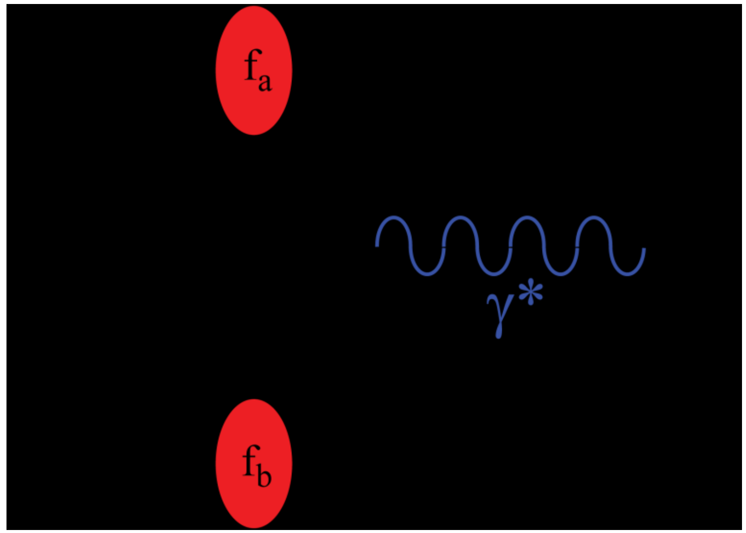
The A_NDY Project



A new effort at RHIC to make the first measurement of the analyzing power (A_N) for Drell Yan (DY) production at $\sqrt{s}$=500 GeV

L.C. Bland

Brookhaven National Lab

1 September 2011

A$_N$DY

"Large Rapidity Drell Yan Production at RHIC"

Letter of Intent submitted 24 May 2010:

http://www.bnl.gov/npp/docs/pac0610/Crawford_LoI.100524.v1.pdf

PAC presentation:

http://www.bnl.gov/npp/docs/pac0610/aschenauer_DY-collider_june10.pdf

Proposal to 2011 PAC:

http://www.bnl.gov/npp/docs/pac0611/DY_pro_110516_final.2.pdf

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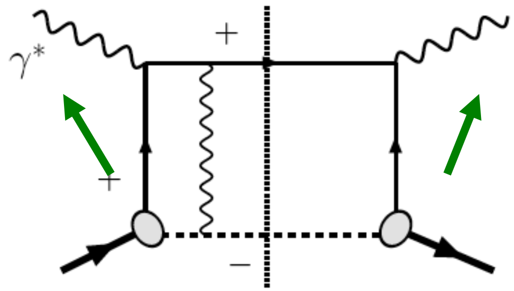
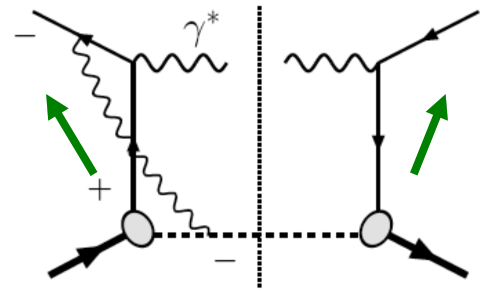
Attractive vs Repulsive Sivers Effects

Unique Prediction of Gauge Theory !

Simple QED example:

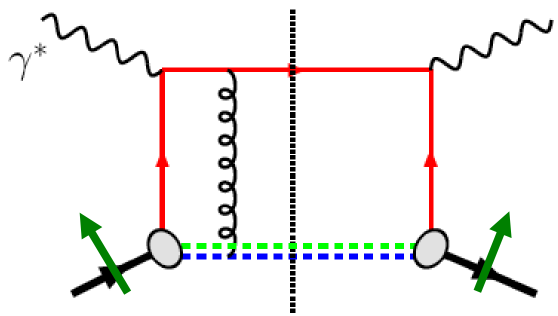


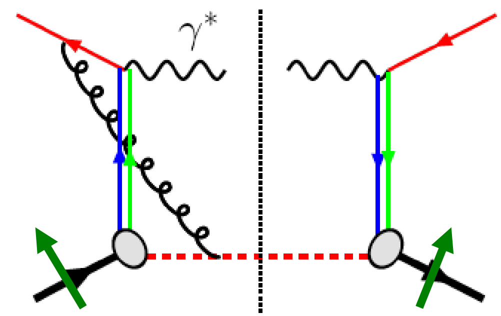


DIS: attractive

Drell-Yan: repulsive

Same in QCD:





