PHENIX Run-11 Report

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Run-11 PHENIX Run Coordinator

Run-11 PHENIX detector

Central Arms:
- **hadrons, photons, electrons**
- **$|\eta| < 0.35$**
- **$\Delta\varphi = \pi$ (2 arms x $\pi/2$)**

Global Detectors:
- **Beam-Beam Co**
- **Zero Degree Ca**

Muon Arms:
- **muons**
- **$1.2 < |\eta| < 2.2$**
- **$\Delta\varphi = 2\pi$**

MPC 3.1 < | η

Both are successfully commissioned t

Run-11 history (PHENIX DAQ)

- 500GeV p+p
  - Feb 27 - Apr 18
- 19.6GeV Au+Au
  - Apr 19 - May 2
- 200GeV Au+Au
  - May 6 - Jun 20
- 27GeV Au+Au
  - Jun 21 - Jun 29

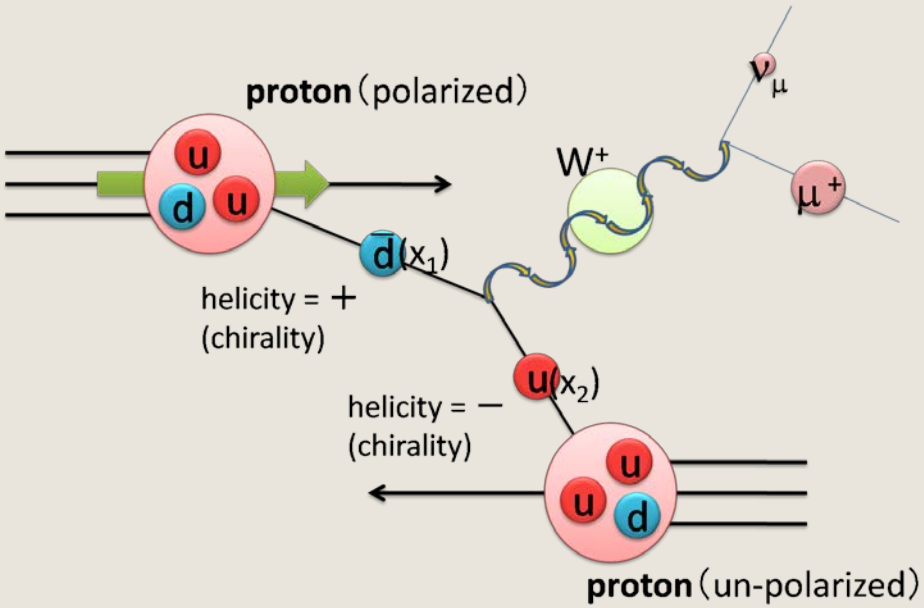
500GeV p+p

- $W^{+/-} \rightarrow \mu\ \nu$ measurement
- VTX commissioning

W measurement

- *W* boson production
  - **Parity violation of the weak interaction and u- and d-quark polarizations in proton**
    - **Control over helicity states of colliding partons**
  - **Forward/backward muons**
    - **flavor separation**

- **High luminosity and longitudinally polarized *p+p* collisions at 500 GeV (integrated *L* = 300 pb^{-1}, polarity = 60%)**



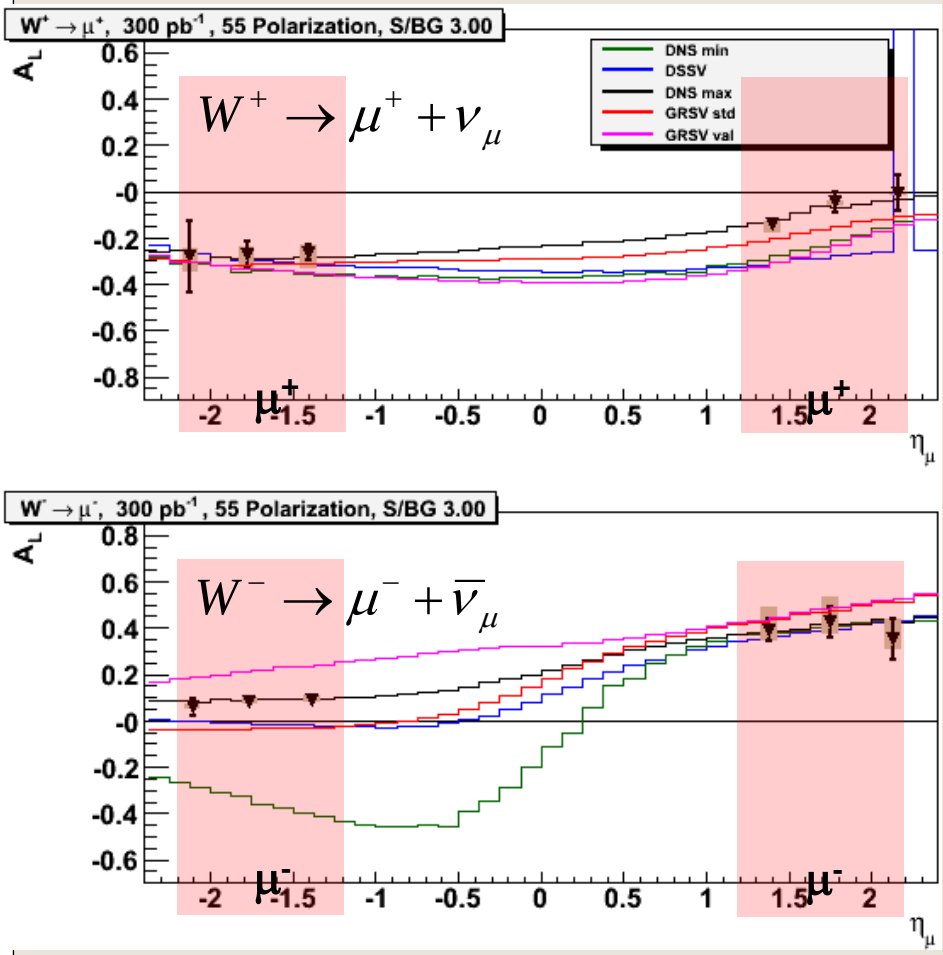
Single spin asymmetry for W^+

$$A_L^{w^+} = \frac{-\Delta u(x_a)\bar{d}(x_b) + \Delta\bar{d}(x_a)u(x_b)}{u(x_a)\bar{d}(x_b) + \bar{d}(x_a)u(x_b)}$$

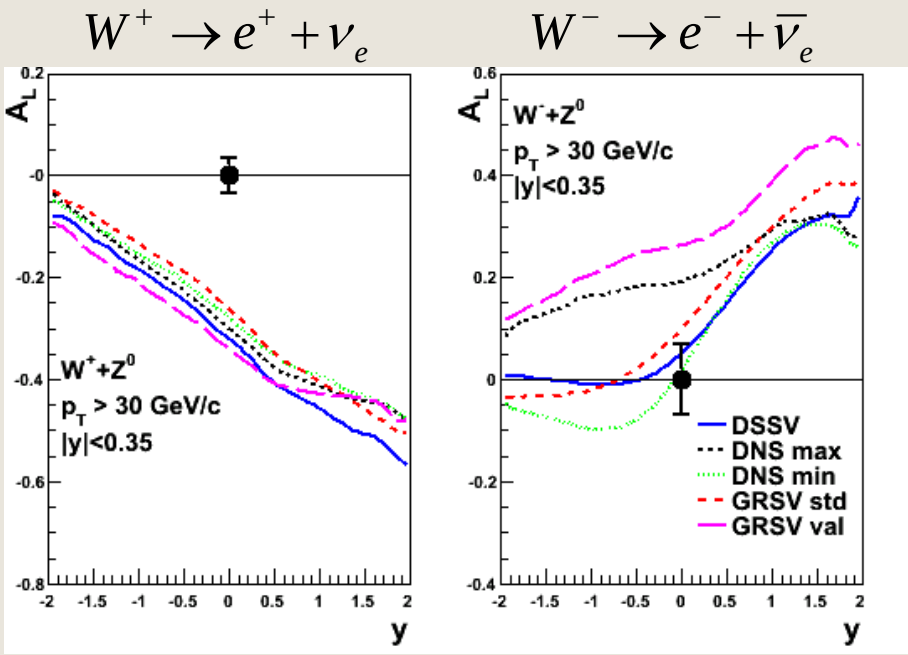
$$x_a >> x_b : A_L^{W^+} \approx \frac{-\Delta u}{u}$$

$$x_b >> x_a : A_L^{W^+} \approx \frac{-\Delta\bar{d}}{\bar{d}}$$

Expected Single Spin Asymmetry of *W*



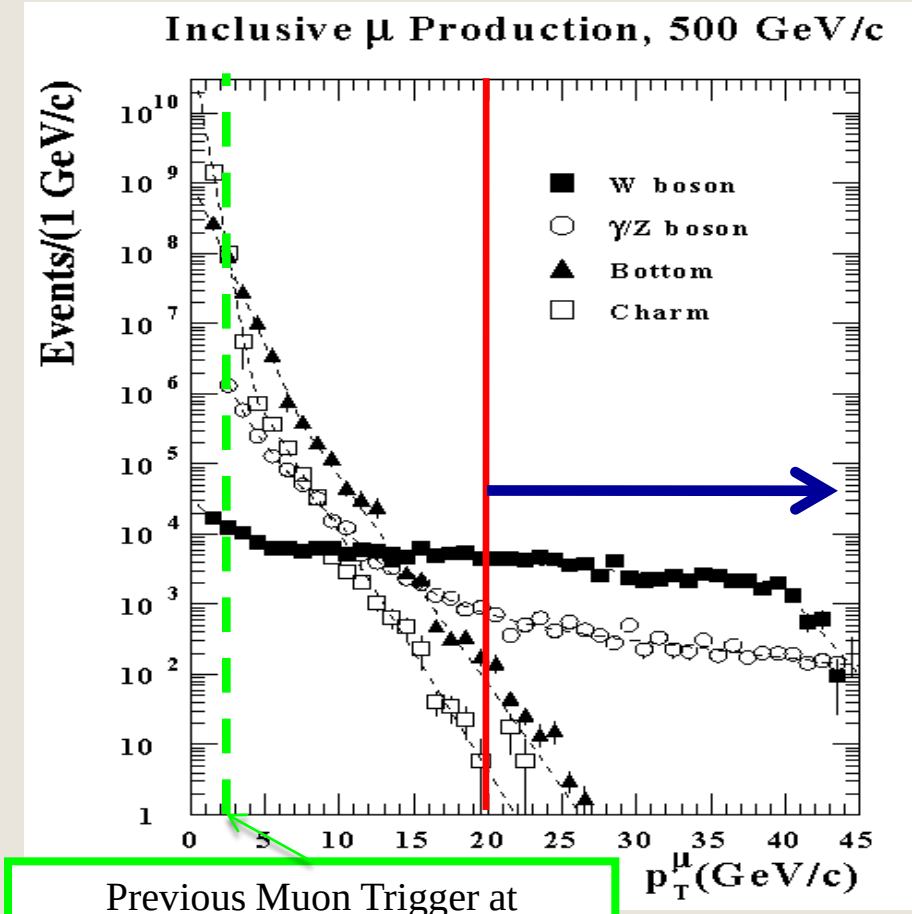
A_L for inclusive high p_T leptons for $\int Ldt=300pb^{-1}$, $P=0.55$



- Central Arms: *W* measurement at RHIC Run-9
- Muon Arms: Forward muon trigger was upgraded in Run-11

Triggering muons from *W*

- In order to measure *W* at 500 GeV, we need a first level trigger rejection of a factor 10000
- The current muon trigger accepts muons above 2 GeV/*c* and current DAQ cannot take full rate at 500 GeV
- The upgraded first level trigger will select events with muons of high transverse momentum $p_t \geq 20$ GeV/*c* from *W* boson

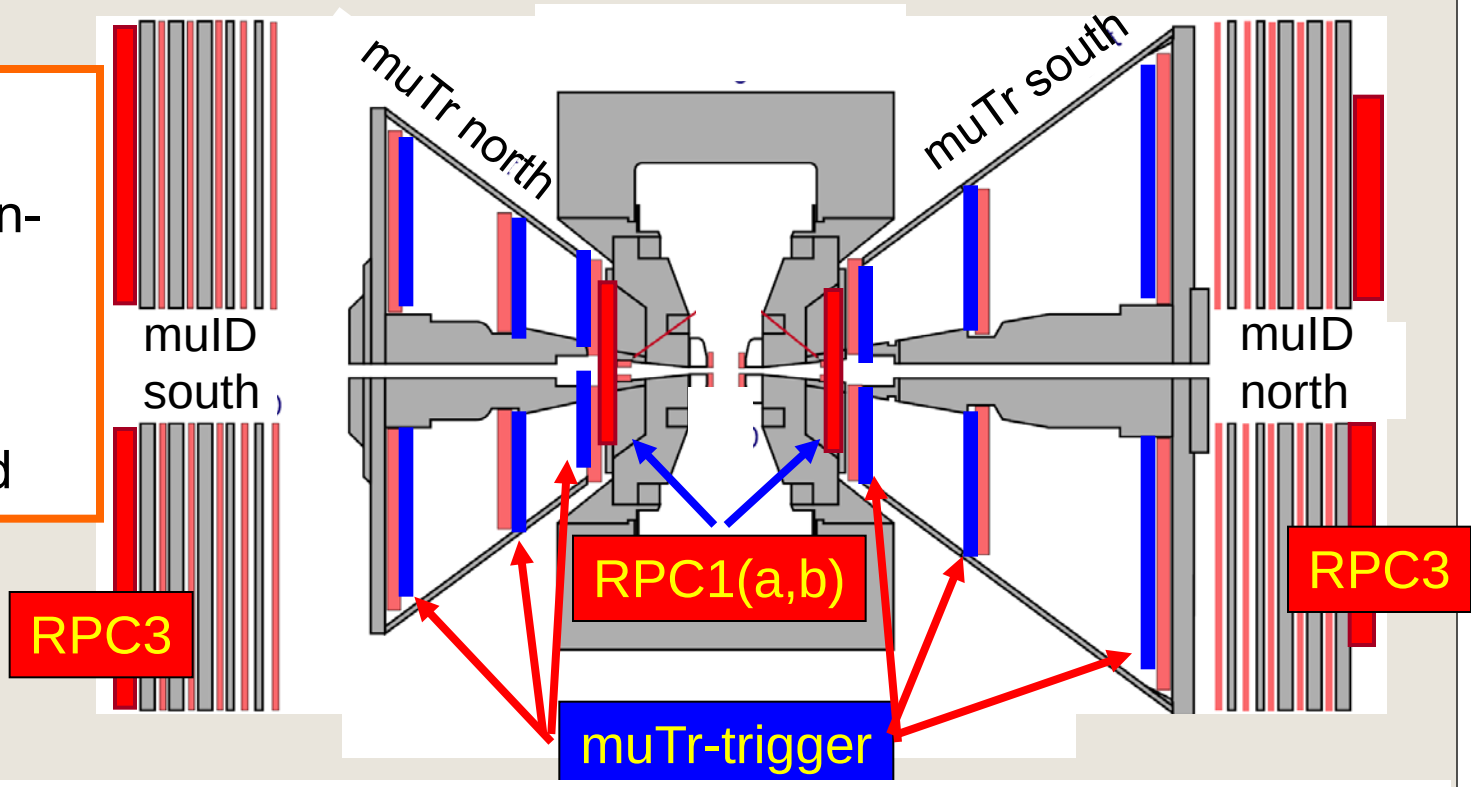


Muon Trigger Upgrade

Trigger idea:

Reject low momentum muons

Cut out-of-time beam background



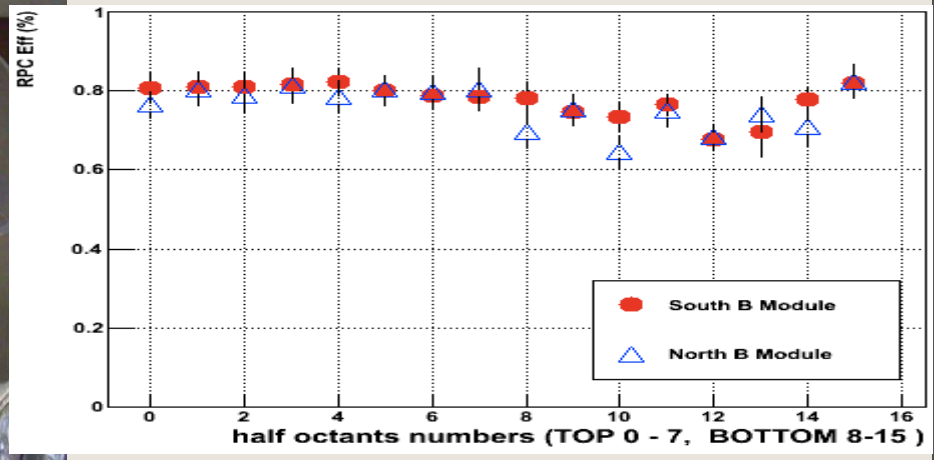
Upgrade:

o muTr trigger electronics: muTr 1-3 ➔ send tracking info to level-1 trigger

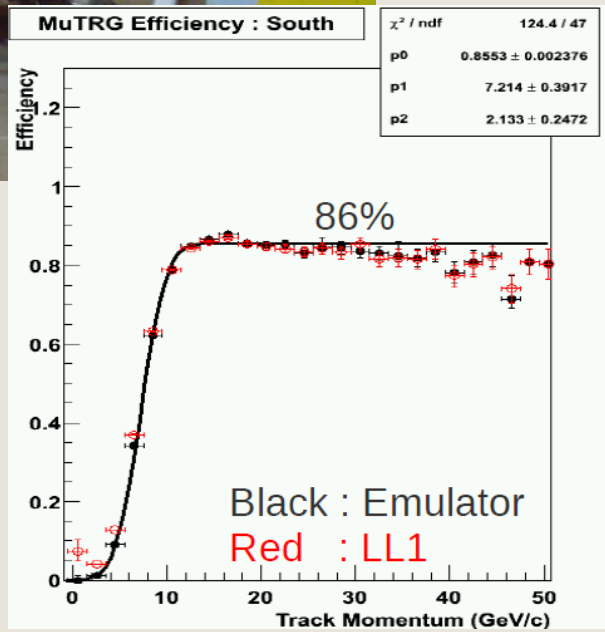
o RPC stations: RPC 1+3 ➔ tracking + timing info to level-1 trigger

