**	**4.5**
B1	ϕ/Ω up to $p_T/n_q=2$ GeV/c		56	25	**18**	**13**	**12**
B2	R_{CP} up to p_T ~4.5 GeV/c (at 17.3) 5.5 (at 27) & 6 GeV/c (at 39)				**15**	**33**	**24**
B3	untriggered ridge correlations		27	13	**8**	**6**	**6**
B4	parity violation		**5**	**5**	**5**	**5**	**5**

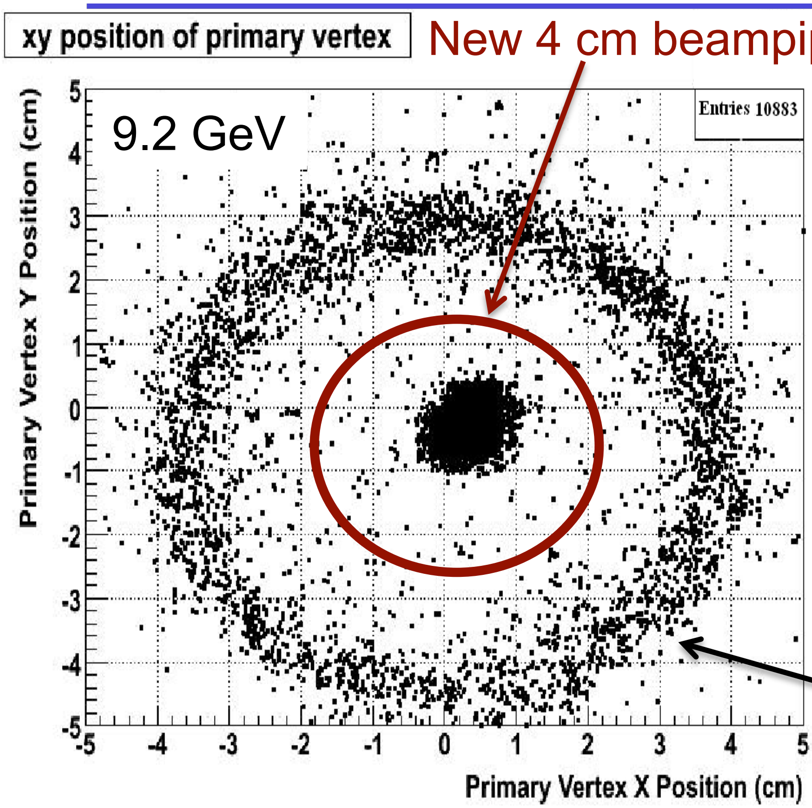
Proven capabilities

- 9.2 GeV in Run 8 a success
  - Established rates, triggers
  - First measurements: ~3000 events
- STAR detector is ready: optimal configuration Run 10

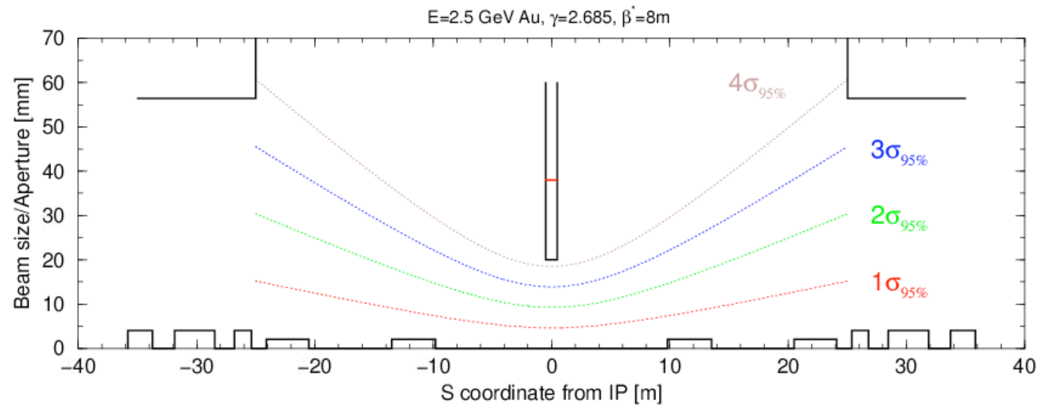




Why now? Technical Considerations



Aperture in the beampipes uncomfortably small



Indications of background from 9.2 GeV Beam on Beampipe: Au+Be

- Detector optimal: full ToF, FTPC's, large beampipe
  - FTPC's: proven capability (RP, η reach) but incompatible with HFT, FGT
  - Backgrounds: small beampipes → large backgrounds
- Start with $\sqrt{s_{NN}}$=7.7 GeV where the beams are largest