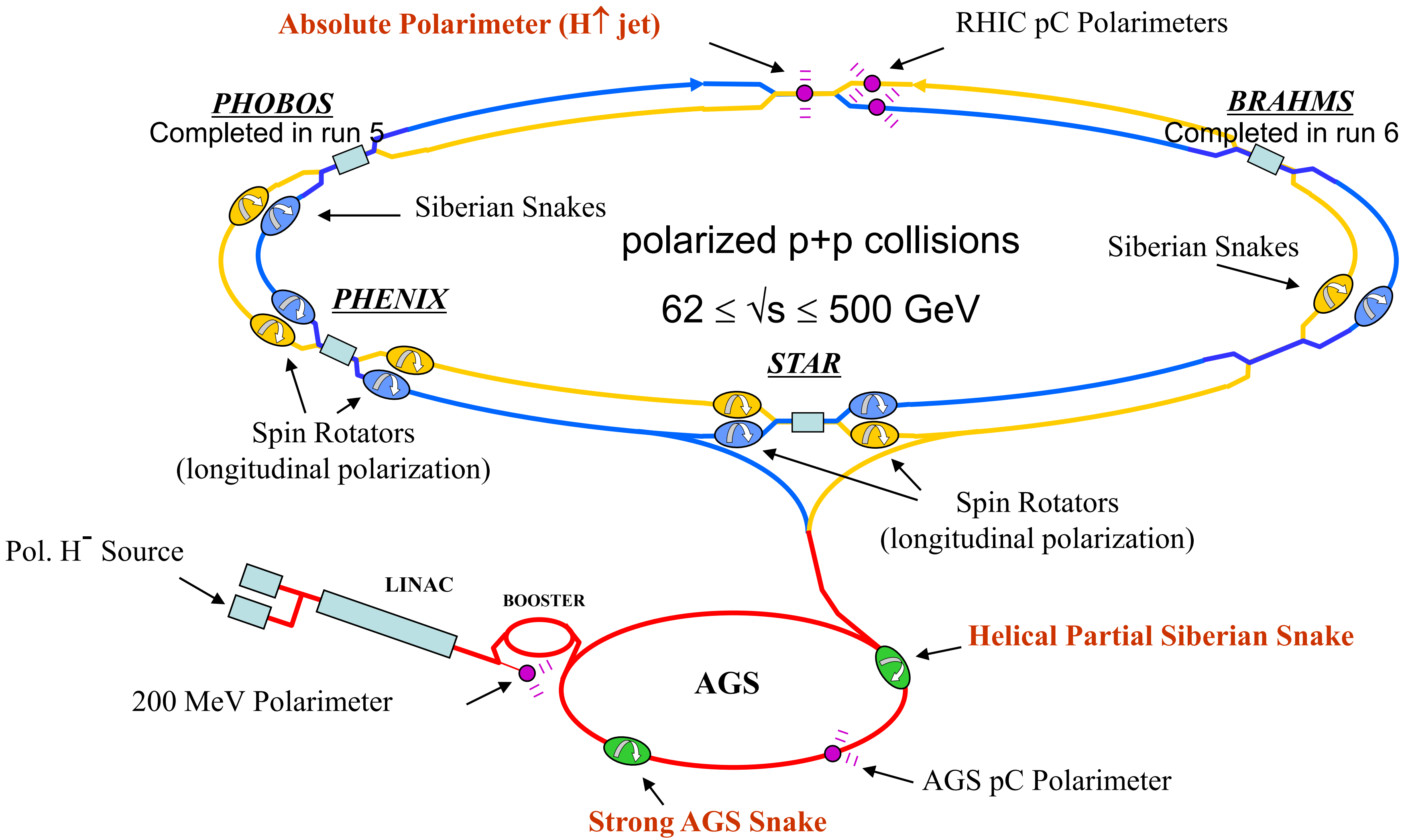
As a result:

$$\text{Sivers}|_{\text{DIS}} = -\text{Sivers}|_{\text{DY}}$$

Transverse Spin Drell-Yan Physics at RHIC (2007)