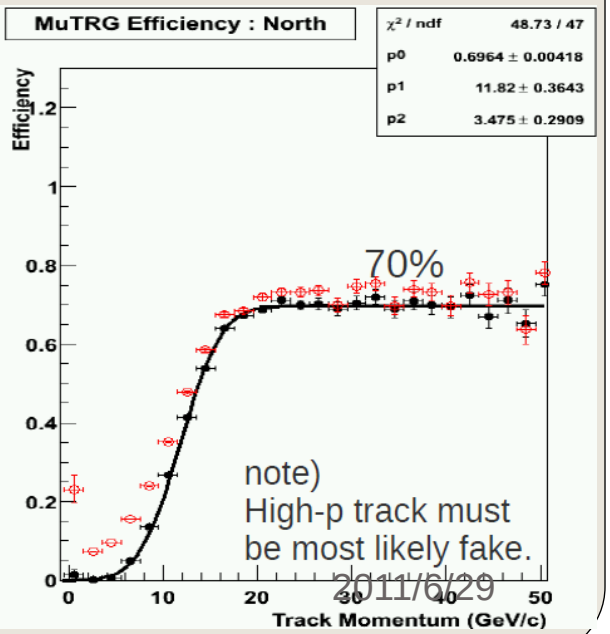
Muon trigger performance

RPC efficiency



MuTrigger efficiency





Rejection power ~1100 @ 2.7MHz

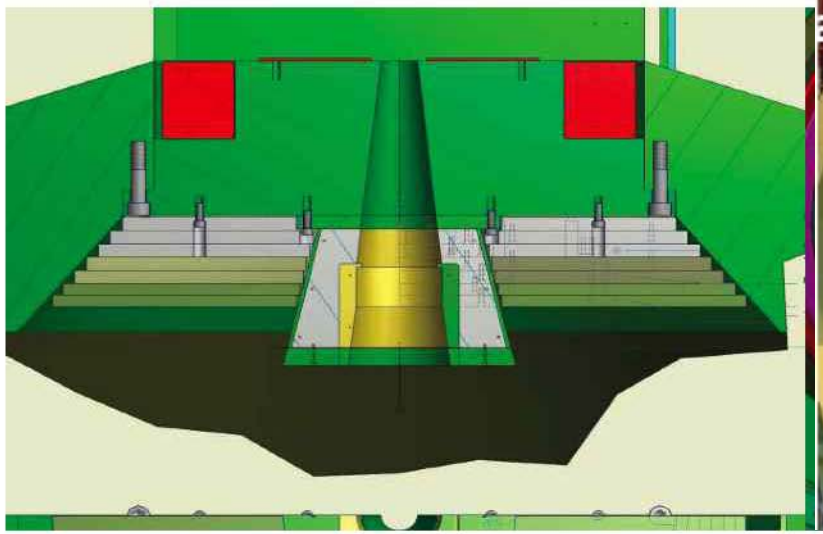
S/B~1/2 first look

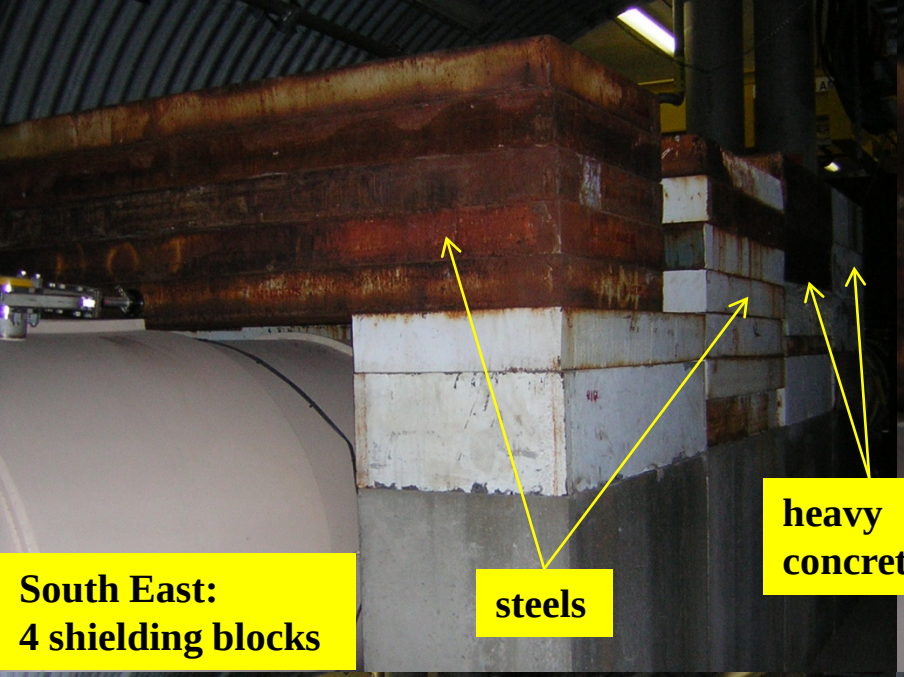
Anticipate 3/1 after tuning

Sakaguchi, RHIC/AGS

Muon arm background reduction

- Stainless steel SS-130 absorbers, 12 tons each side
- 2 interaction lengths, based upon simulations
- Additional shielding in tunnels during the run
  - Avoid splash off from the beam




South East:
4 shielding blocks
steels
heavy
concretes

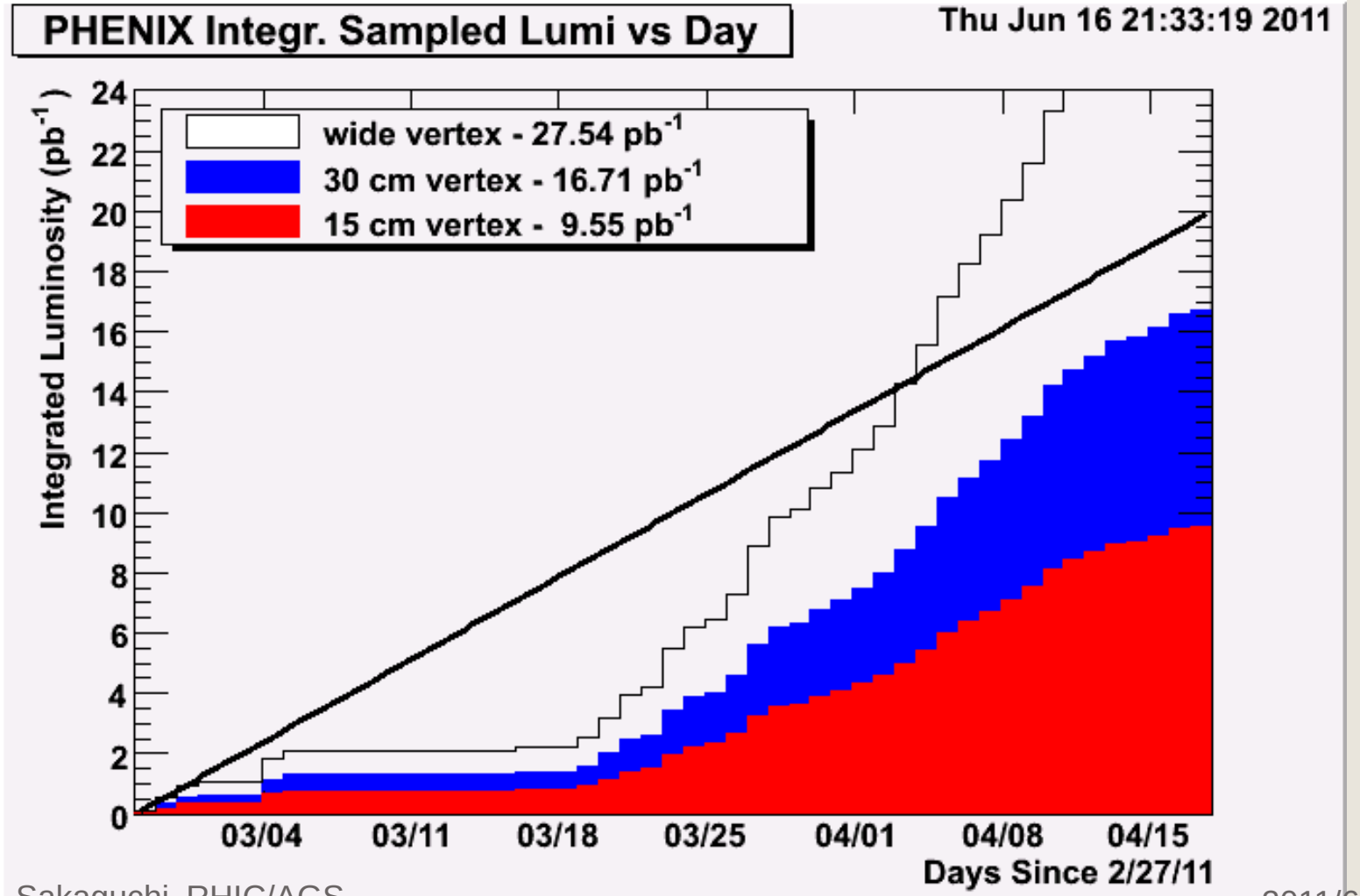
South East

heavy
concretes
steels
West:
3 shielding blocks

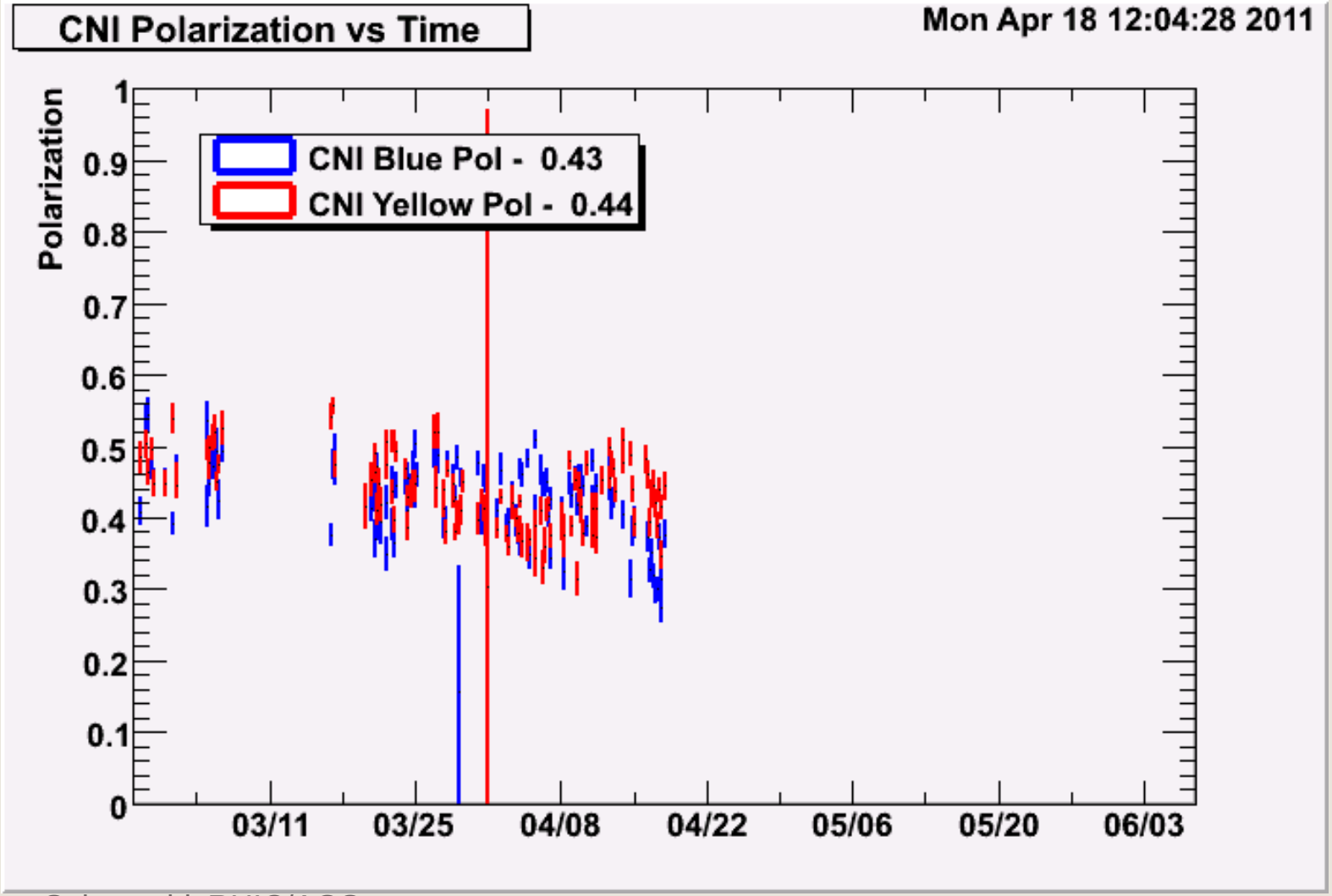
shielding
blocks
South West

Integrated luminosity in 500GeV p+p

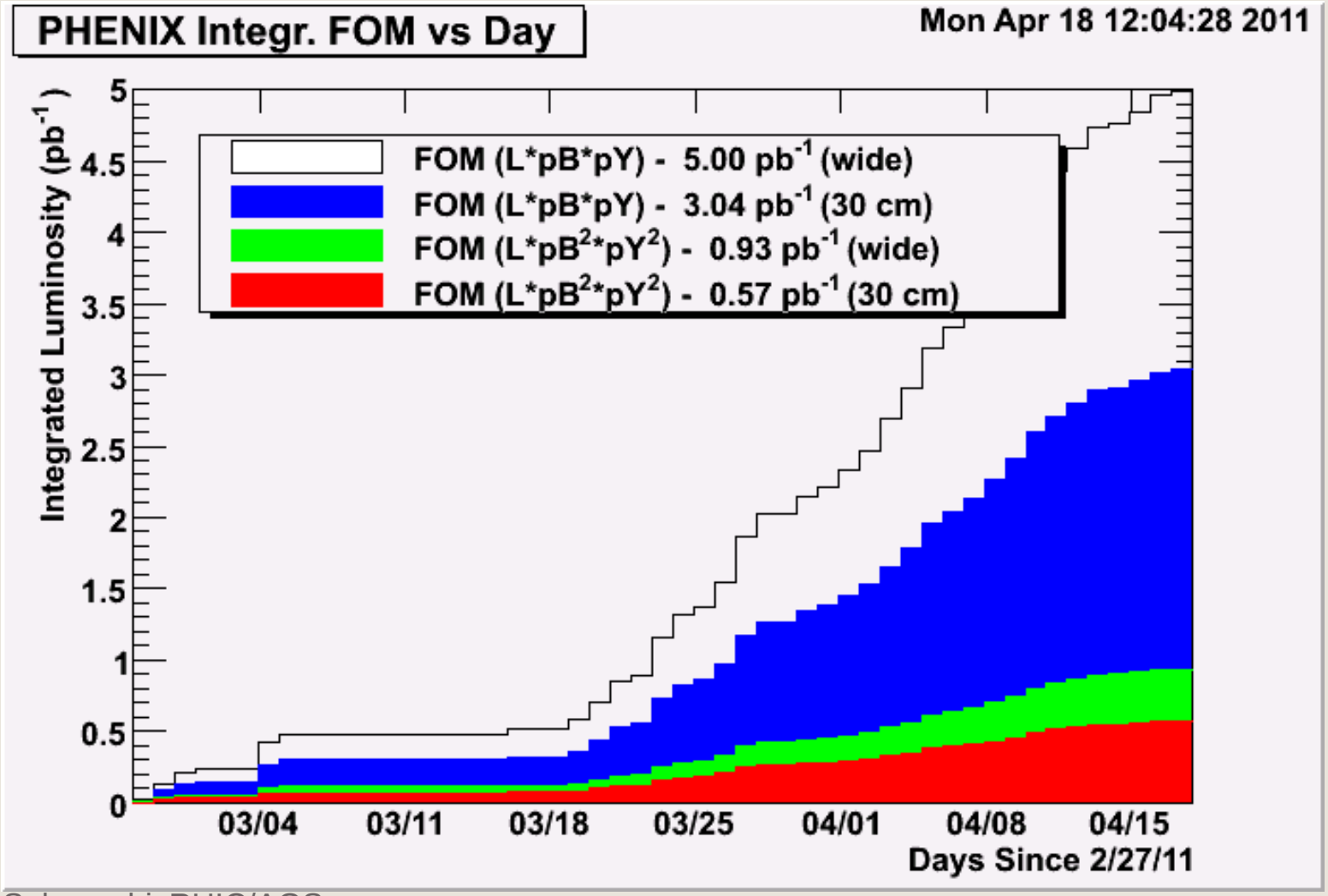
- 16.7 /pb out of 20 /pb (goal) in |z|<30cm



CNI polarization measurements

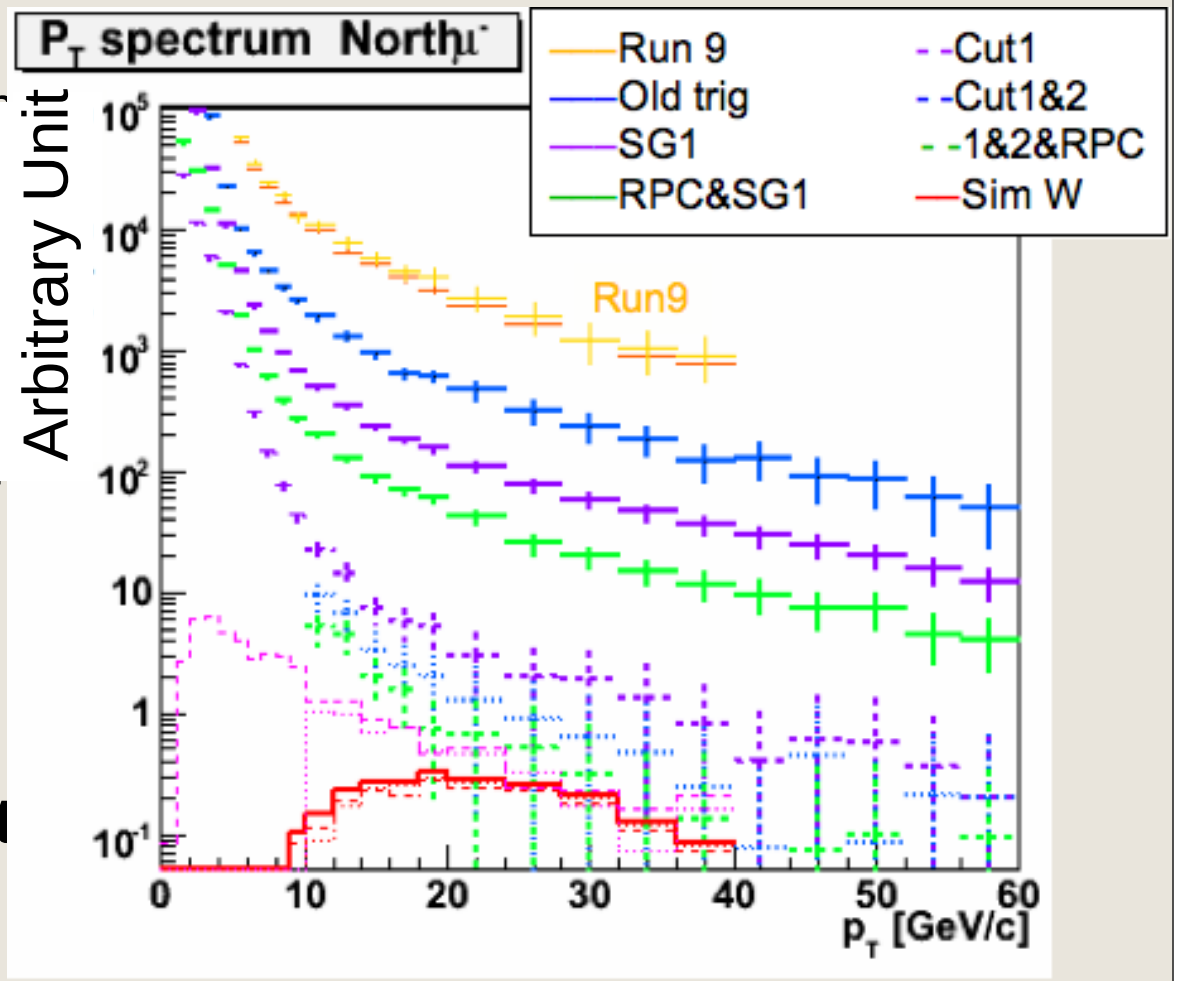


Integrated figure of merit (prel.)