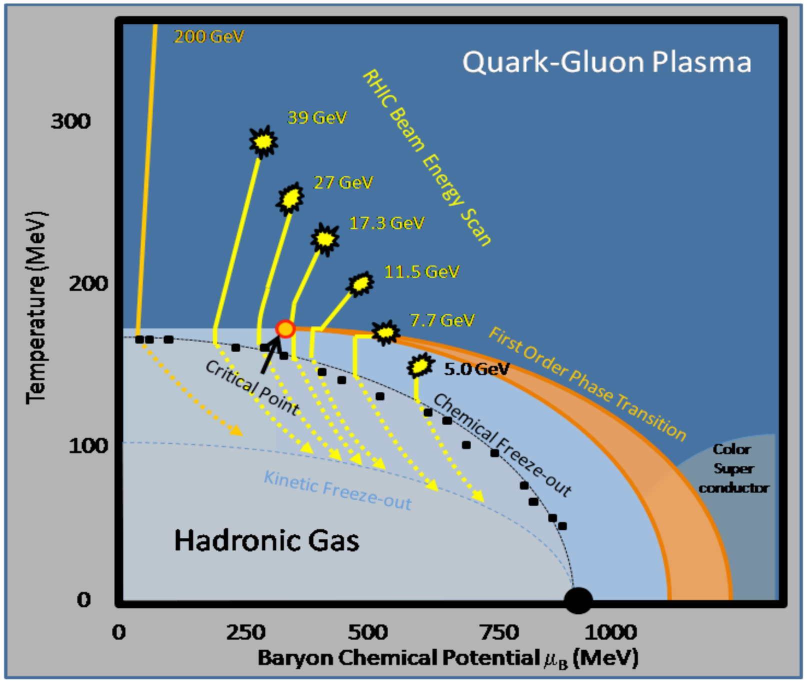
Critical Point Search: Why Now?

Intense international interest in program now

– CPOD 09: >100 participants last week, 60% from foreign institutions

STAR is ready and best positioned to make these measurements now

Beam use proposal designed to make definitive measurements now



Run 10: Au+Au at 200 GeV

Run	Energy	System	Time	Goal
10[(1)]	$\sqrt{s_{NN}}$ =7.7-39 GeV	Au + Au	16 weeks	Critical Point search
	$\sqrt{s_{NN}}$ = 5 GeV	Au + Au	1 week[(a)]	Commissioning and first look at data
	$\sqrt{s_{NN}}$ = 200 GeV	Au + Au	8 weeks	250M central 300M minbias 2 nb^{-1} sampled
11[(2)]	$\sqrt{s}$ = 200 GeV[(b)]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$	[illegible] weeks	30 pb^{-1} long [(d)] 15 pb^{-1} transverse
	$\sqrt{s}$ = 500 GeV[(c)]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$		15 pb^{-1} longitudinal 6.5 pb^{-1} transverse
	$\sqrt{s}$ = 200 GeV	$p_{\rightarrow} p_{\rightarrow}$	5 days	pp2pp at high β*
	$\sqrt{s_{NN}}$ =200 GeV	U + U	4 weeks[(e)]	400M events

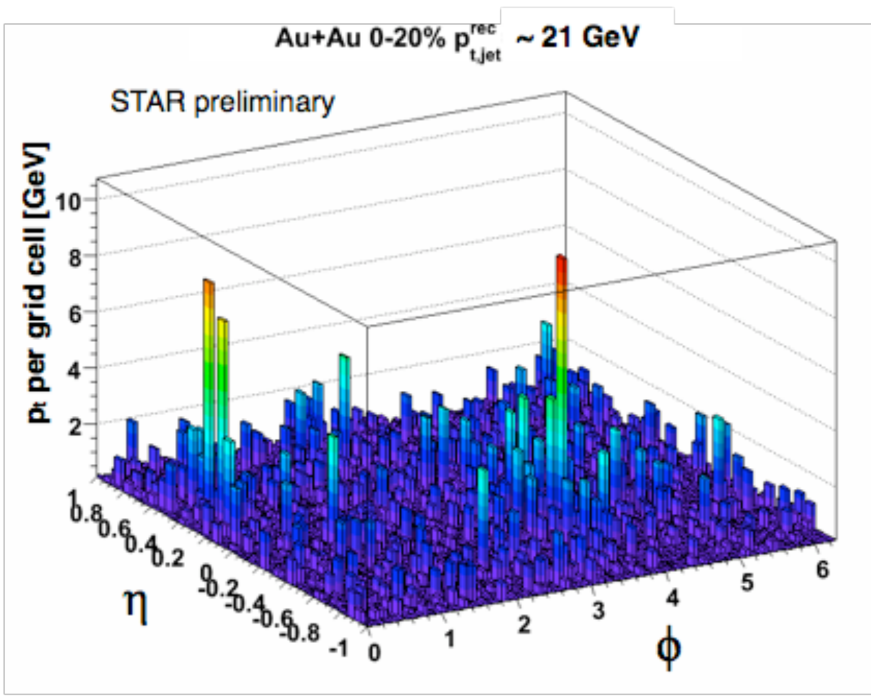
(1) 30 cryo weeks, 25 weeks production with one species
(2) 25 cryo weeks, 18 weeks production with two species.
(a) C-AD test for higher luminosity at the lower energy
(b) 60% or higher polarization in both yellow and blue rings is needed.
(c) 50% or higher polarization in both yellow and blue ring is needed.
(d) Request is to finish the minimum 50 pb^{-1} goal and make progress towards the portion of the long-term goal of 80 pb^{-1} at 60% polarization remaining after Run 9 is completed
(e) Contingent on EBIS operation at moderate rates (5-10 kHz)