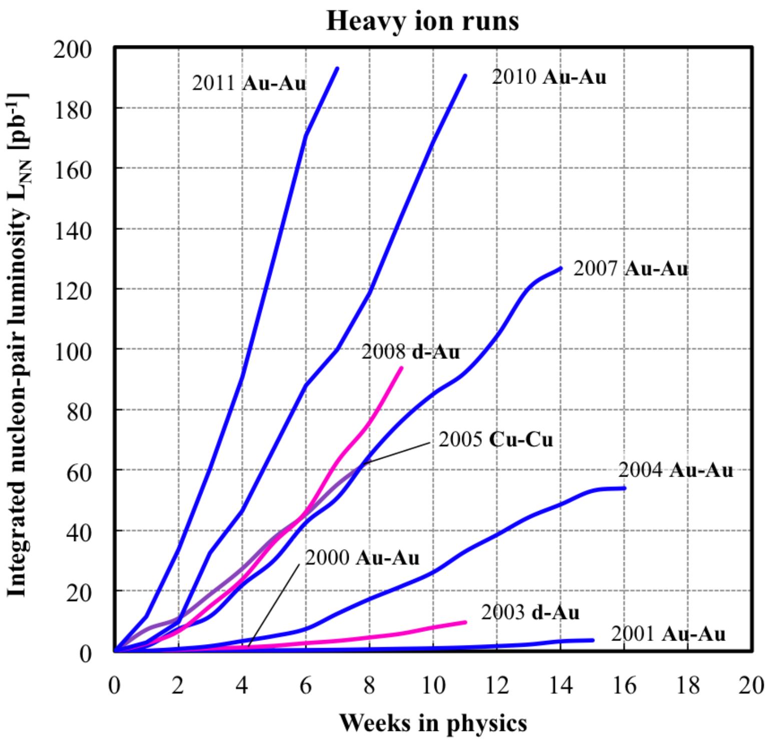
http://spin.riken.bnl.gov/rsc/write-up/dy_final.pdf