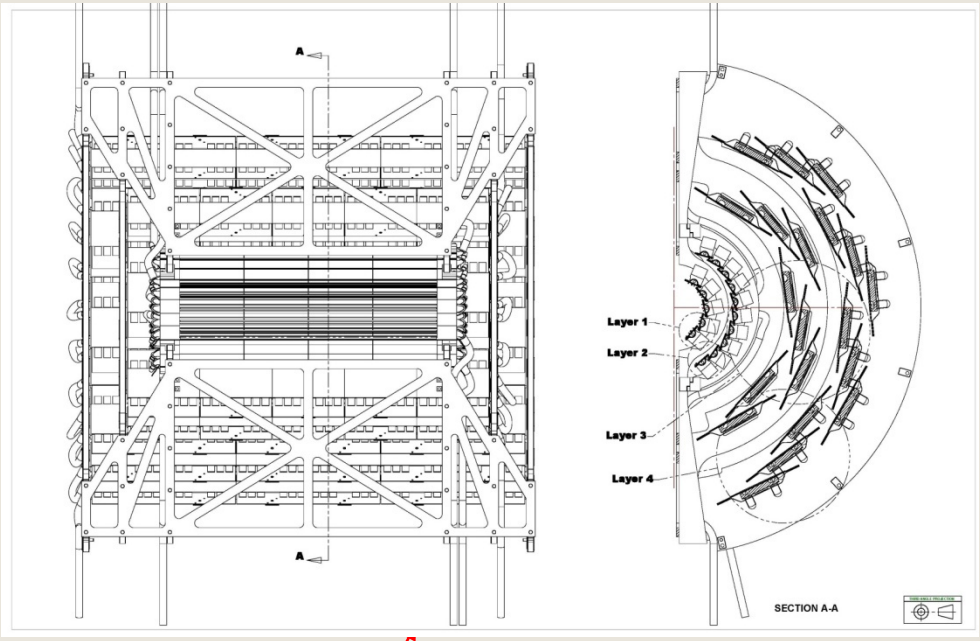
A Look at muon data

- Tracks triggered with MuID&&BBC&&SG1
  - SG1 uses track sagita in Muon Tracker
  - **From first 7.5 pb^{-1} recorded**
- Yellow is Run9
  - Blue is old trigger (lower due to added absorber)
  - Purple is SG1 triggered tracks
  - Green is with RPC
- **With SG1, we did not need to prescale even at highest rates**

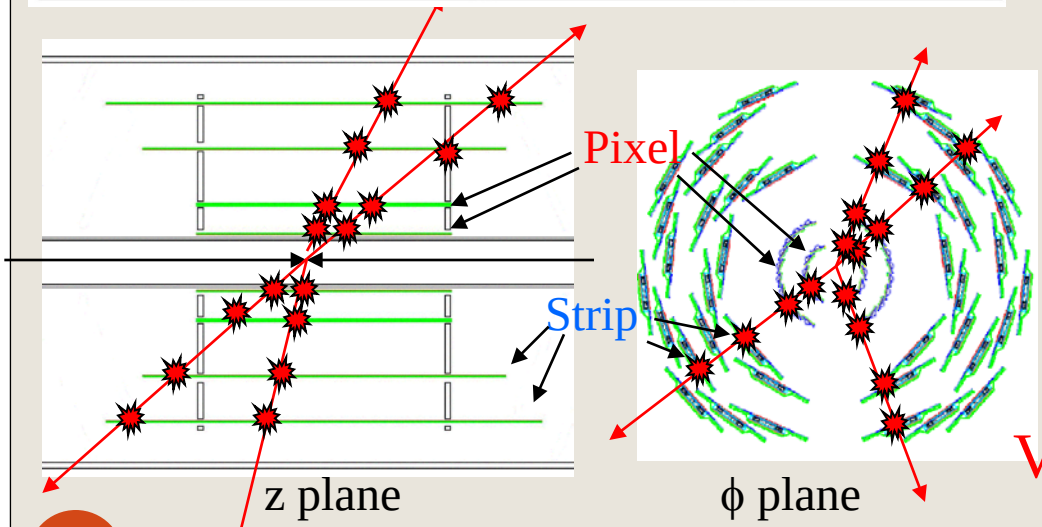


This dataset gives ~10% to our integrated luminosity goal for the W-physics program

Overview of VTX



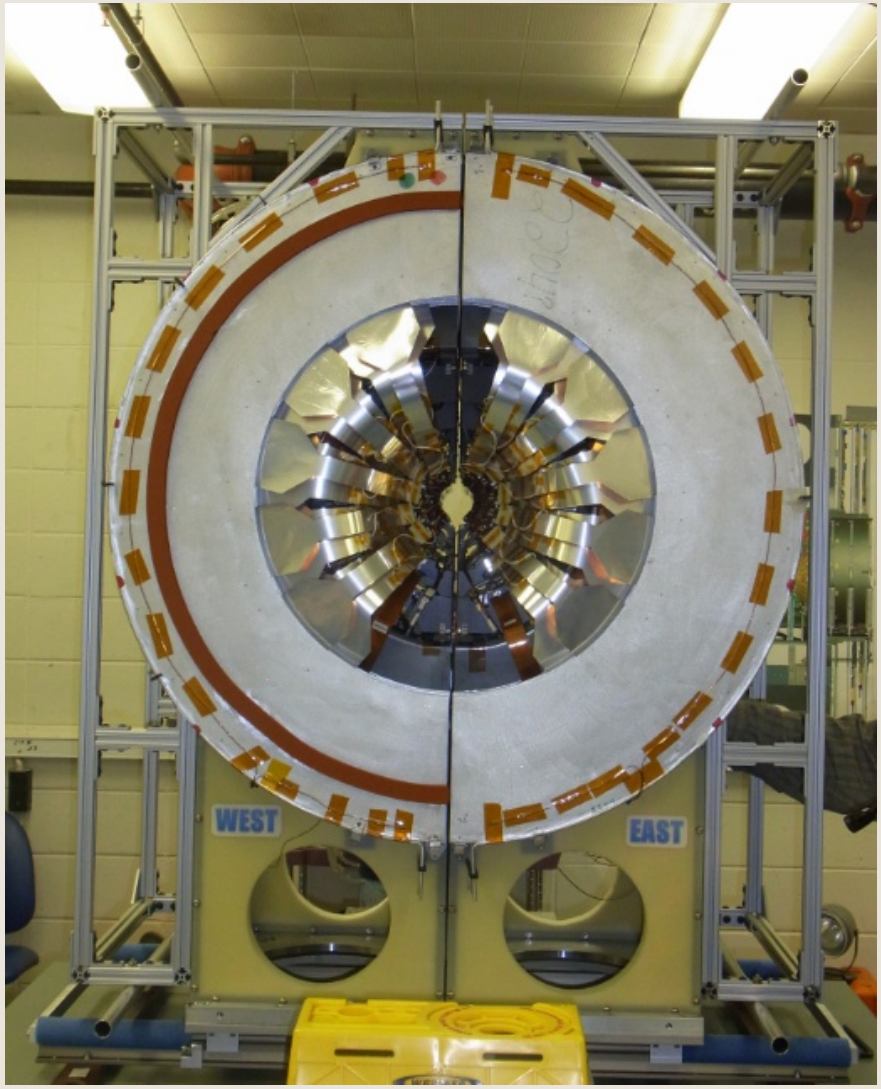
- ✓Fine granularity, low occupancy
  50μm×425μm pixels for L1 and L2
  R1=2.5cm and R2=5cm
- ✓ Stripixel detector for L3 and L4
  80μm×1000μm pixel pitch
  R3=10cm and R4=14cm
- ✓Large acceptance
  $|\eta|<1.2$, almost 2π in ϕ plane
- ✓Stand-alone tracking capability

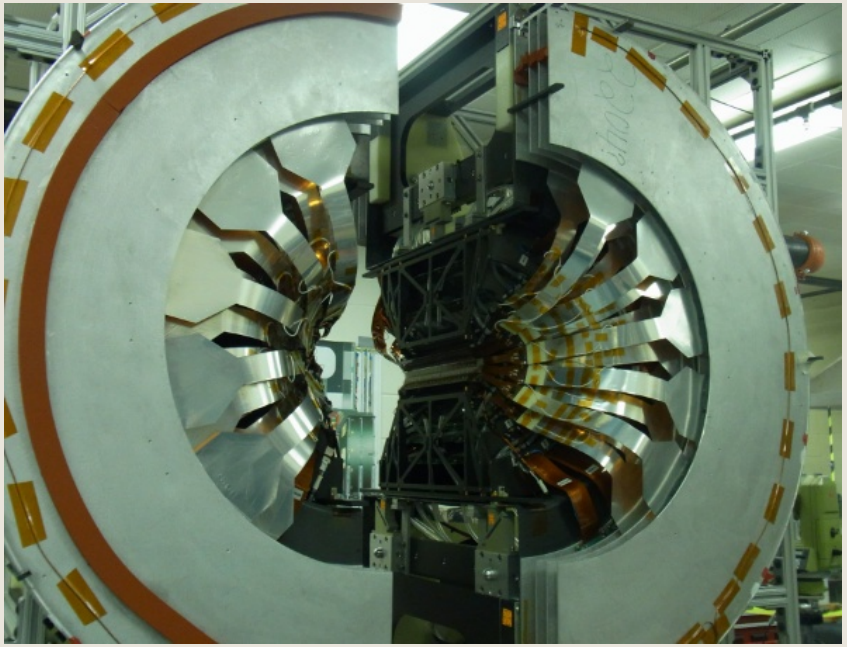


For charm / hadron separation requires enhanced goal of 50 μm DCA

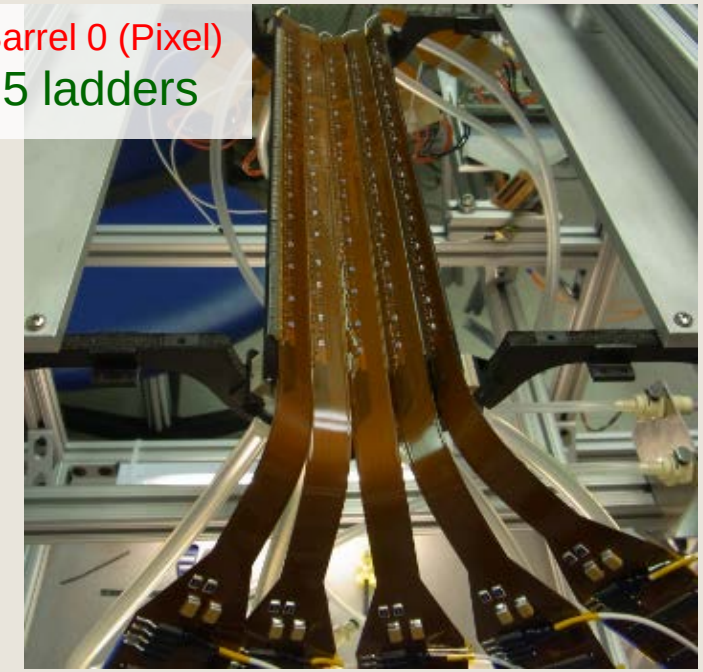
VTX was installed in PHENIX IR in Nov-Dec 2010.