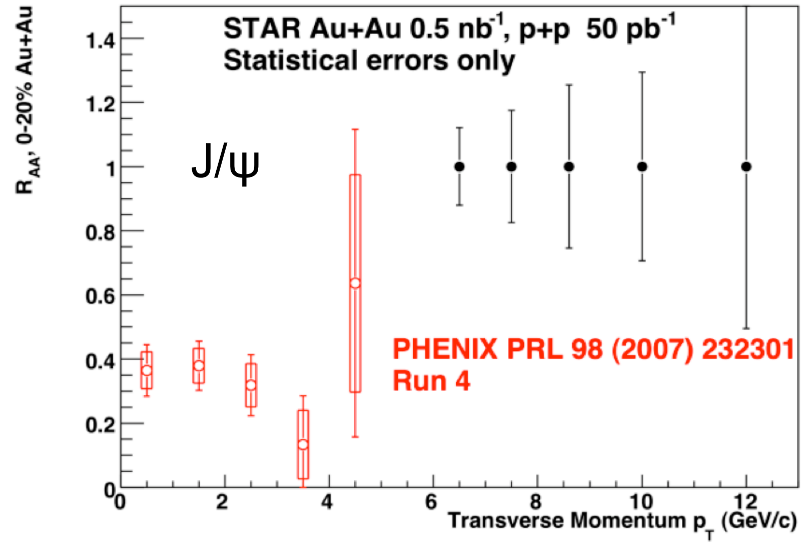
Run 10: Au+Au $\sqrt{s_{NN}}$ = 200 GeV

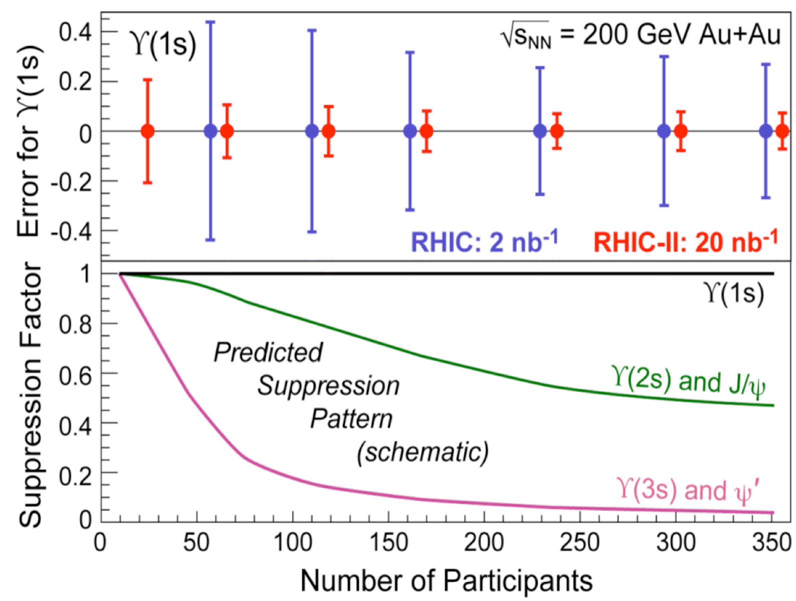
- Major improvements in detector and machine
- **Triggered: 2 nb^{-1} sampled (x4 vs. Run 7)**
  - Non-photonic electrons with low material: Open Heavy Flavor R_{AA}
  - Quarkonia: Upsilon and high-p_T J/Ψ with low material
  - γ-hadron: hadron z_T~0.3 at hadron p_T~5 GeV/c to distinguish E_{loss} scenarios
  - Triggered fully reconstructed jets for jet-jet and identified jet-hadron correlations
- **Central: 250M (x10 vs. Run 4 and x30 relative to Run 7)**
  - Extension of fully reconstructed jets, unbiased by trigger, to 40-50 GeV
  - Di- and tri-hadron identified particle correlations: jet-medium interactions
- **Minimum bias: 300M (x4 relative to Run 7)**
  - Jet conversion via K for p_T>10 GeV/c in peripheral collisions
  - Low-mass dileptons with low material: begin ToF for E.M. probes
  - 10σ measurement of hypertriton and anti-hypertriton production

Hard probes in Run 10

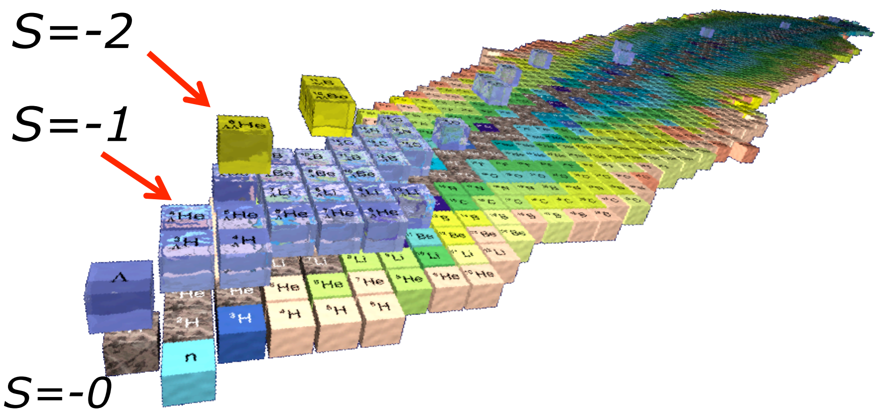
- DAQ1000+machine → 2 nb^{-1}
- Fully utilize RHIC I and prepare for RHIC II
- Low material: time window before installation of HFT

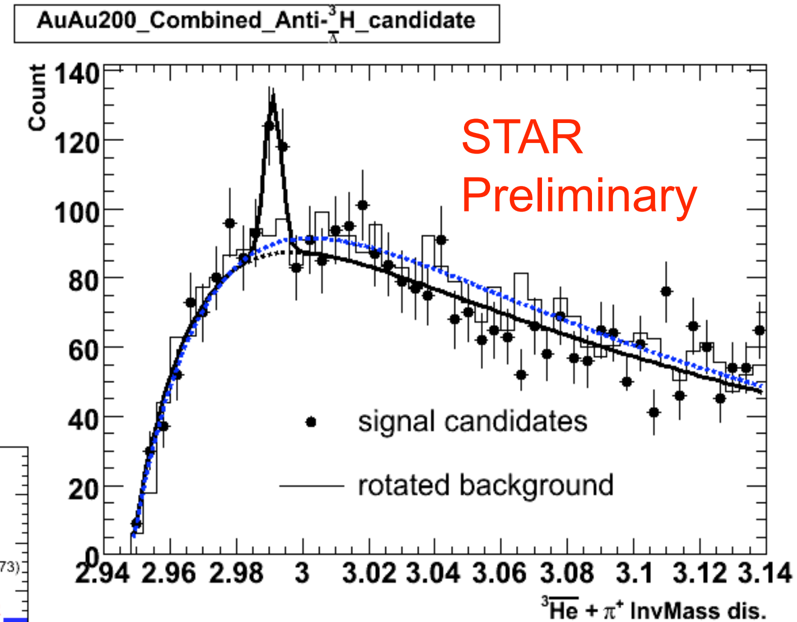


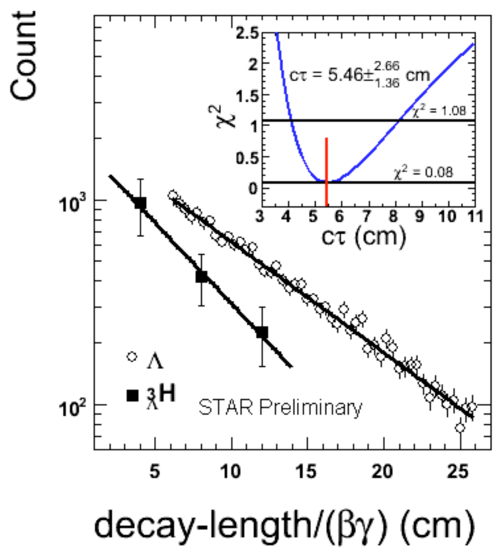


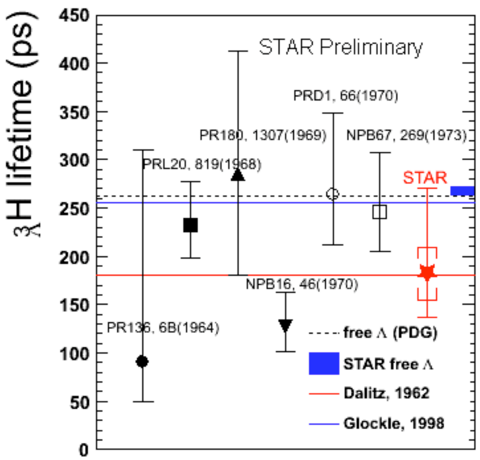


Anti-hypertriton in Run 10









World data

- 1st observation of anti-hypertriton (Run 7) reported QM2009
- 300M minbias events: 10σ anti-hypertriton+hypertriton