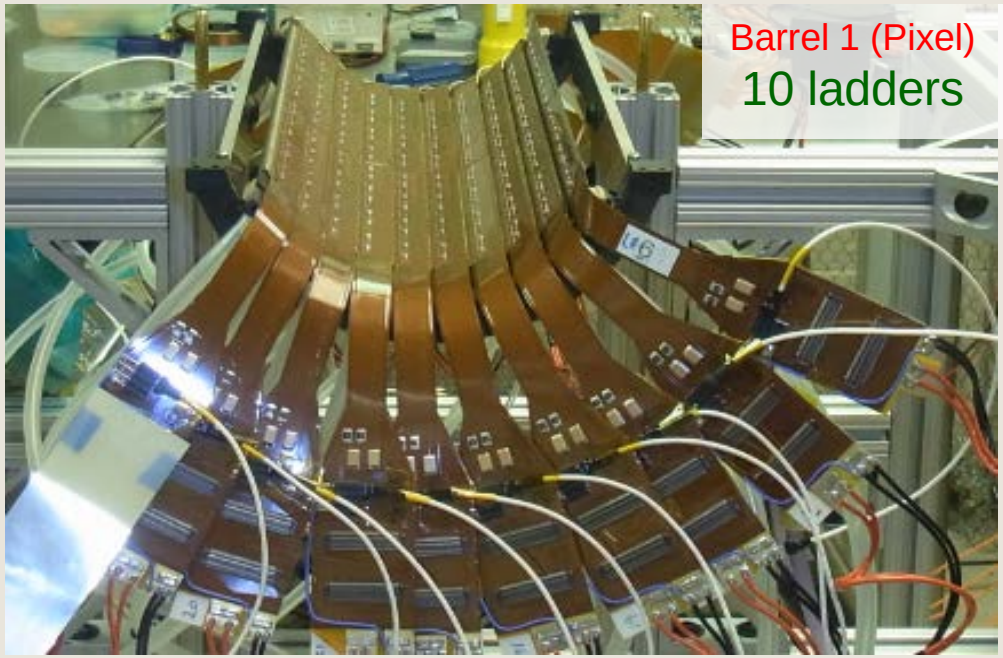
East and West VTX

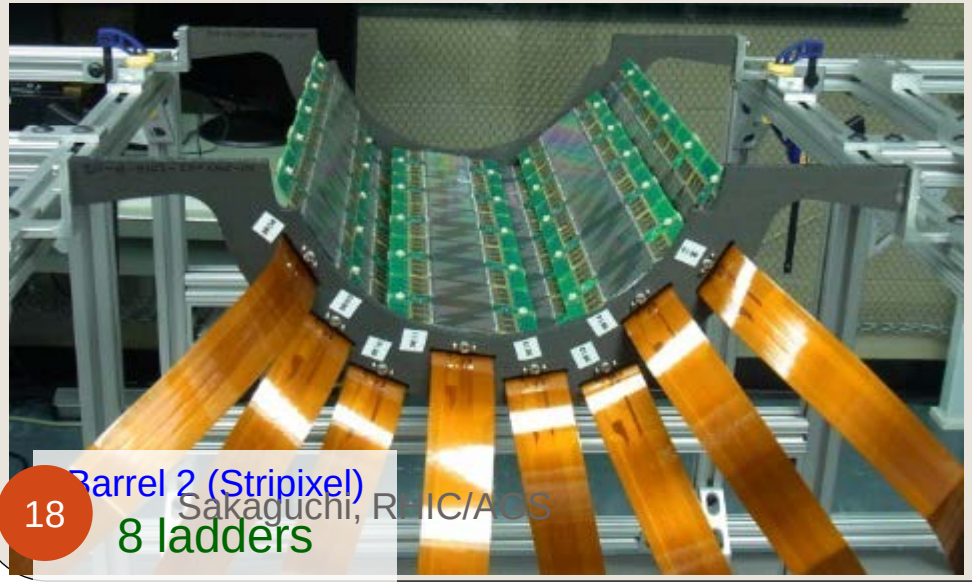


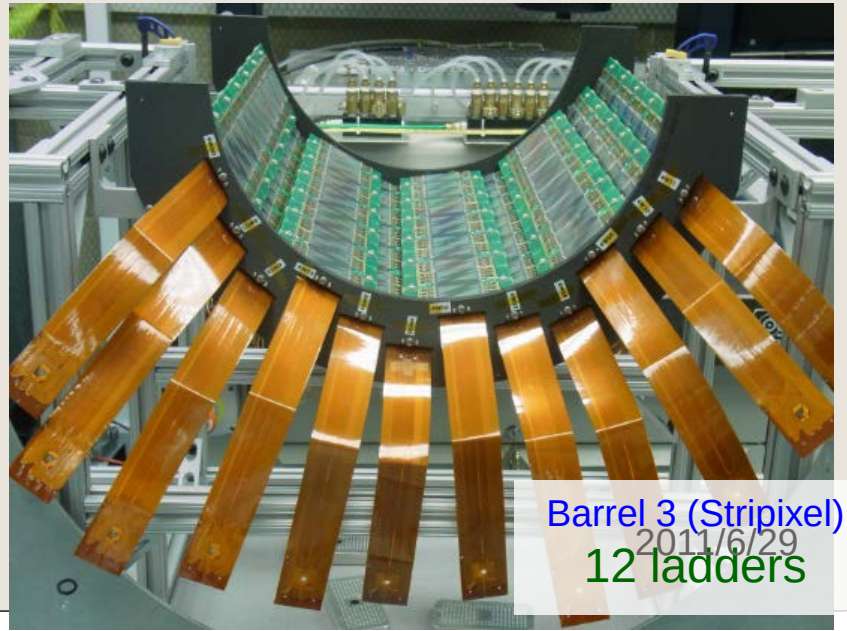


A peek inside the VTX

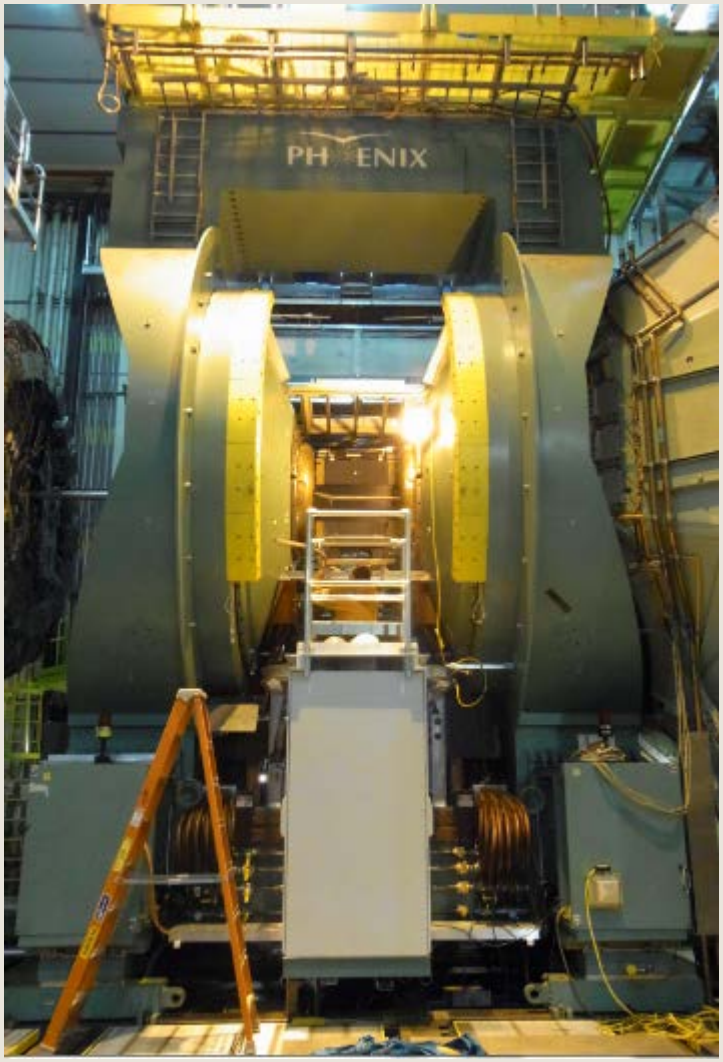


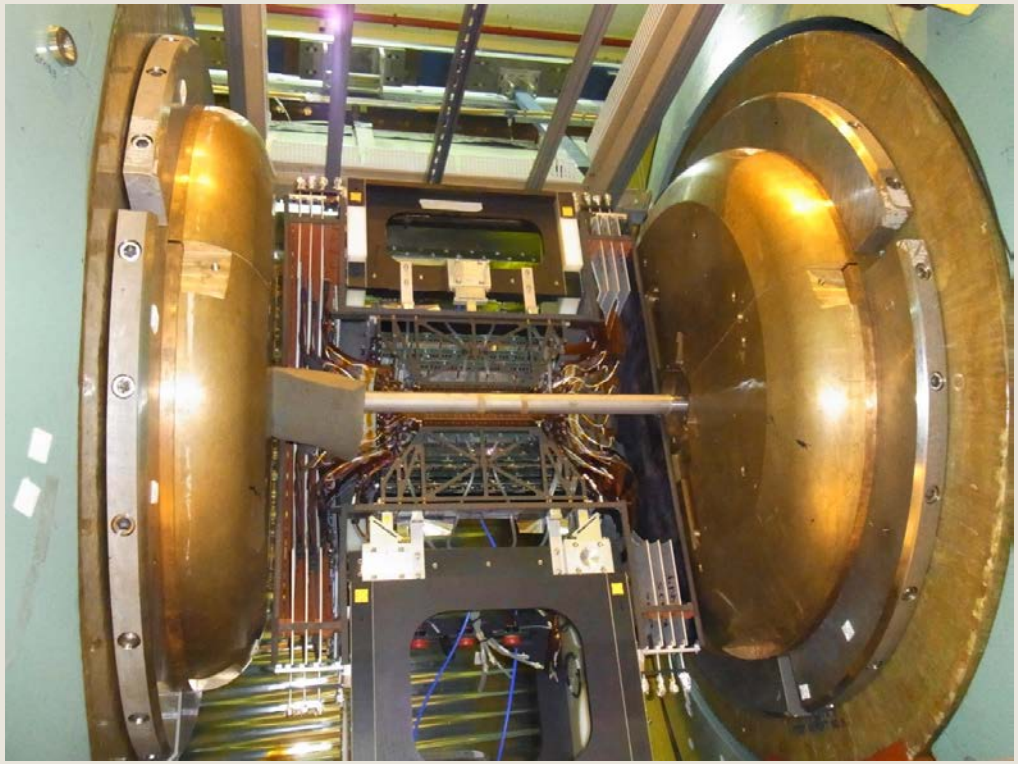






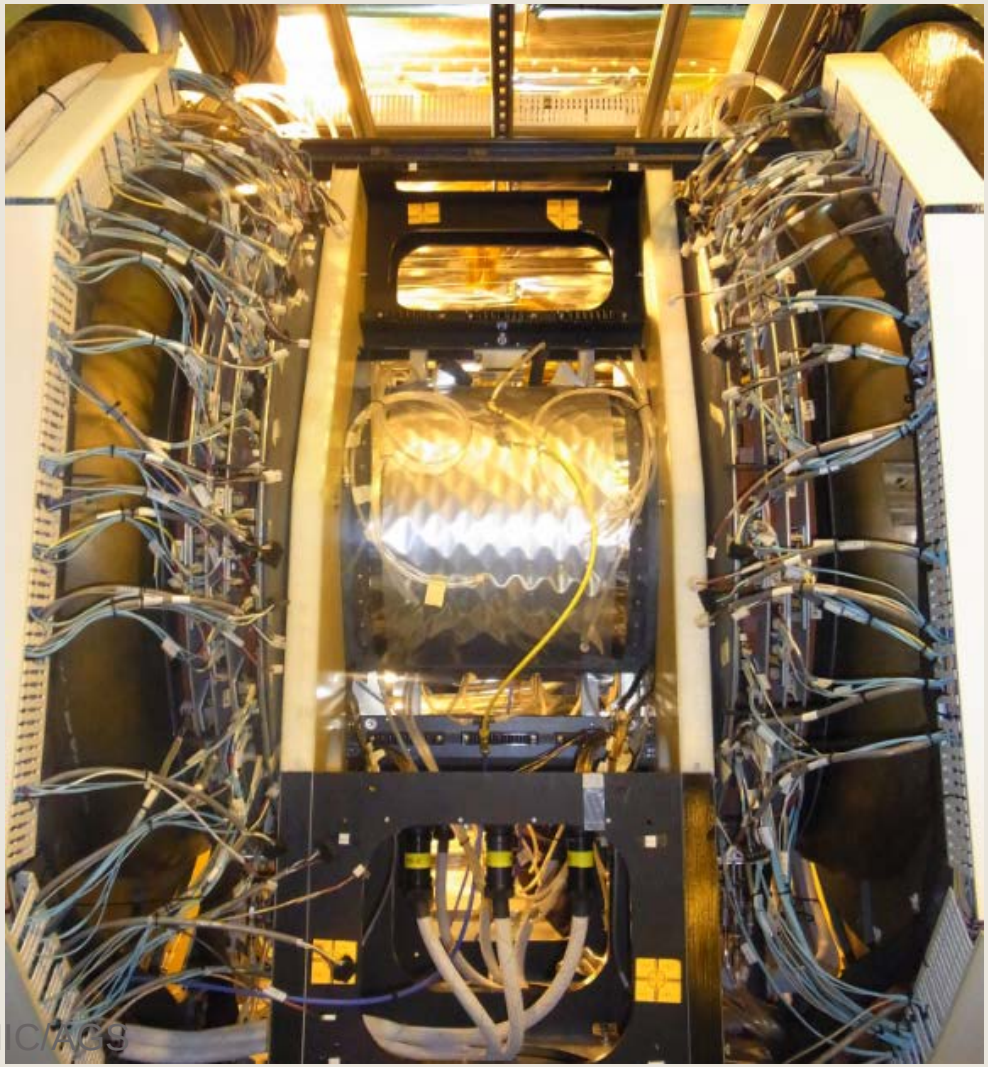
Installed West VTX at PHENIX IR



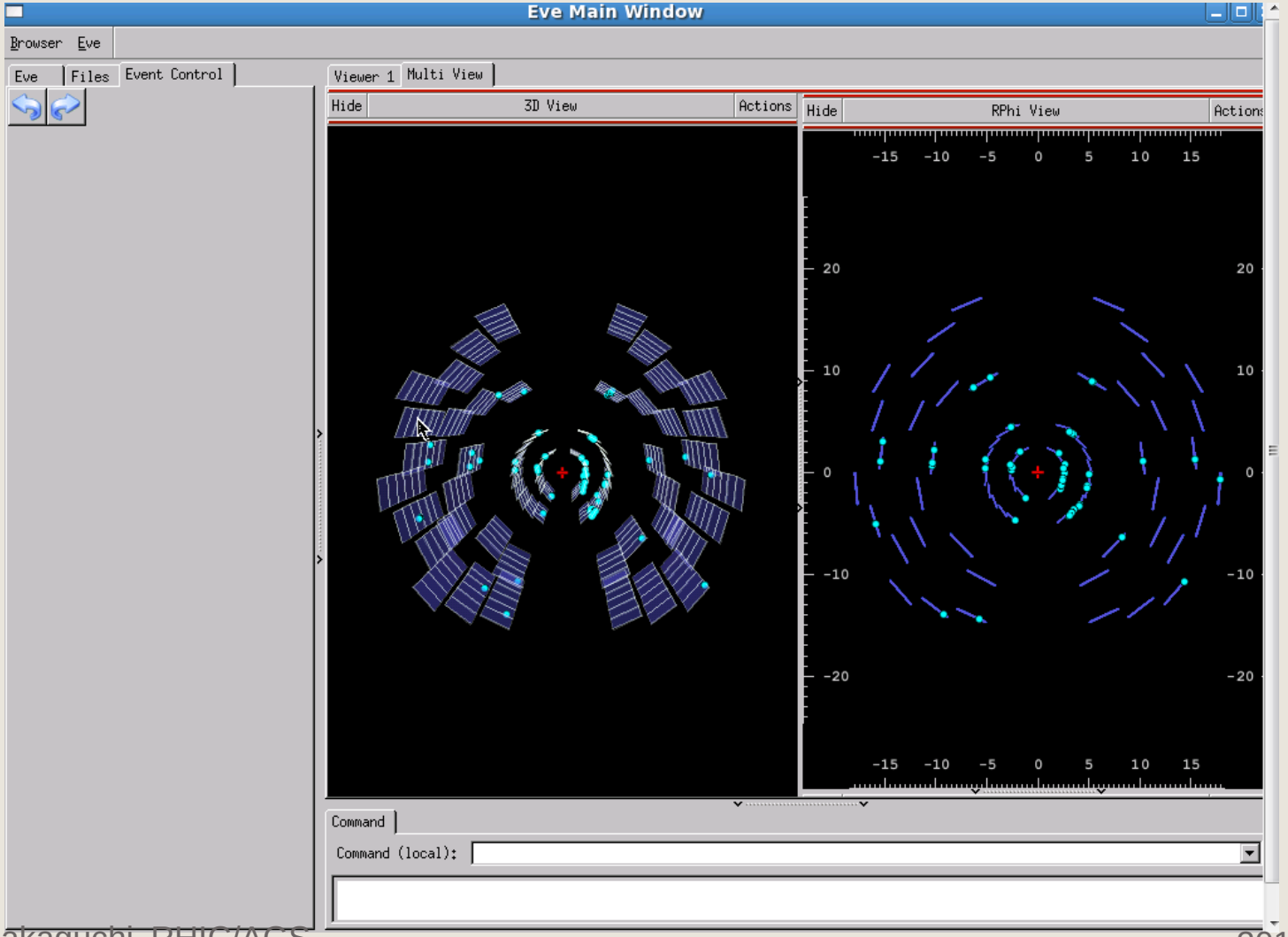


Completed VTX installation in the IR

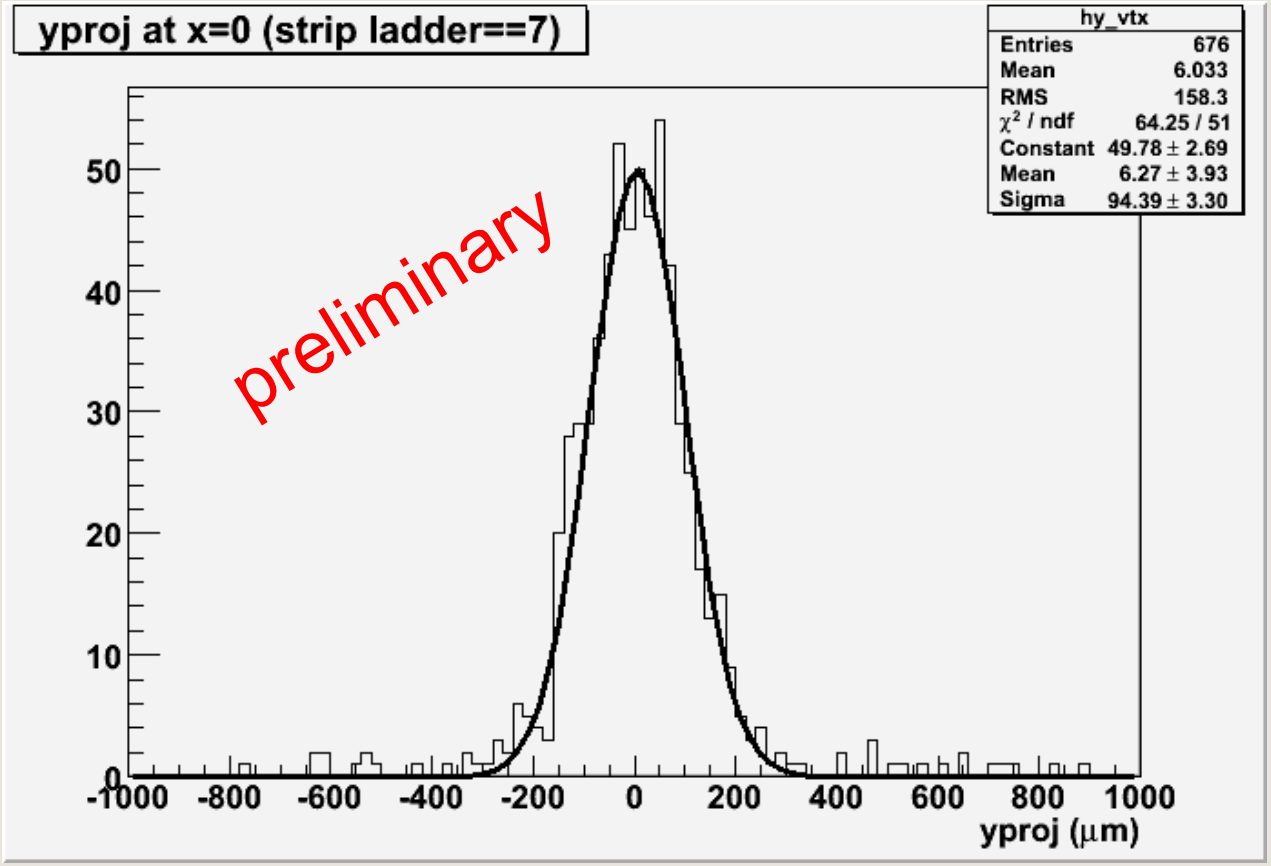
- Achieved in early January



VTX Event Display – 500 GeV p+p



Measured Y vertex in 500 GeV p+p



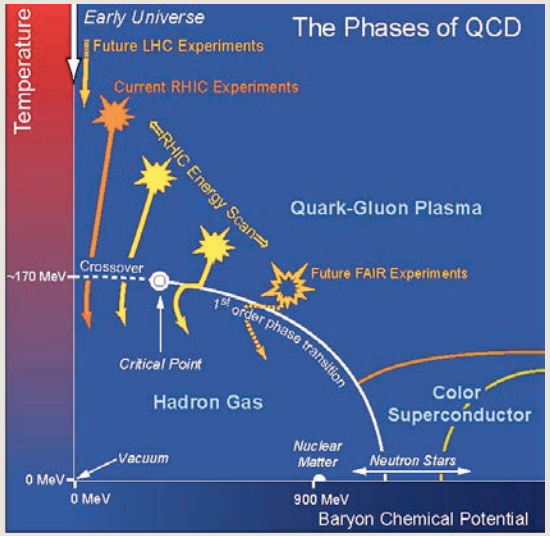
- Projected Y at X=0 plane for selected high pT tracks
- Only small part of VTX (1 ladder in strip) is used to avoid detector-wide alignment
- Width ~ 95 micron, comparable to the beam spot size (~85 micron)

19.6GeV Au+Au

- VTX commissioning
- Critical point search

Finding the QCD Critical Point

Singular point in phase diagram that separates 1st order phase transition (at small T) from smooth cross-over (at small μ_b)



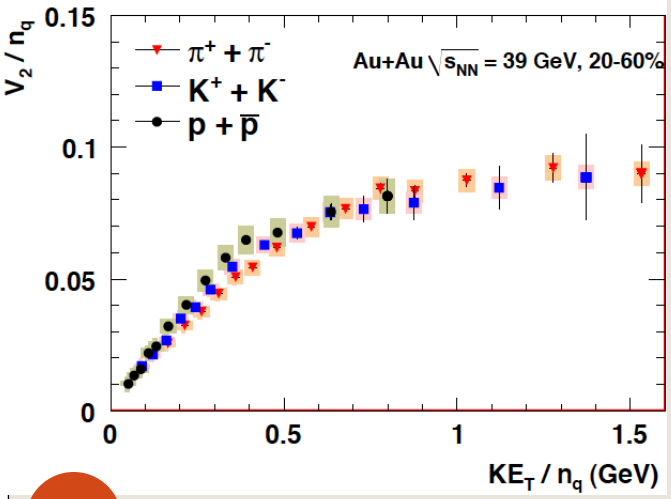
Quark-number scaling of V_2

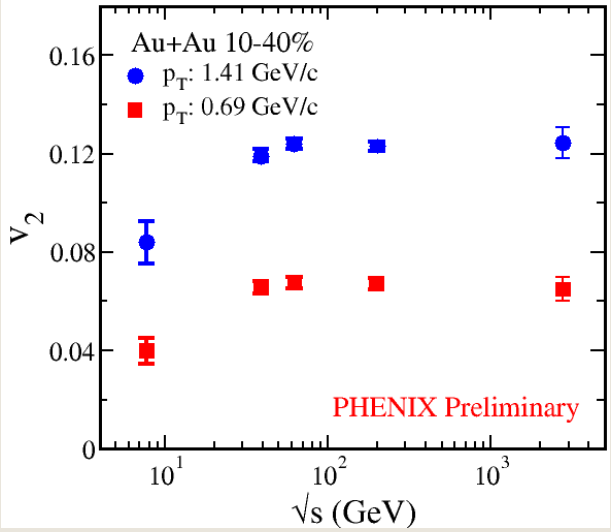
- saturation of flow vs collision energy
- η/s minimum from flow at critical point

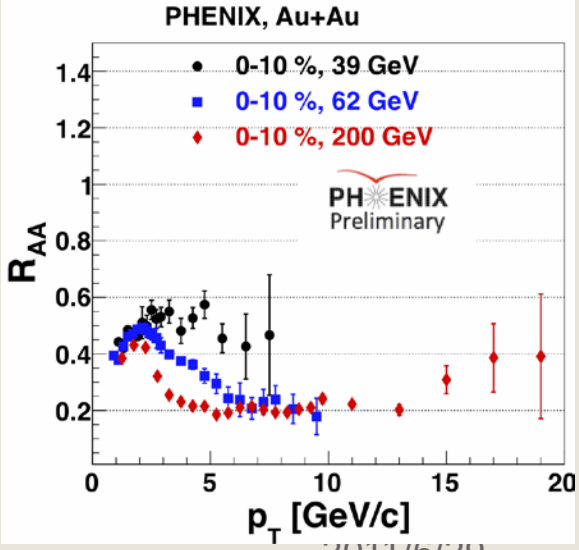
Critical point may be observed via:

- fluctuations in $\langle p_T \rangle$ & multiplicity
- K/π, π/p, pbar/p chemical equilibrium
- R_{AA} vs $\sqrt{s}$, ...