Run 11

Run	Energy	System	Time	Goal
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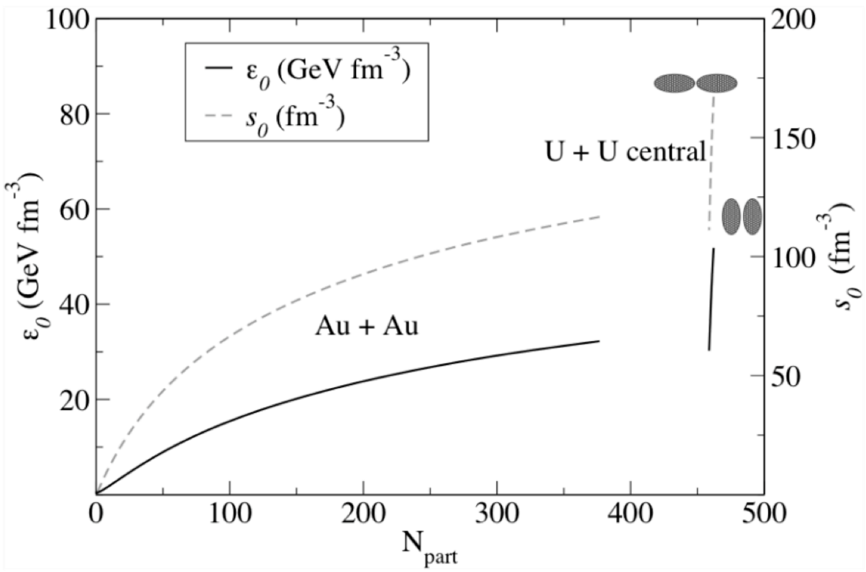
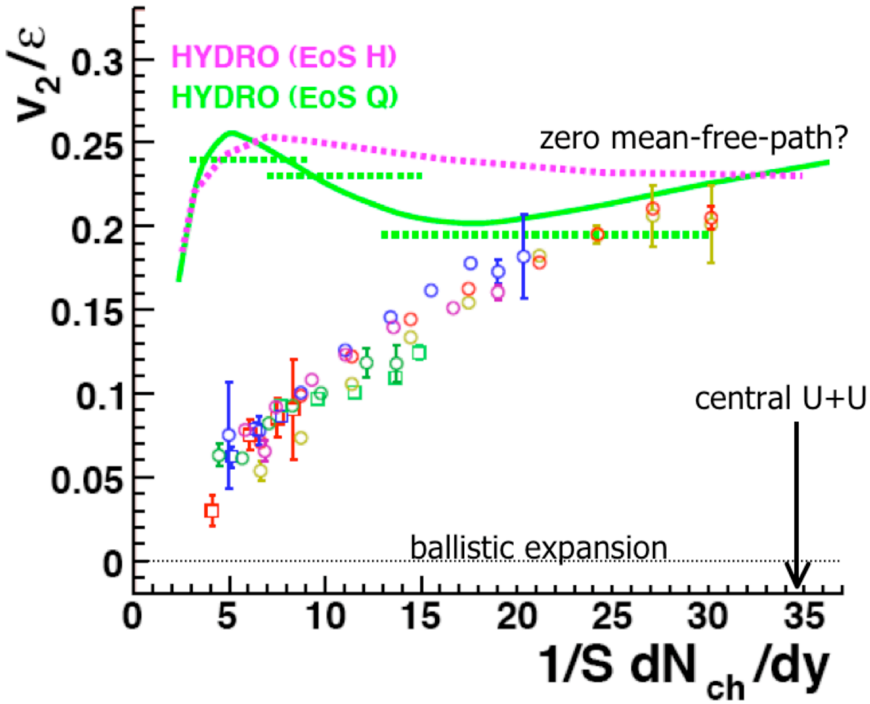
	$\sqrt{s_{NN}}$ = 200 GeV	Au + Au	8 weeks	250M central 300M minbias 2 nb^{-1} sampled
11[2]	$\sqrt{s}$ = 200 GeV[b]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$	13 weeks	~30 pb^{-1} long.[d] 15 pb^{-1} transverse
	$\sqrt{s}$ = 500 GeV[c]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$		15 pb^{-1} longitudinal 6.5 pb^{-1} transverse
	$\sqrt{s}$ = 200 GeV	$p_{\rightarrow} p_{\rightarrow}$	5 days	pp2pp at high β^*
	$\sqrt{s_{NN}}$ =200 GeV	U + U	4 weeks[e]	400M events

(1) 30 cryo weeks, 25 weeks production with one species
(2) 25 cryo weeks, 18 weeks production with two species.
(a) C-AD test for higher luminosity at the lower energy
(b) 60% or higher polarization in both yellow and blue rings is needed.
(c) 50% or higher polarization in both yellow and blue ring is needed.
(d) Request is to finish the minimum 50 pb^{-1} goal and make progress towards the portion of the long-term goal of 80 pb^{-1} at 60% polarization remaining after Run 9 is completed
(e) Contingent on EBIS operation at moderate rates (5-10 kHz)

Run 11: U+U





- Significant increase in energy density for hydrodynamic studies
- Prolate shape: path-length dependence of E_{loss} at high density
- First run from EBIS likely to be moderate intensity
  - 4 weeks: sufficient statistics for studies of event selection, hydrodynamic quantities, and first look at hadron suppression

Spin Goals in Run 11

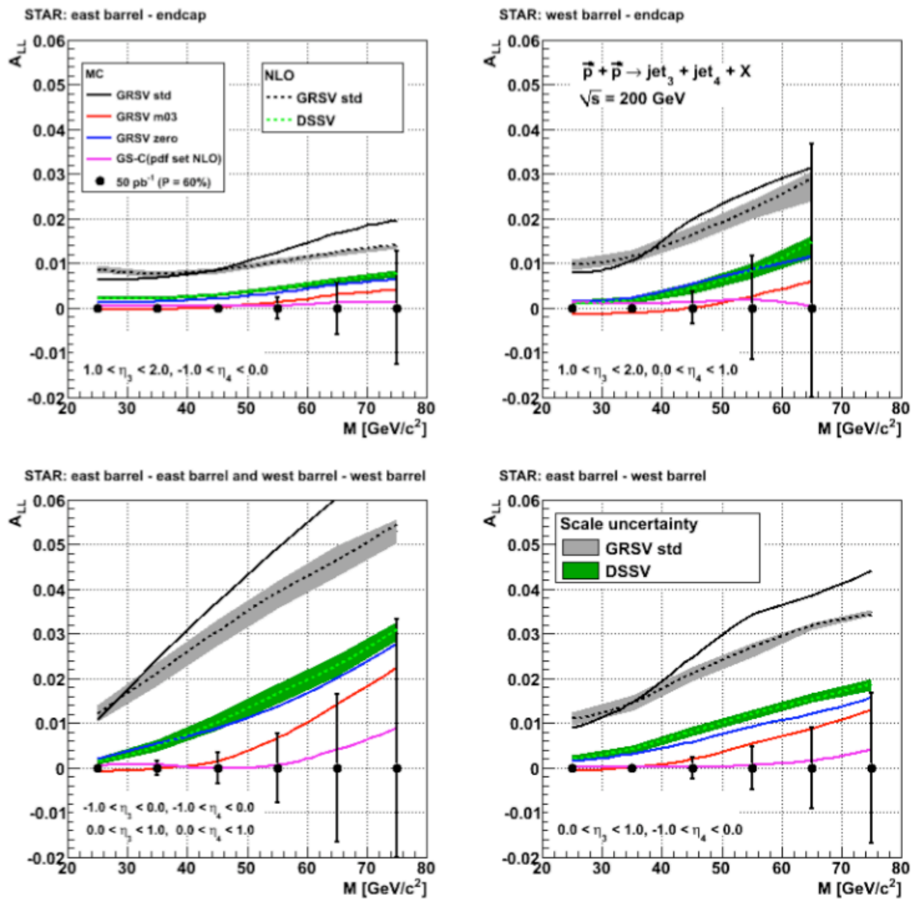
Significant time set aside for precision measurements

- Gluon polarization and its Bjorken-x dependence
- (anti-)quark polarizations via leptonic W-decay
- transverse spin asymmetries: Sivers

Significant progress towards a selection of these goals

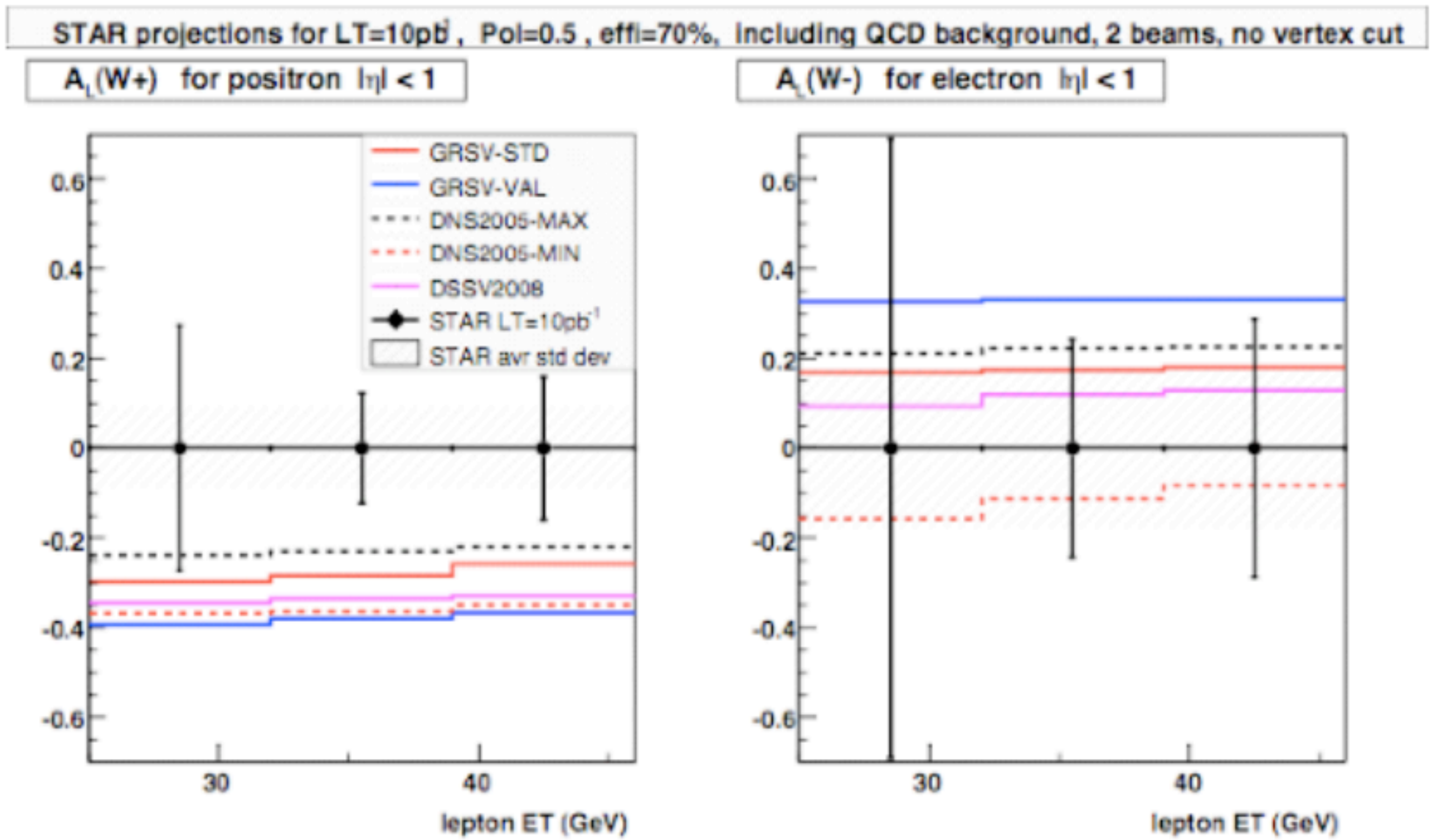
Detailed breakdown awaits knowledge gained from Run 9