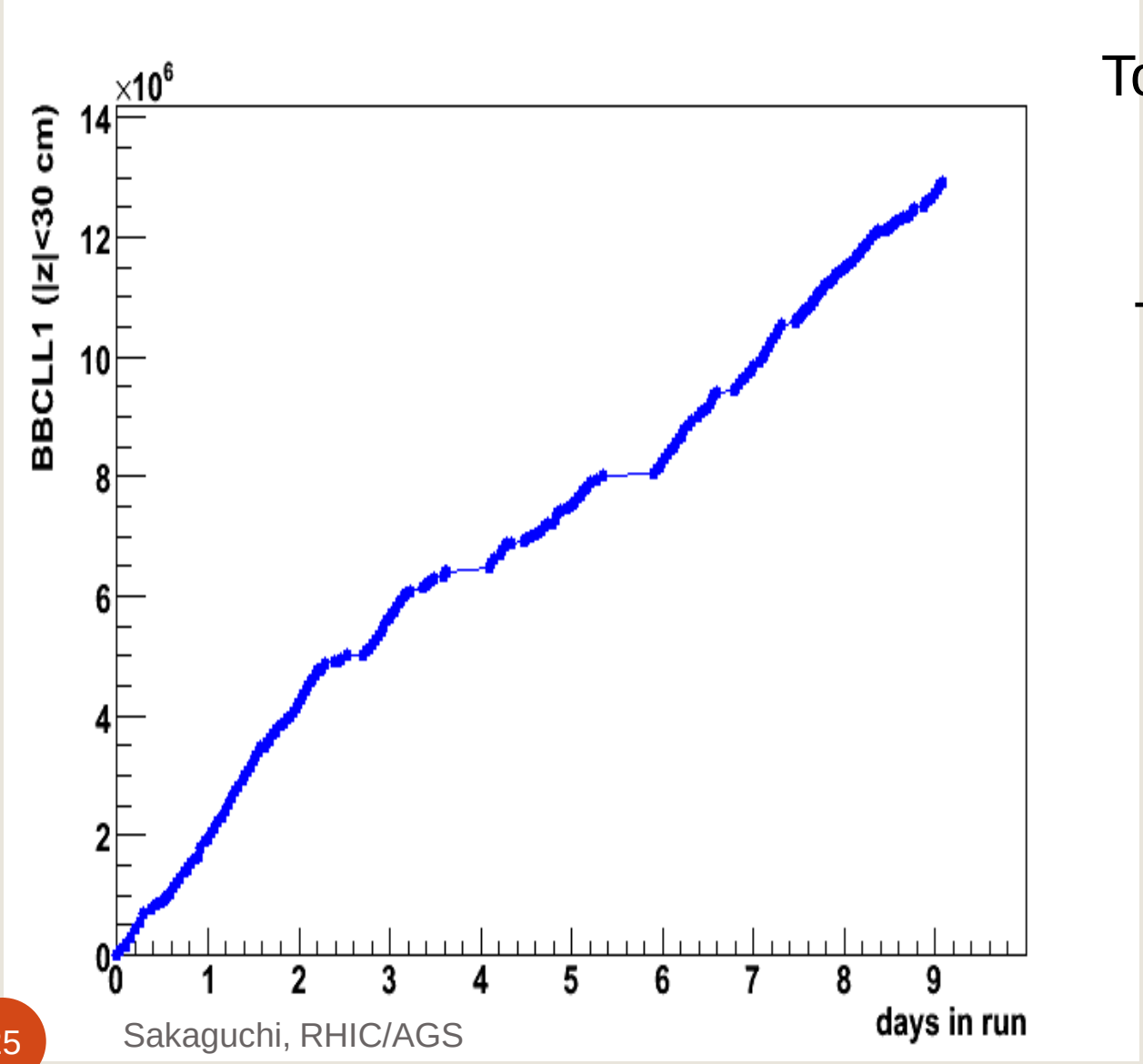
VTX provides large azimuthal acceptance & identification of beam on beam-pipe backgrounds







Statistics in 19.6 GeV Au+Au



Total BBC(|z|<30 cm)

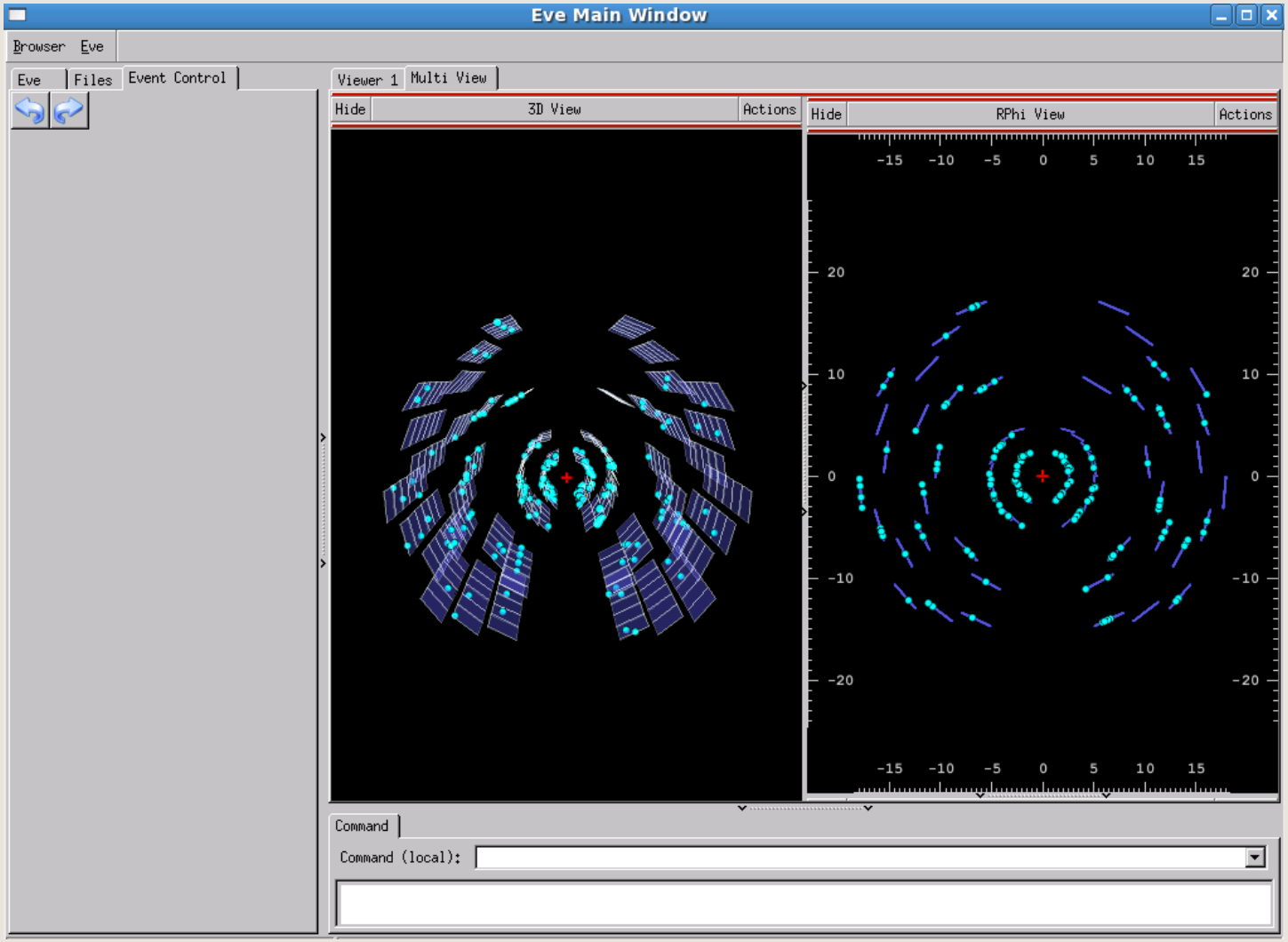
13M Events

To be compared to

1.5M@7.7 GeV
250M@39 GeV

With the VTX in, recorded
~5M Events

VTX Event Display – 19.6 GeV Au+Au



Analysis in progress!

200GeV Au+Au

- VTX commissioning & Physics DAQ (c/b separation)

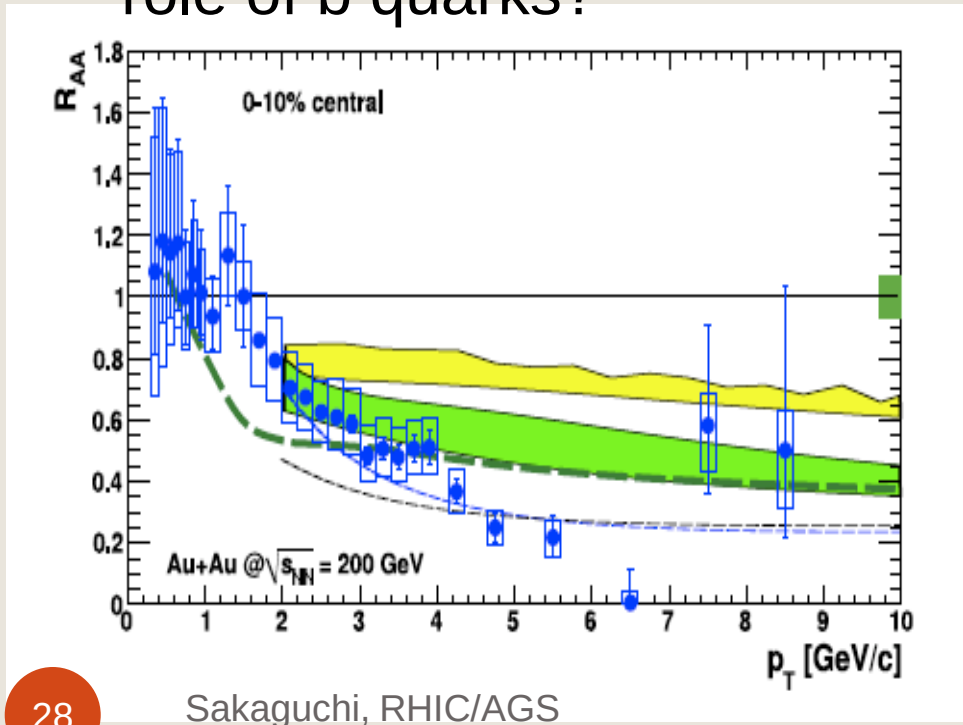
heavy quark suppression & flow?

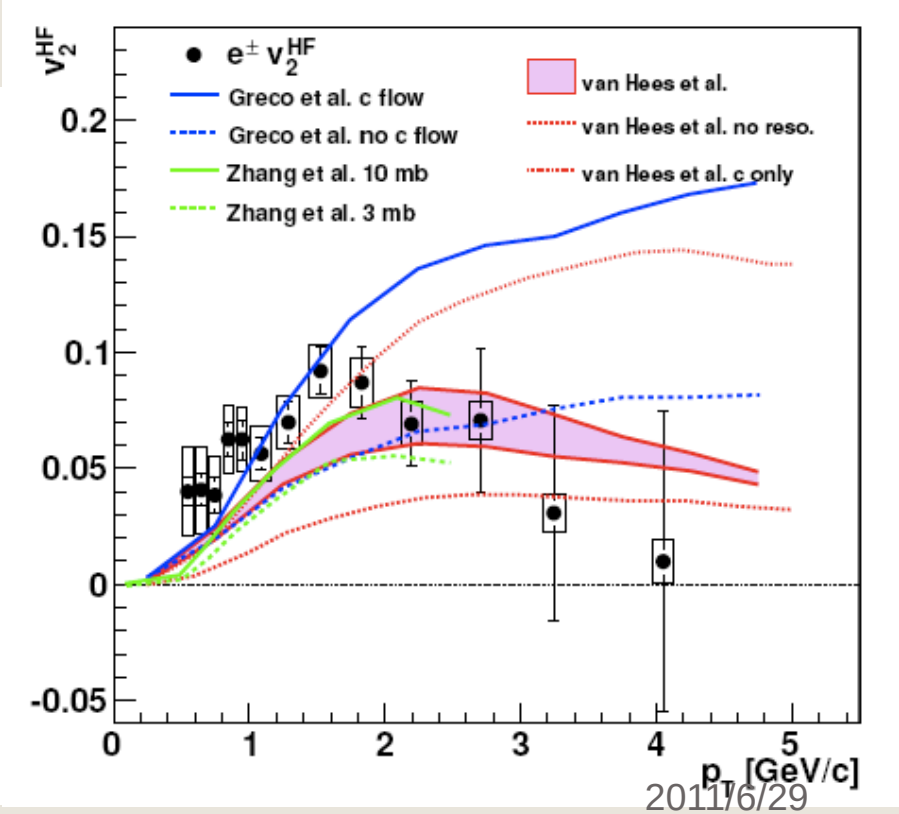
Collisional energy loss?

v_2 decrease with p_T?

role of b quarks?