Longitudinal at 200 GeV



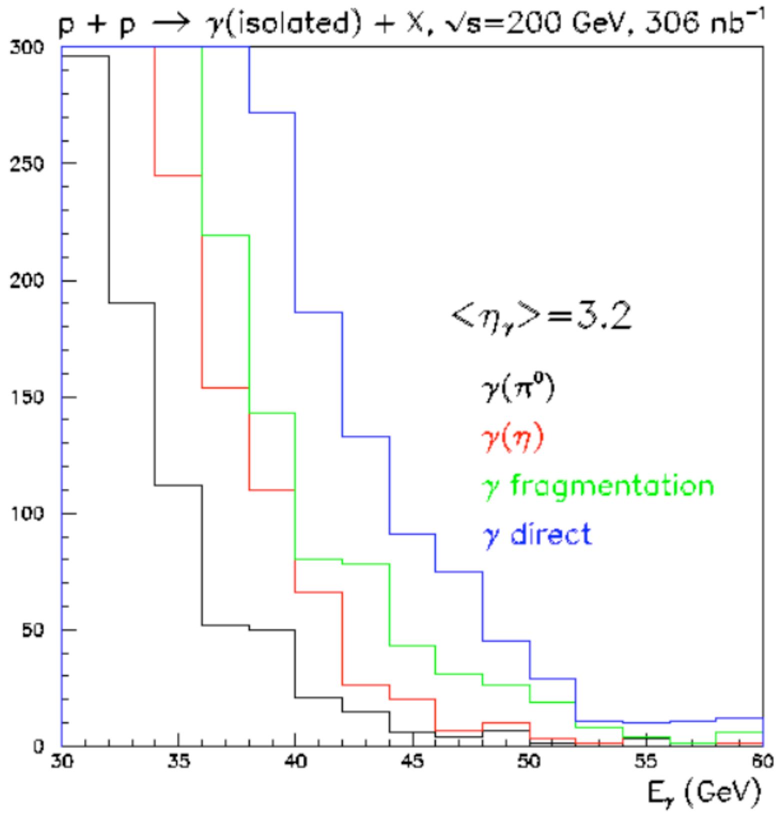
- Significant A_{LL} measurement of dijets to constrain $\Delta g(x)$
  - Completion of 50 pb^{-1} at 60% polarization (Run 9 BUR request)
- Key step towards completion of 200 GeV program

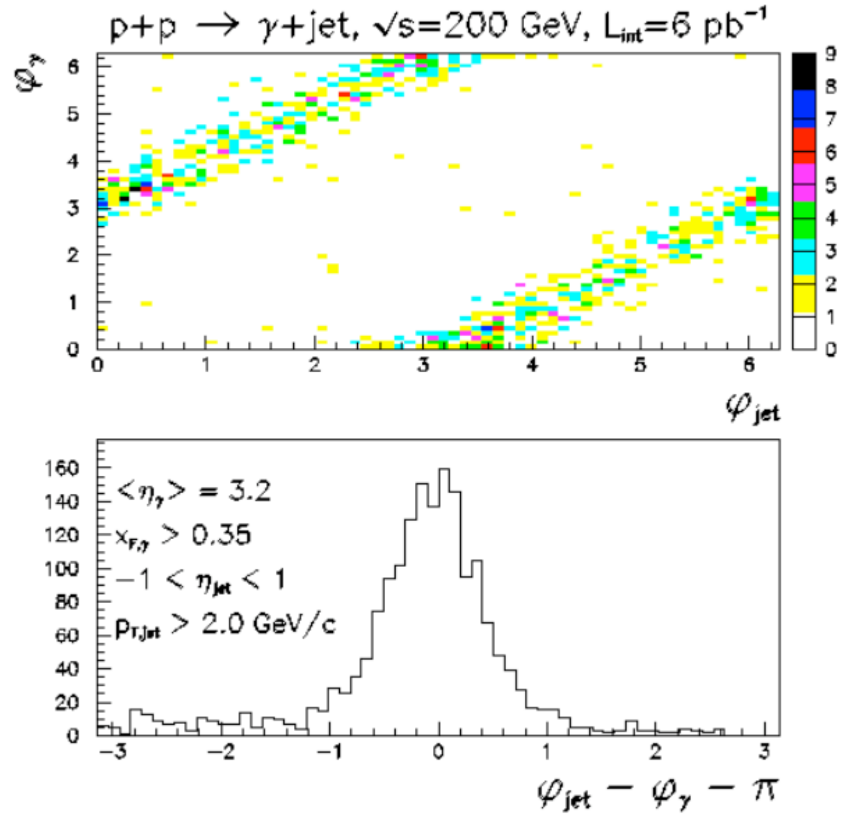
Longitudinal at 500 GeV



- Significant first measurement of W A_L at mid-rapidity
  - Requires 10 pb^{-1}, 50% polarization
- Precision discrimination awaits FGT (Run 12) and later runs