PRL.98: 172301,2007
arXiV: 1005.1627

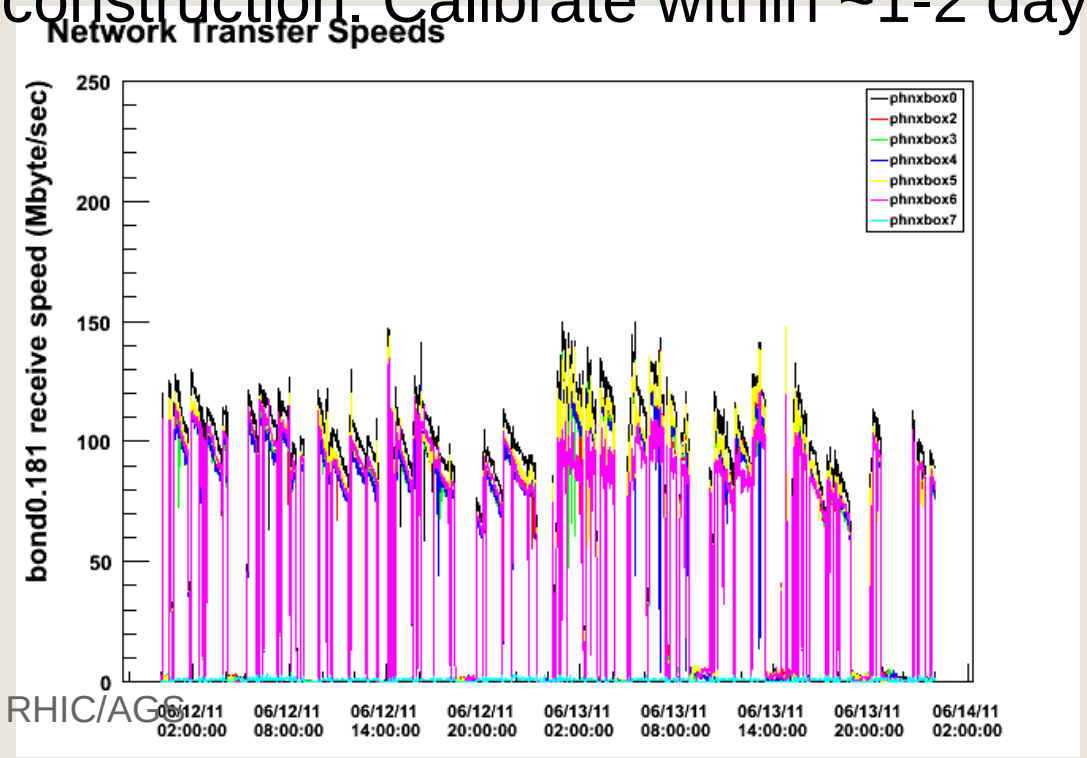




Data Acquisition and Processing

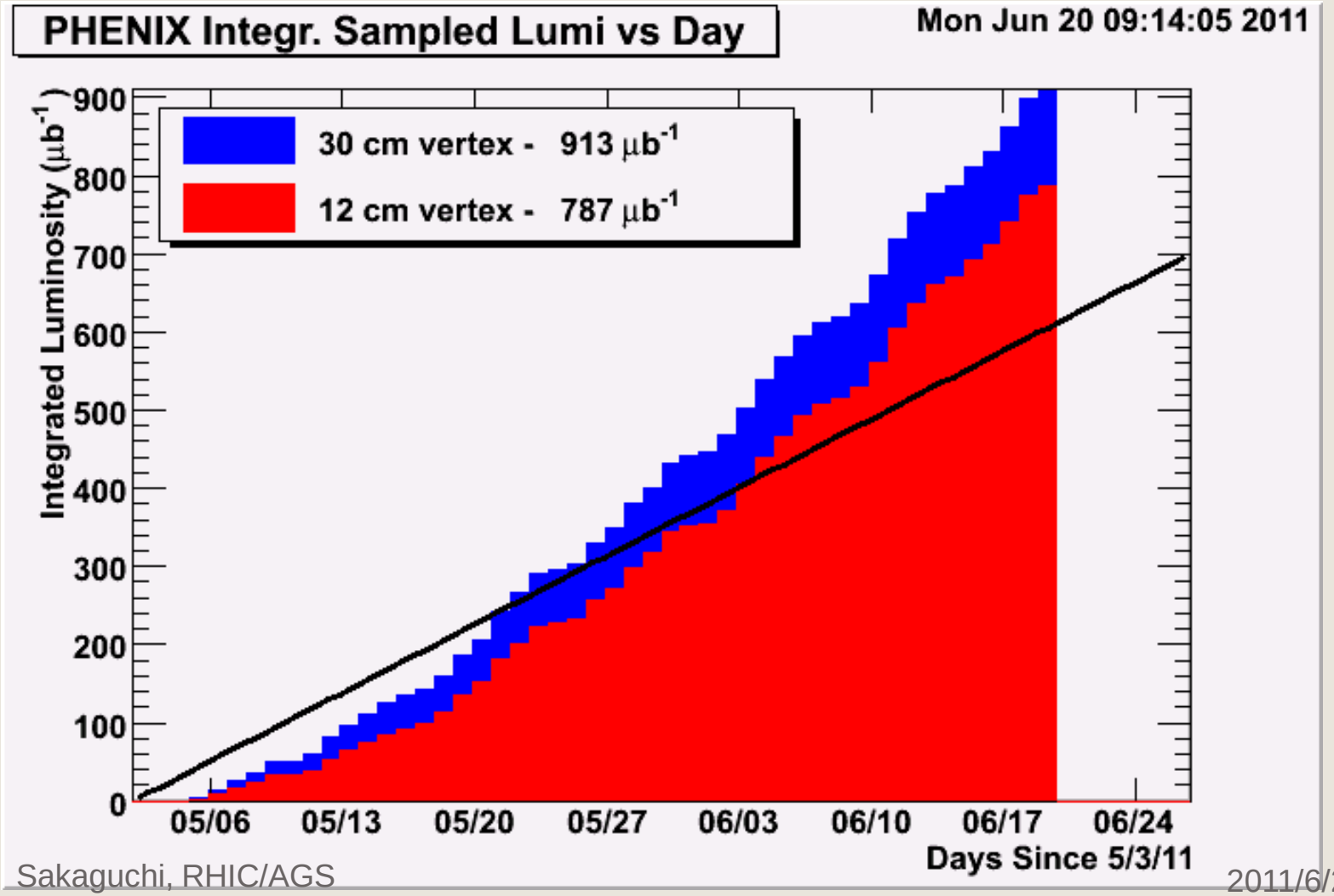
- Fully utilize RHIC luminosity
  - Data rate maintained with VTX ~5kHz (AuAu), ~7kHz(p+p)
  - ~120MBytes/s data transfer to one Hard Disk
  - Typical event size: ~450MBytes/s (Au+Au)

- Timely reconstruction. Calibrate within ~1-2 days.



Integrated luminosity in 200GeV Au+Au

- 787 /ub out of 700 /ub (goal) in |z|<12cm



Characteristic numbers for recorded luminosities

PHENIX Uptime:

200 GeV Au+Au: 71%

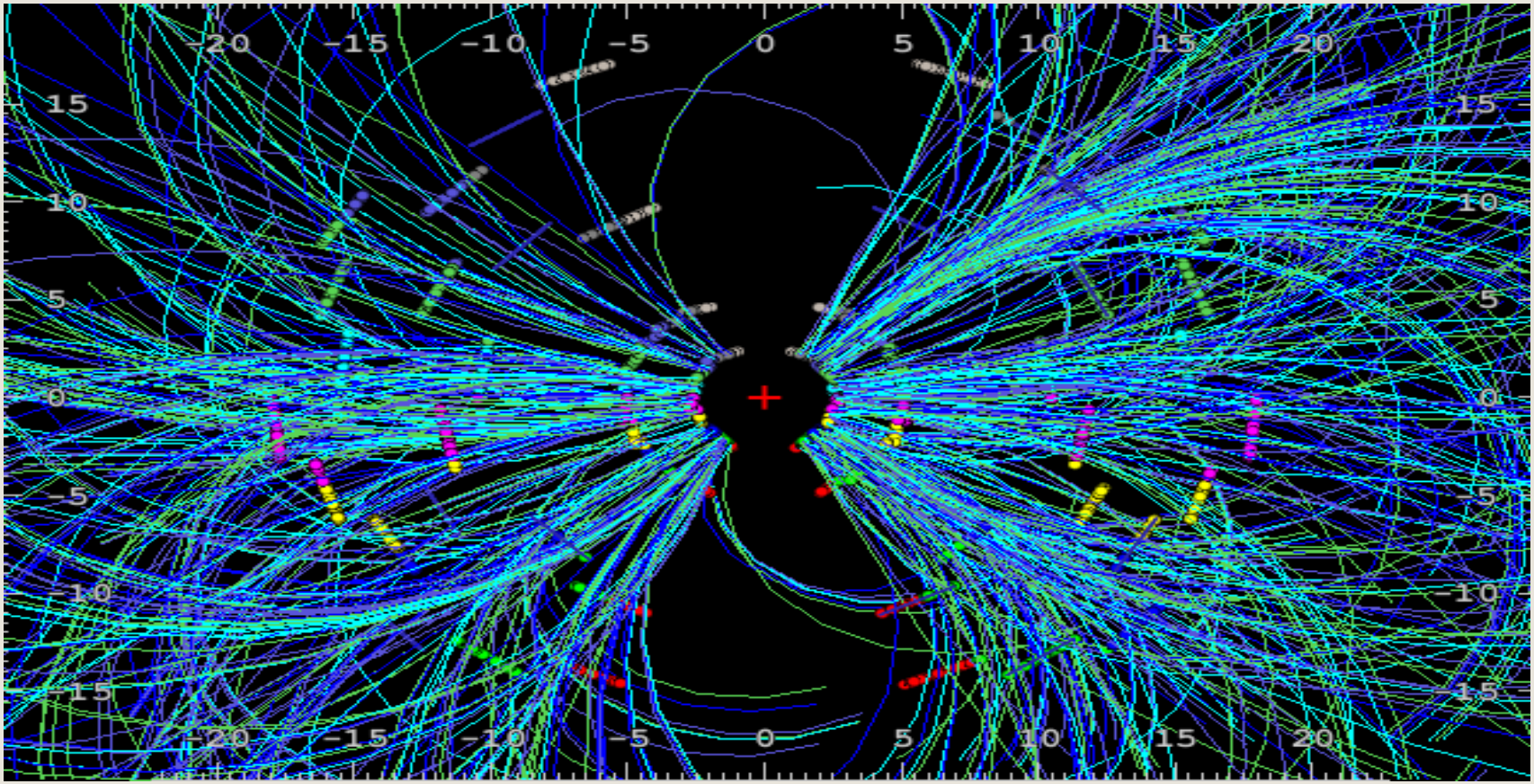
500 GeV p+p: 62%

(not corrected for PHYSICS ON/OFF or for APEX days or Polarization measurements – i.e. just using ZDCNS to guage if physics is ON)

PHENIX Efficiencies	500 GeV p+p	200 GeV Au+Au
Livetime	91%	92%
30 cm vertex	61%	48%
12 cm vertex	35%	27%
Uptime	62%	71%

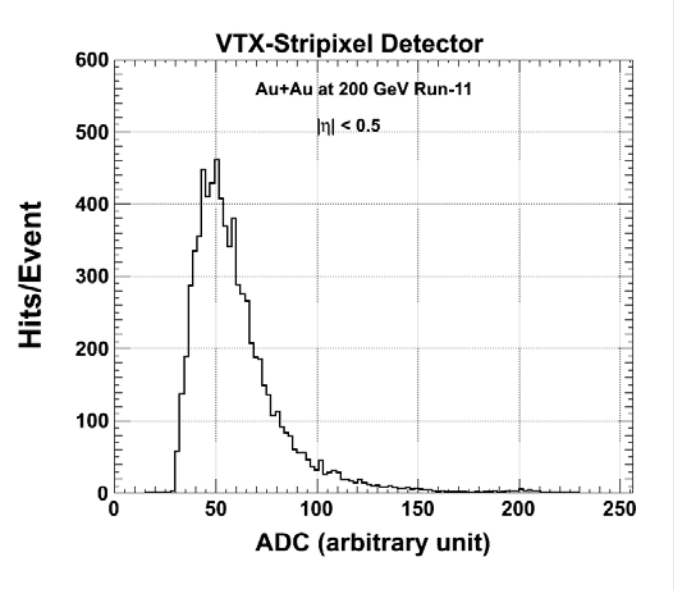
VTX Event Display – 200 GeV Au+Au

Au+Au@200 GeV, 2011

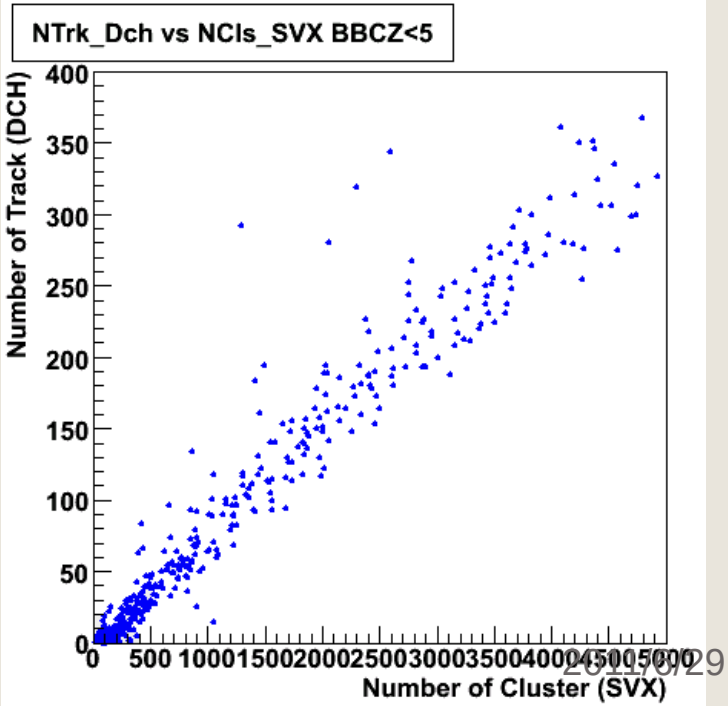


VTX performance quick look in 200GeV

- VTX Stripixel
  - Showing good MIP peak
  - Peak in ADC from stripixel SVX4 ADC ~50 for clusters

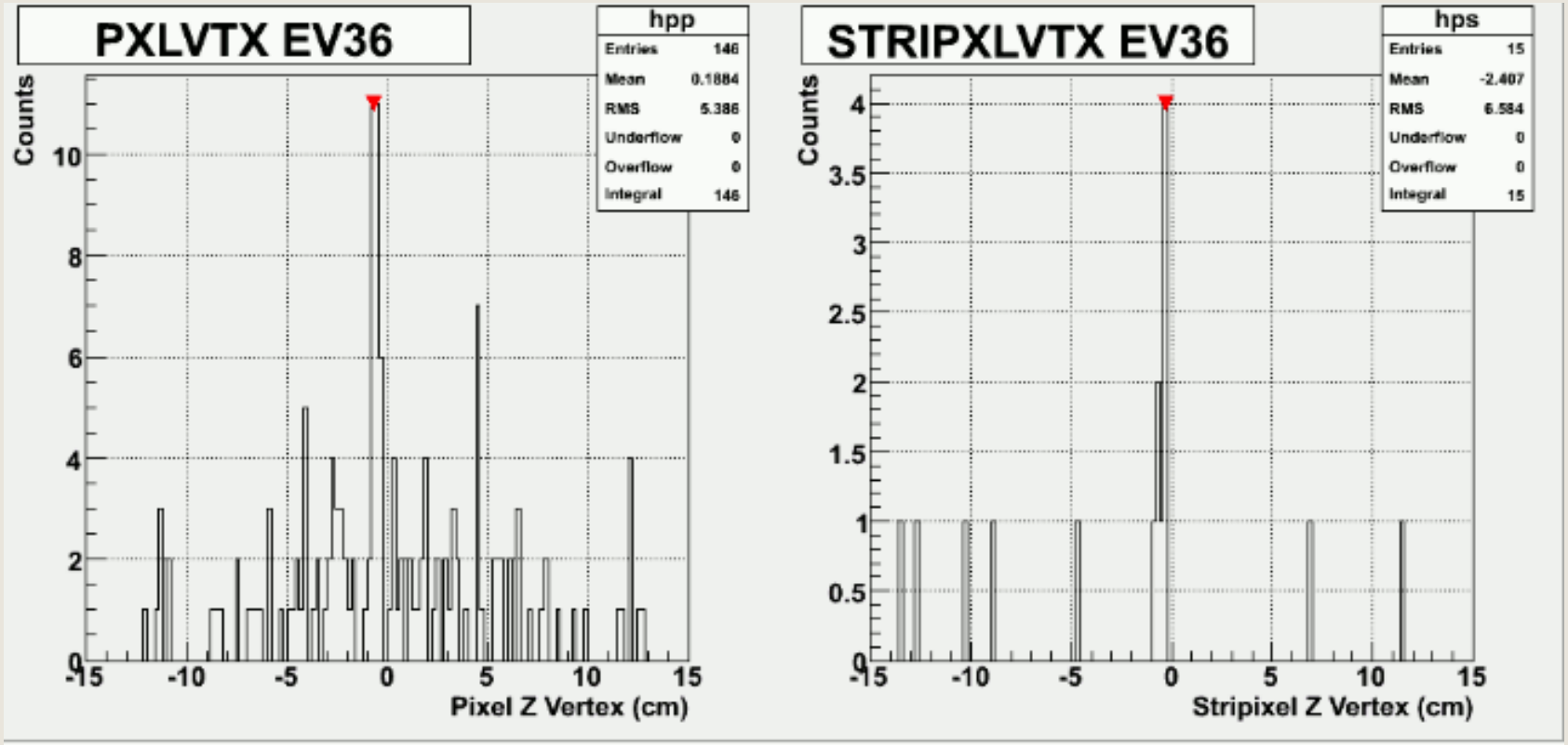


- VTX Pixel
  - Estimated ~80% live pixels
  - Good correlation between number of clusters and number of Drift chamber tracks.



Vertices from VTX Stripixel and Pixel

- Reconstructed vertices in a same single event
- Coincidence of the vertices at ~0cm is clearly seen



Bin width in analysis code : 500um

27GeV Au+Au

- Another critical point search.
- All detectors in orchestra. Expecting ~5.2/ub luminosity.

Summary

- PHENIX had successful run this year for all collision energies and species
- W measurement succeeded in 500GeV p+p with upgraded muon detectors and trigger electronics
- VTX was commissioned in 500GeV p+p and 19.6GeV Au+Au
- VTX was operational in 200GeV Au+Au and 27GeV Au+Au
  - c/b separation by DCA analysis on-going
- Beam was excellent in low energy running
  - Accumulated good statistics to do physics

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Hiroshima University, Kagamiyama, Higashi-Hiroshima 739-8526, Japan
KEK, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan
Kyoto University, Kyoto 606-8502, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki 851-0193, Japan
RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 351-0198, Japan
Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
Department of Physics, Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japan
Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan
Chonbuk National University, Jeonju, Korea
Ewha Womans University, Seoul 120-750, Korea
Hanyang University, Seoul 133-792, Korea
KAERI, Cyclotron Application Laboratory, Seoul, South Korea
Korea University, Seoul, 136-701, Korea
Myongji University, Yongin, Kyonggido 449-728, Korea
System Electronics Laboratory, Seoul National University, Seoul, South Korea
Yonsei University, IPAP, Seoul 120-749, Korea
IHEP Protvino, State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, 142281, Russia
Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
Russian Research Center "Kurchatov Institute", Moscow, Russia
PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
Saint Petersburg State Polytechnic University, St. Petersburg, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, [illegible] 19992, Russia
De[illegible] Physics, Lund University, Box 118, SE-221 00 Lund, Sweden

PHENIX

14 Countries; 70 Institutions

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Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
University of California - Riverside, Riverside, CA 92521, U.S.
University of Colorado, Boulder, CO 80309, U.S.
Columbia University, New York, NY 10027 and Nevis Laboratories, Irvington, NY 10533, U.S.
Florida Institute of Technology, Melbourne, FL 32901, U.S.
Florida State University, Tallahassee, FL 32306, U.S.
Georgia State University, Atlanta, GA 30303, U.S.
University of Illinois at Urbana-Champaign, Urbana, IL 61801, U.S.
Iowa State University, Ames, IA 50011, U.S.
Lawrence Livermore National Laboratory, Livermore, CA 94550, U.S.
Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.
University of Maryland, College Park, MD 20742, U.S.
Department of Physics, University of Massachusetts, Amherst, MA 01003-9337, U.S.
Morgan State University, Baltimore, MD 21251, U.S.
Muhlenberg College, Allentown, PA 18104-5586, U.S.
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New Mexico State University, Las Cruces, NM 88003, U.S.
Oak Ridge National Laboratory, Oak Ridge, TN 37831, U.S.
Department of Physics and Astronomy, Ohio University, Athens, OH 45701, U.S.
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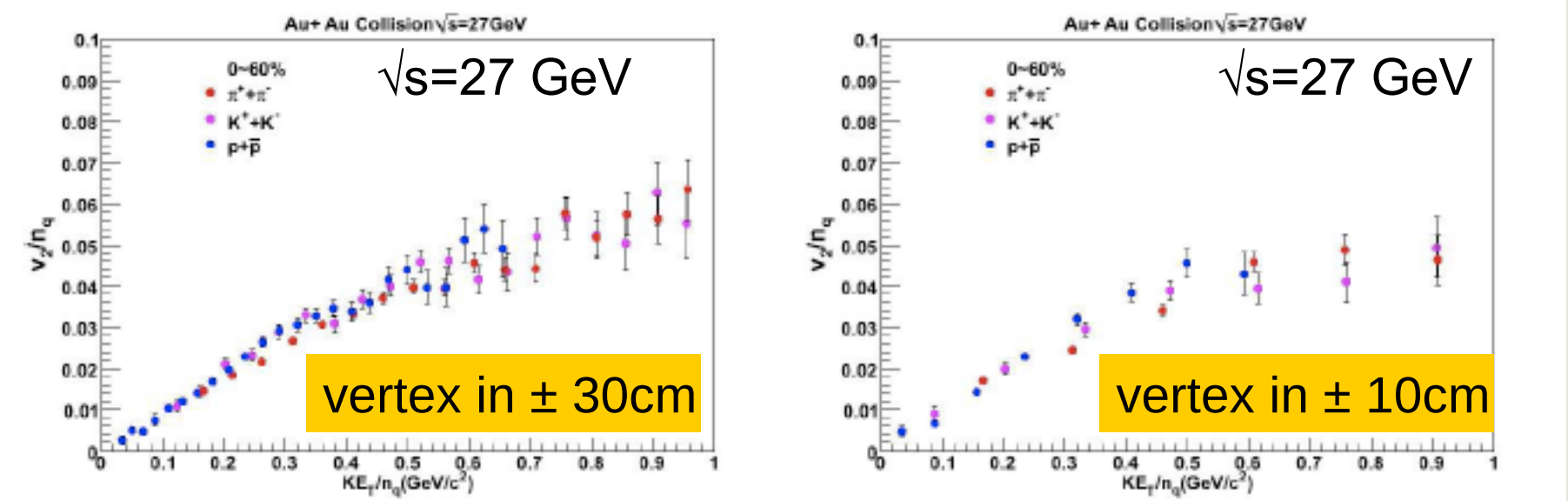
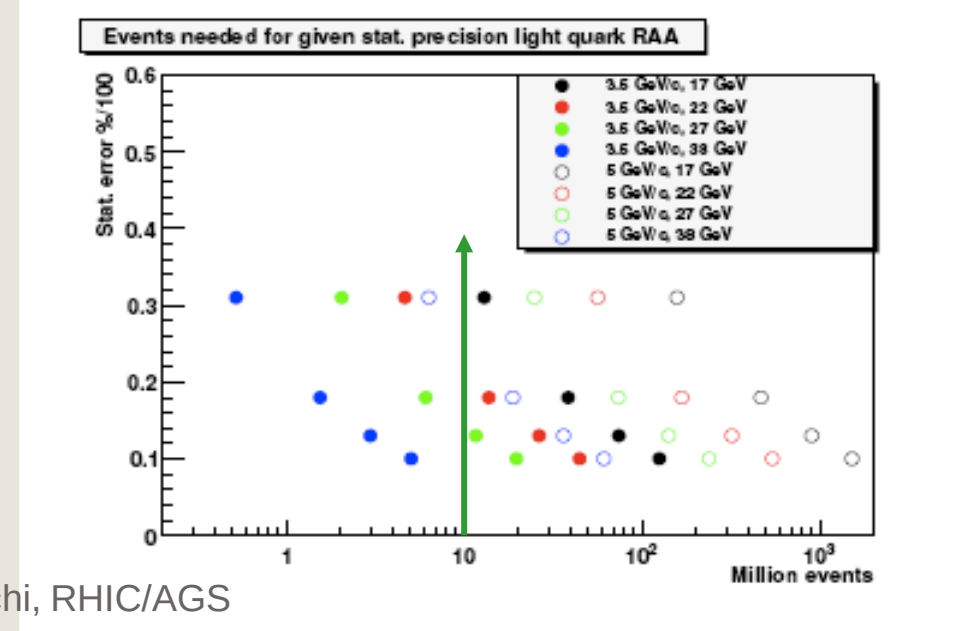
Department of Physics and Astronomy, Stony Brook University, SUNY, Stony Brook, NY 11794, U.S.
University of Tennessee, Knoxville, TN 37996, U.S.
Vanderbilt University, Nashville, TN 37235, U.S.

Backup

v_2 measurement & …



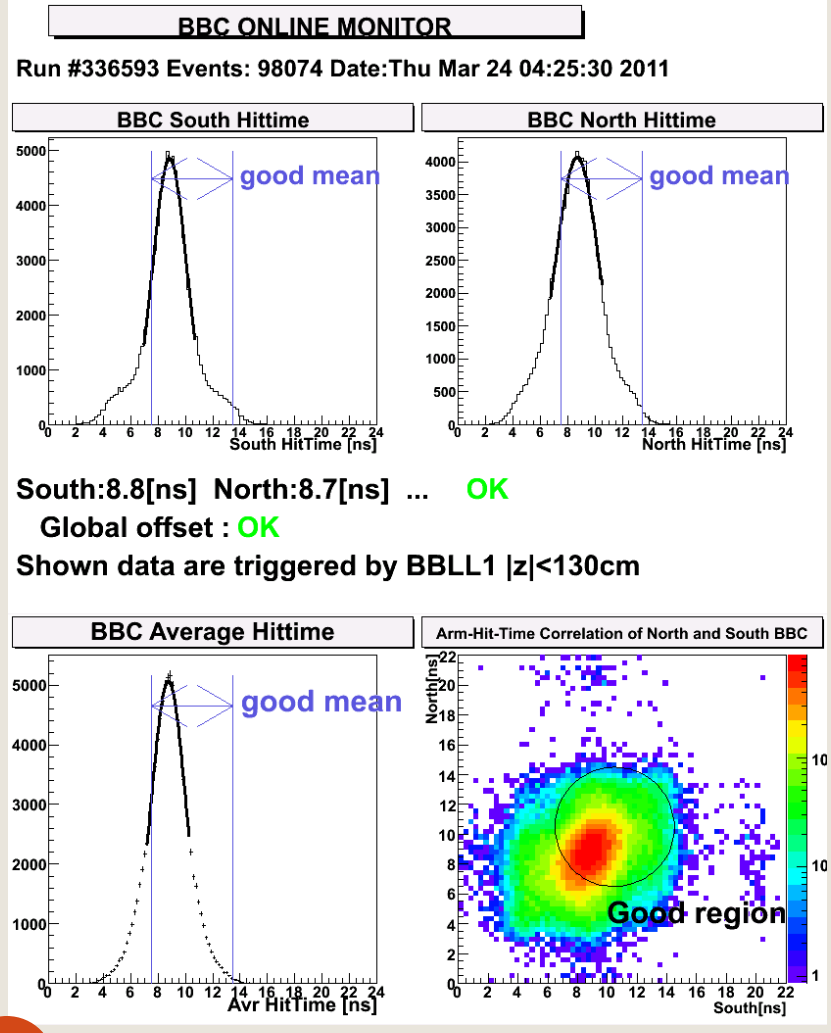
Vertex cut
± 10 cm



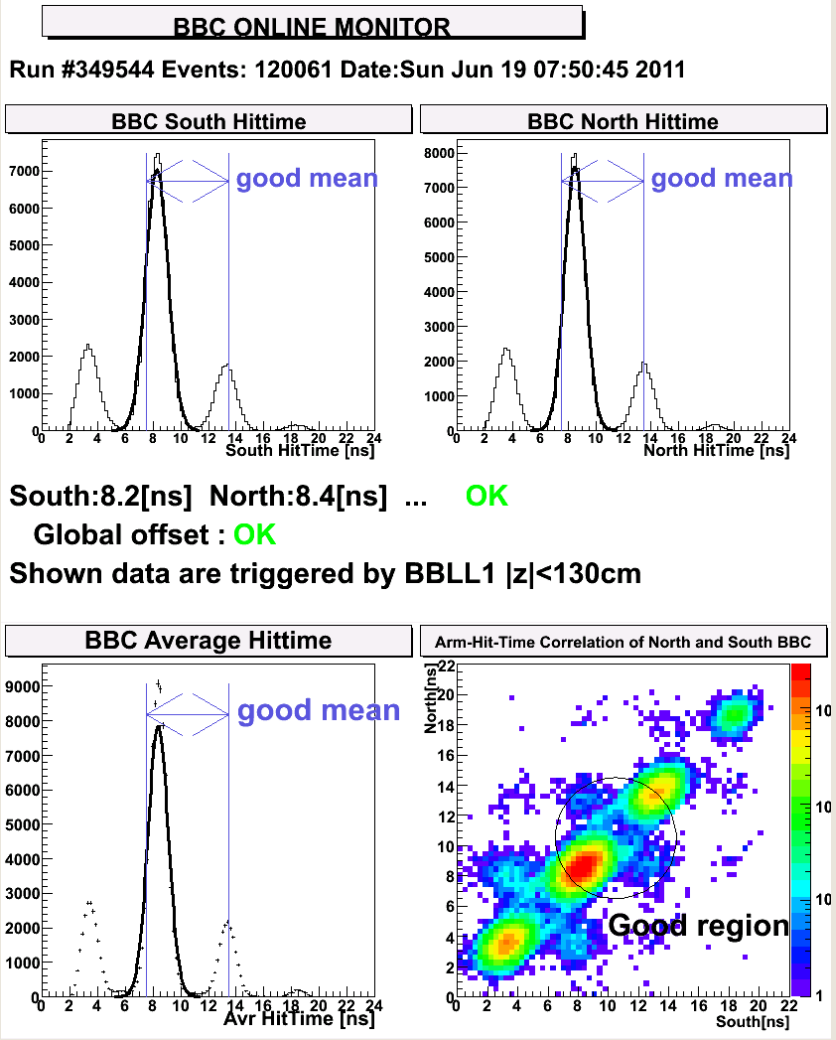
1 week of running (~11M events) uncertainty at p_T = 3.5 GeV:
~14% at 27 GeV
Marginal for n_q scaling

Differences in Vertex Distributions between p+p and Au+Au

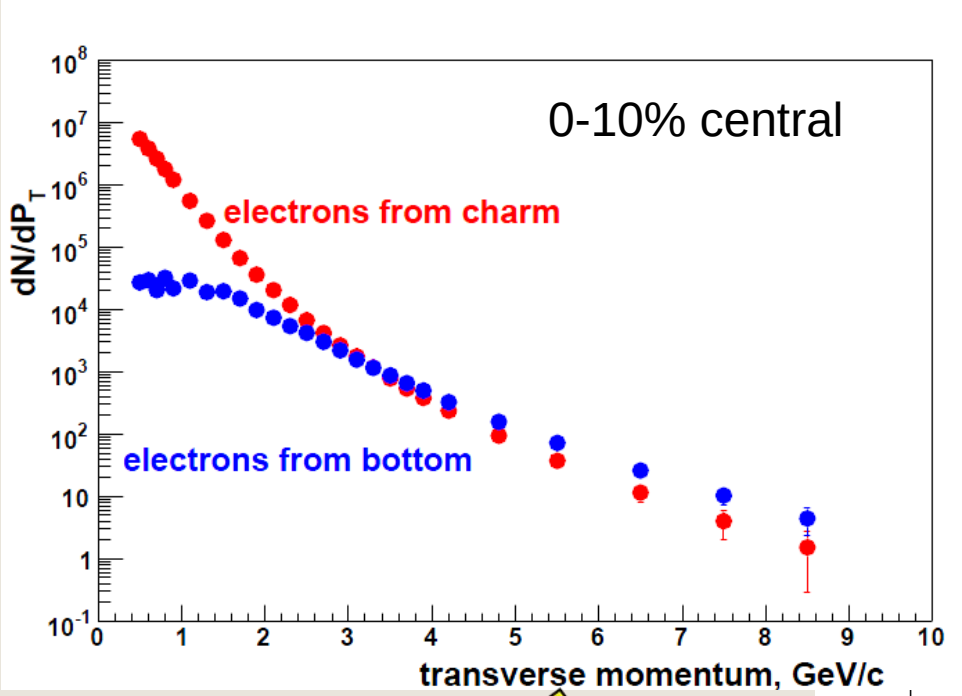
500 GeV p+p (R336593)



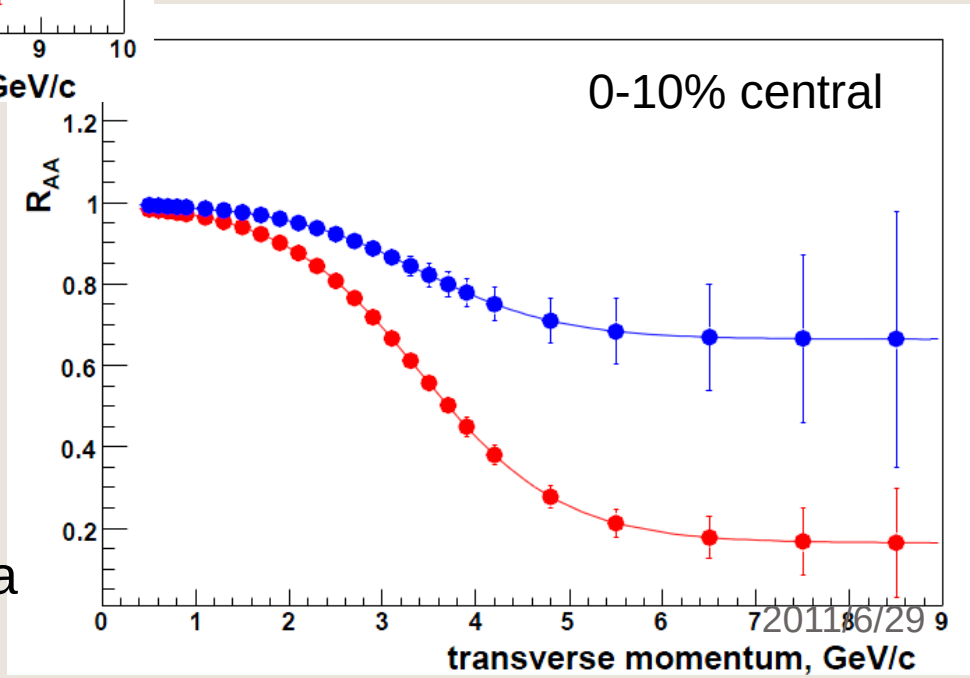
200 GeV Au+Au (R349944)



With 8 weeks Au+Au at √s = 200 GeV



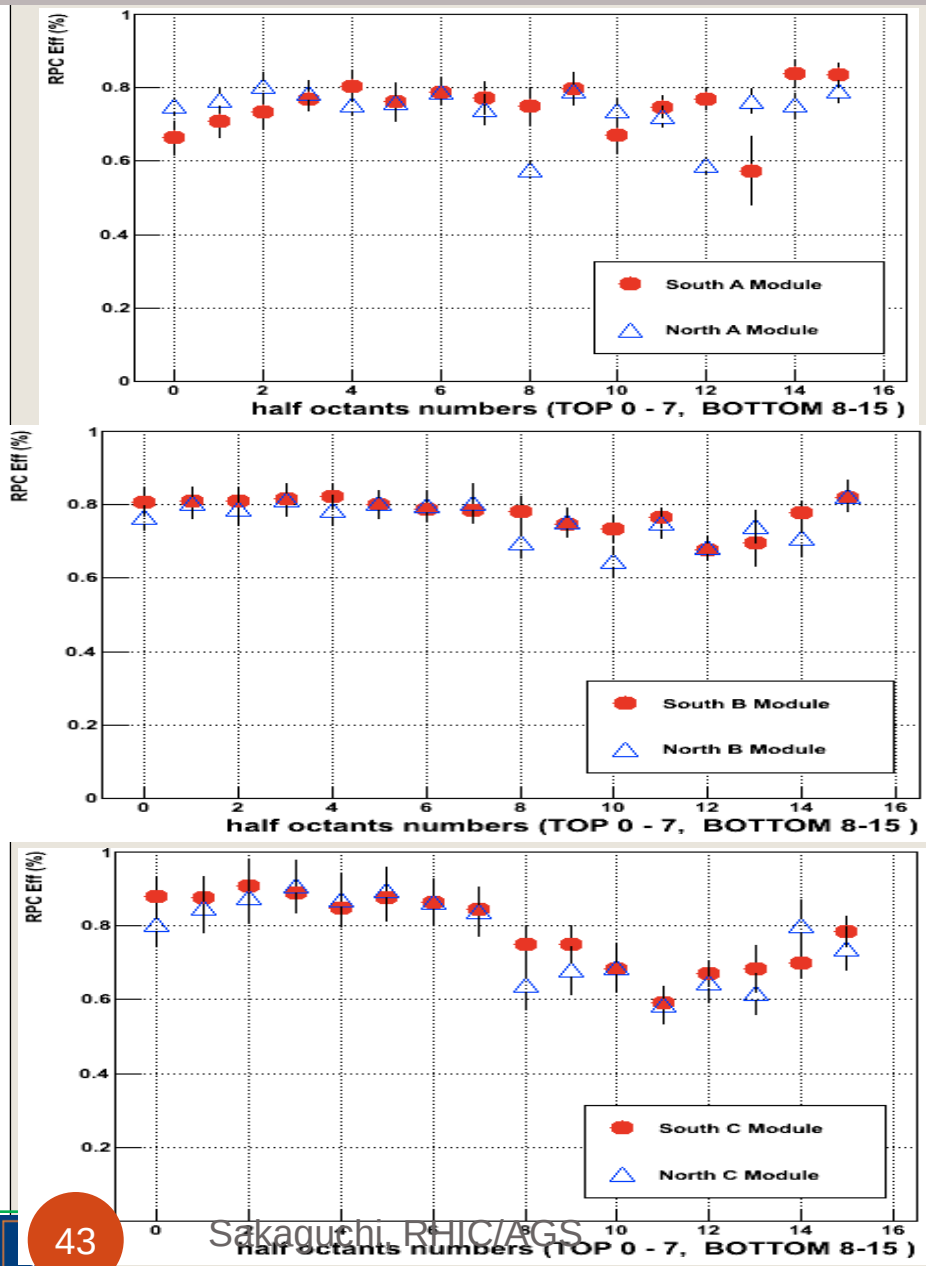
Assumption here: Full 8 weeks used for data taking in RUN11