Transverse Polarization





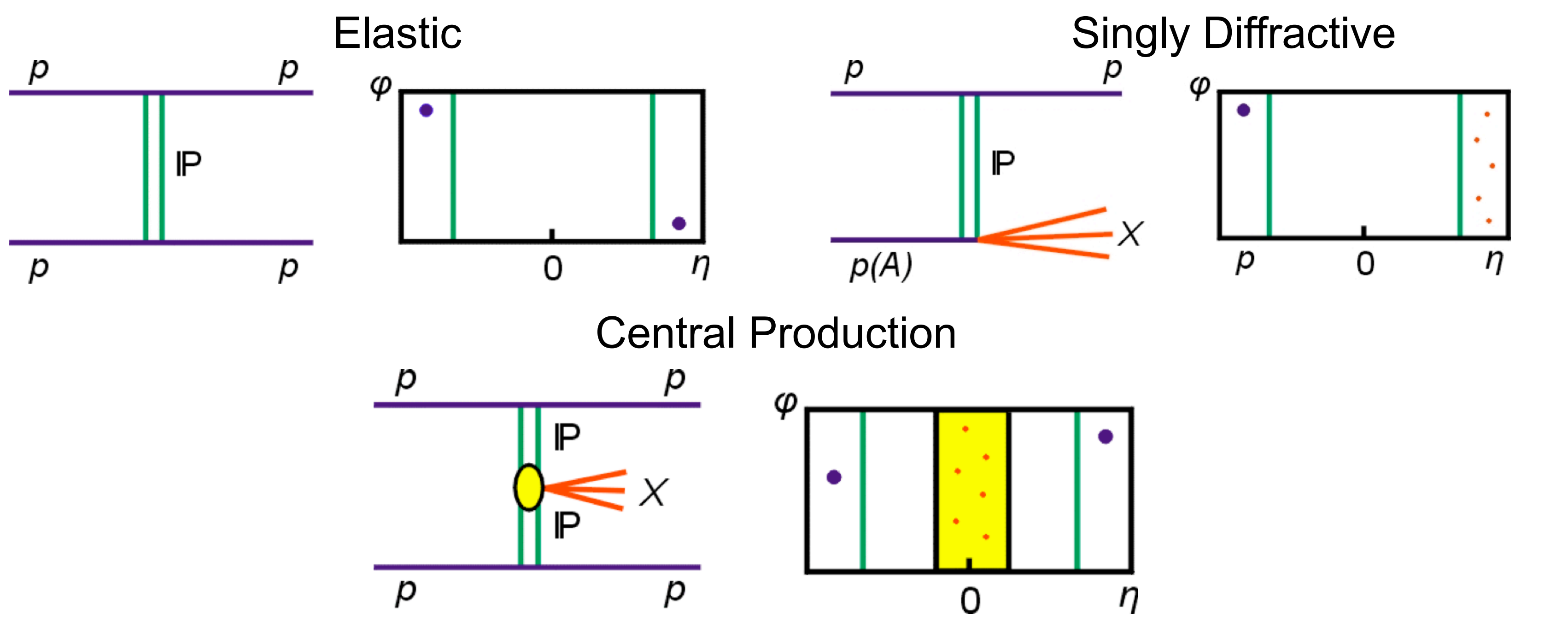
DOE transverse milestone at 200 GeV: HP13 (2015)

15 pb^{-1}, 65% transverse polarization: 50% towards milestone

500 GeV A_N: does the large A_N persist to 500 GeV?

6.5 pb^{-1}, 50% polarization will enable measurement

pp2pp



- Expect to complete first part of the program Run 9
- Need to return in Run 11 for longitudinal portion (5 days)

Summary

- Strong program planned for Runs 10, 11

- New measurement regimes for RHIC
  - Run 10: Critical Point Search at low energies
  - Run 11: Hydrodynamics at high density with U+U
  - Run 11 and beyond: W at 500 GeV

- Major increases in resolving power
  - Run 10: Au+Au with high luminosity and detector improvements
  - Run 11: $\Delta g(x)$ and transverse Sivers via γ-jet

Summary of Beam Use Request

Run	Energy	System	Time	Goal
10[1]	$\sqrt{s_{NN}}$=7.7-39 GeV	Au + Au	16 weeks	Critical Point search
	$\sqrt{s_{NN}}$ = 5 GeV	Au + Au	1 week[a]	Commissioning and first look at data
	$\sqrt{s_{NN}}$ = 200 GeV	Au + Au	8 weeks	250M central 300M minbias 2 nb^{-1} sampled
11[2]	$\sqrt{s}$ = 200 GeV[b]	$p_{\rightarrow} p_{\rightarrow}$ $p_{\uparrow} p_{\uparrow}$	13 weeks	~30 pb^{-1} long.[d] 15 pb^{-1} transverse
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