PHENIX Beam Use Proposal for RUN11

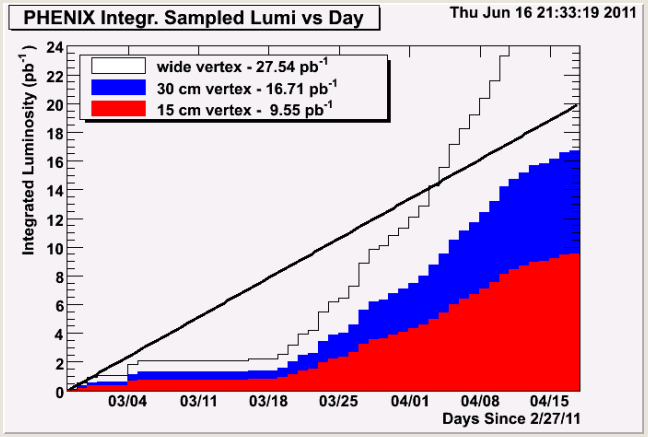
Slides from Y. Akiba

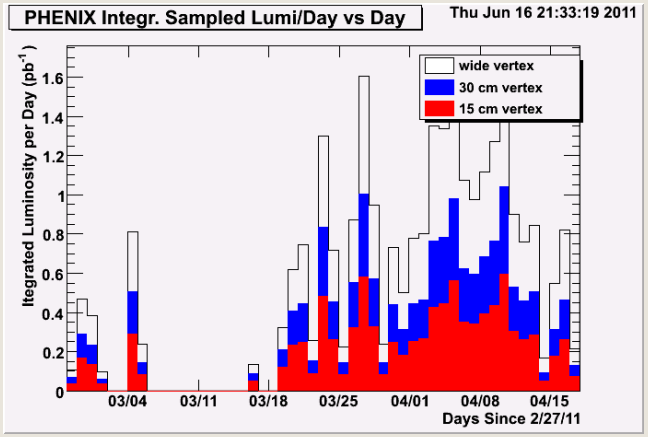
RPC-3 Efficiency during RHIC Run-11

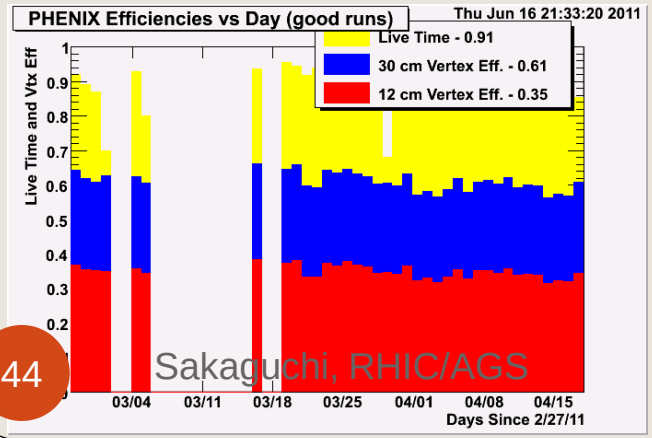


- Before March 21st , there were initial issues with the gas composition/mixing system
- New gas analysis result after gas tuning
- R134a/Isobutane/SF6 = 94.8517%/4.6167%/0.5316%
  - Very close to real RPC gas mixture what we need
  - Data after March 21st can be used for *W* analysis
  - Need to recalibrate power supply at control unit
  - Need to redistribute gas panels and lines

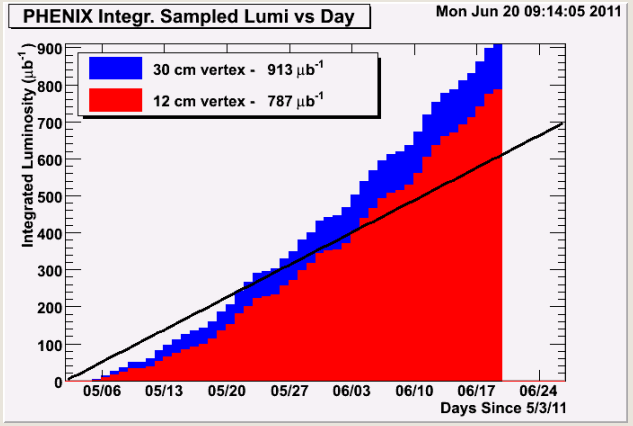
500 GeV p+p

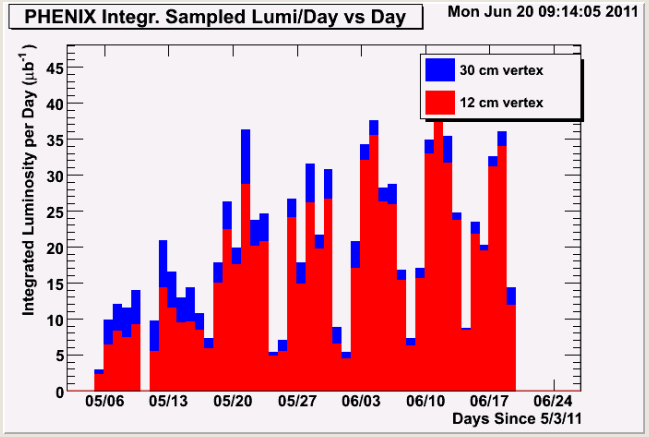


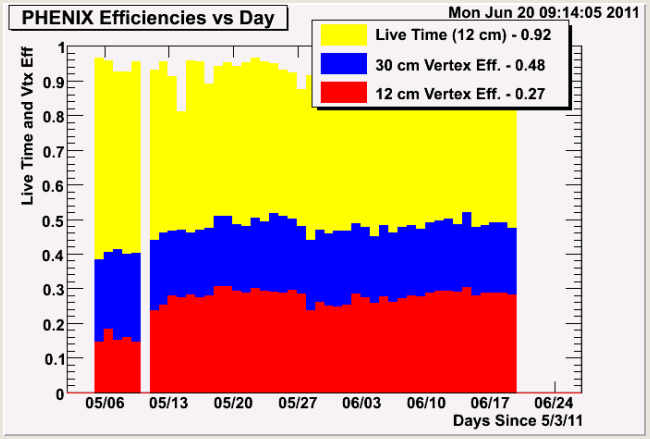




200 GeV Au+Au







PHENIX Uptime:

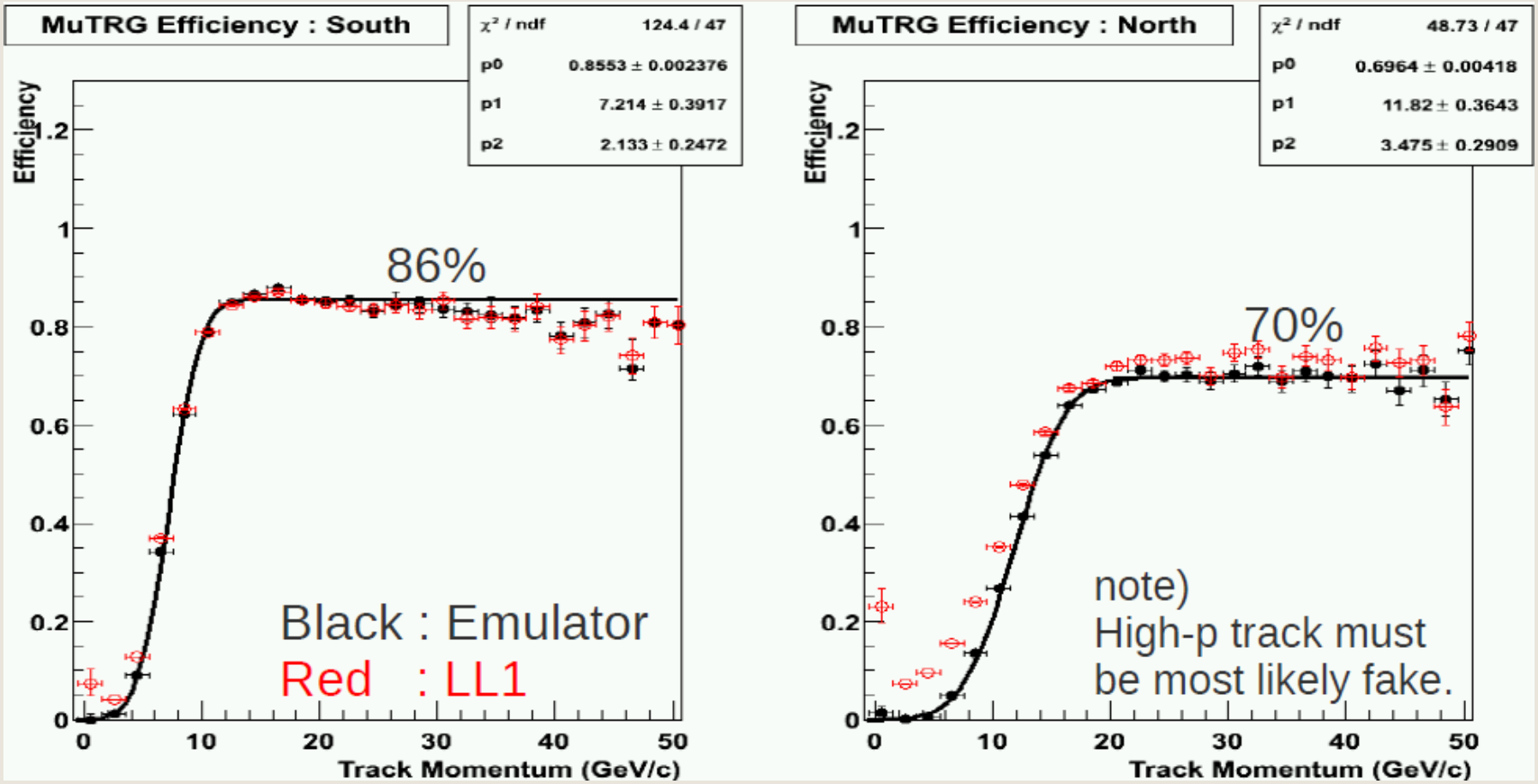
200 GeV Au+Au: 71%

500 GeV p+p: 62%

(not corrected for PHYSICS ON/OFF or for APEX days or Polarization measurements – i.e. just using ZDCNS to guage if physics is ON)

PHENIX Efficiencies	500 GeV p+p	200 GeV Au+Au
Livetime	91%	92%
30 cm vertex	61%	48%
12 cm vertex	35%	27%
Uptime	62%	71%

MuTrg Efficiency



Clustering : Inefficiency ~ 5%

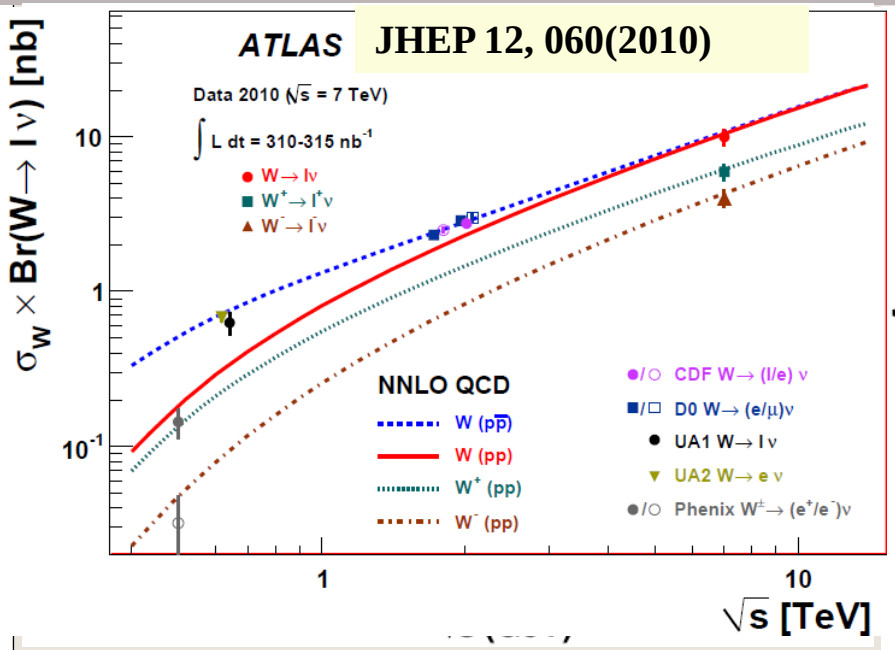
Need to understand North/South difference

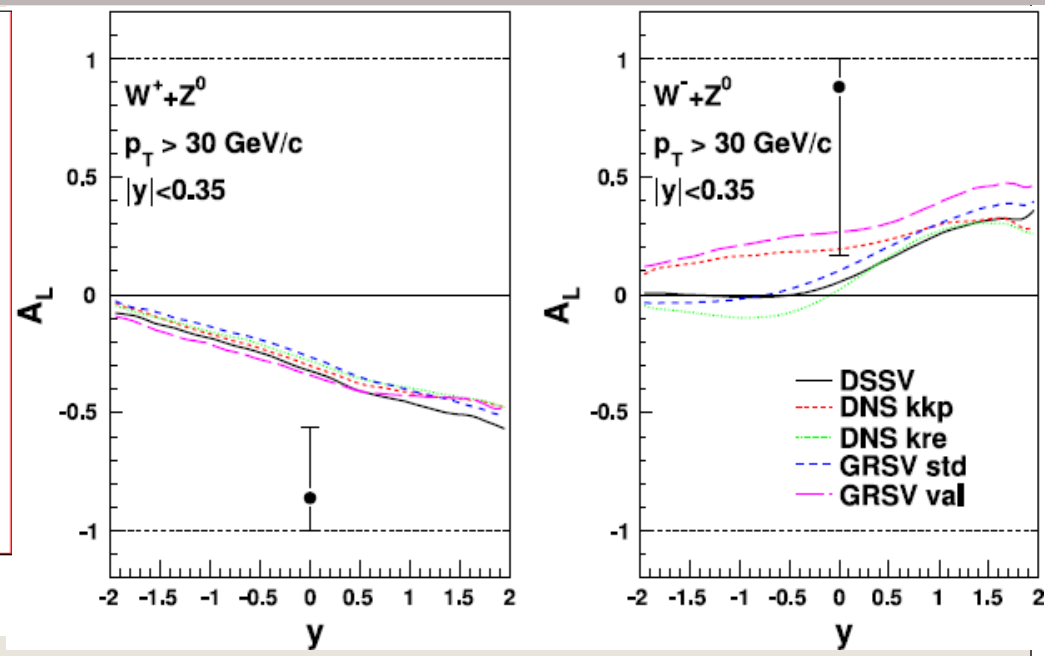
Need (LL1 efficiency) && (Track-by-track matching in emulator)

Possible inefficiency due to fake track must be evaluated

Single Spin Asymmetry of *W* at RHIC Run-9

PHENIX





PHENIX Collaboration: Phys. Rev. Lett. 106, 062001(2010)

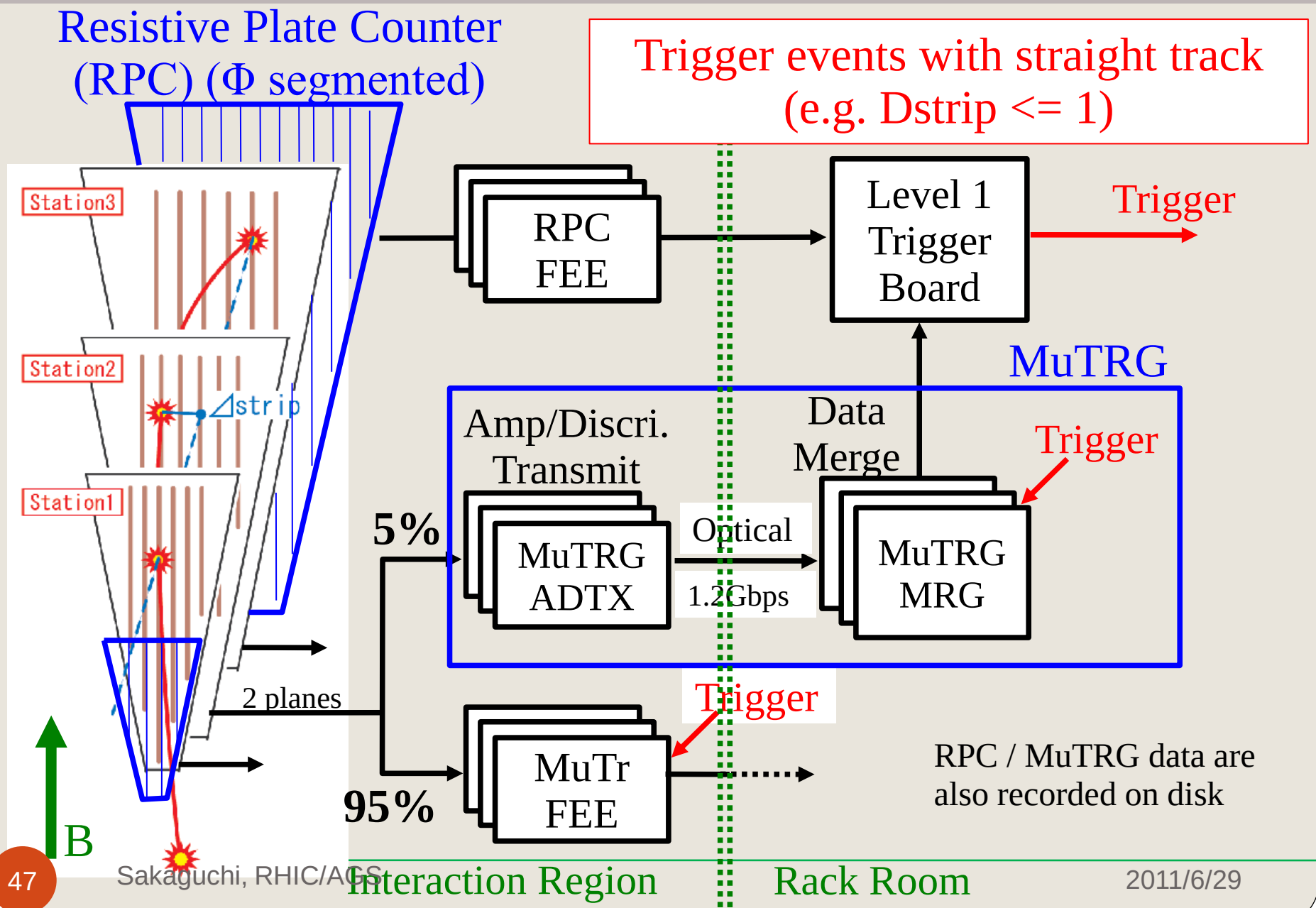
$$\sigma(pp \to W^+X) \times \mathrm{BR}(W^+ \to e^+\nu_e) = 144.1 \pm 21.2(\mathrm{stat})^{+3.4}_{-10.3}(\mathrm{syst}) \pm 21.6(\mathrm{norm})\ \mathrm{pb}$$

$$\sigma(pp \to W^-X) \times \mathrm{BR}(W^- \to e^-\bar{\nu}_e) = 31.7 \pm 12.1(\mathrm{stat})^{+10.1}_{-8.2}(\mathrm{syst}) \pm 4.8(\mathrm{norm})\ \mathrm{pb}$$

- Good agreement between PHENIX and ATLAS data and NNLO pQCD calculations
- At 8.6 pb^{-1}, with average polarization 0.39±0.04, we get

$$A_L^{e^+} = -0.86^{+0.30}_{-0.14}$$

$$A_L^{e^-} = 0.88^{+0.12}_{-0.71}$$

- Asymmetry is corrected for dilution by QCD backgrounds

PHENIX Muon Trigger Upgrade