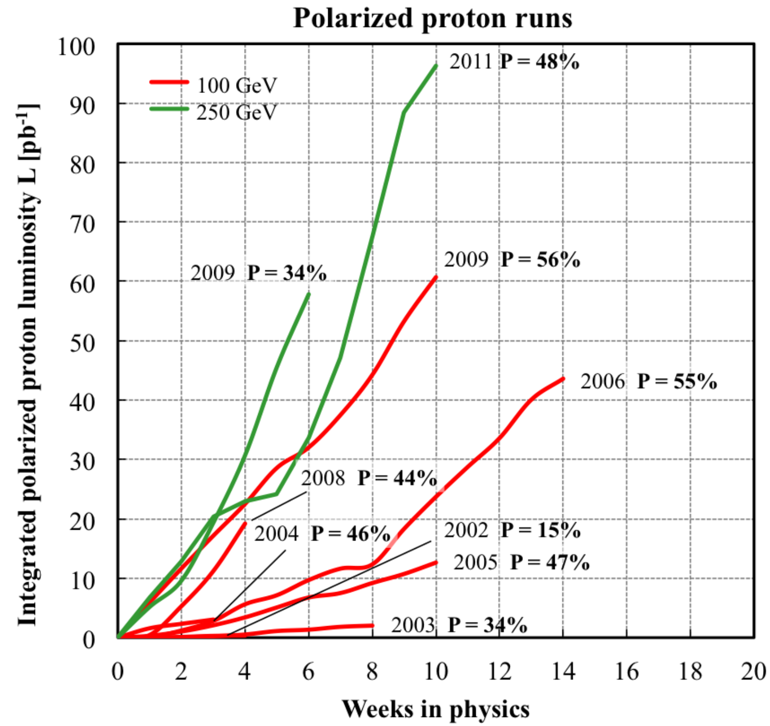
RHIC as a Polarized Proton Collider



RHIC is a QCD Laboratory

RHIC is a Unique Collider…

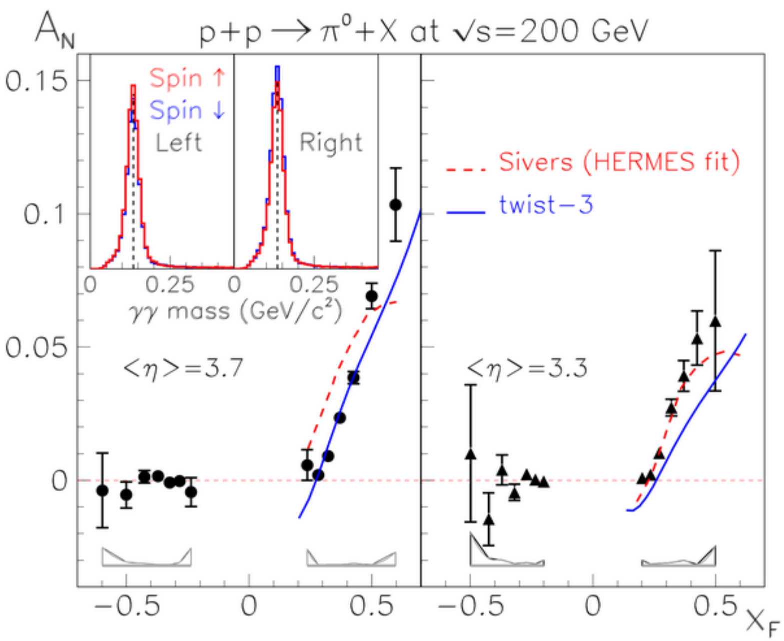




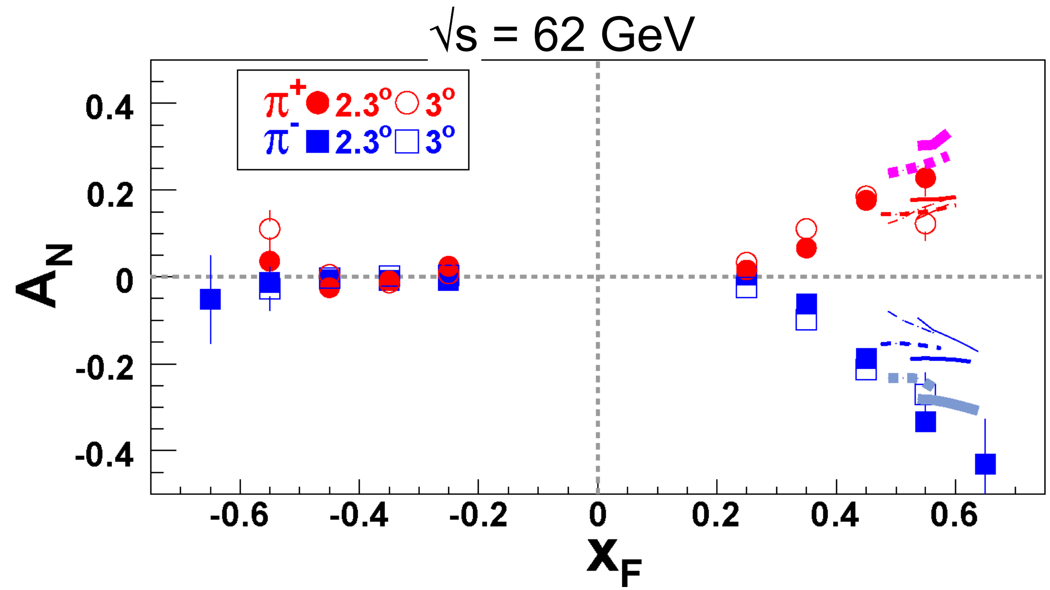
Source: http://www.agsrhichome.bnl.gov/RHIC/Runs/

- capable of colliding essentially all positive ions over a broad range of √s
- with large L/√s, where L is free space at interaction region ⇒ large $x_F=2p_L/\sqrt{s}$ possible
- with a broad and diverse physics program aimed at important questions
  - o What is quark-gluon plasma? ⇒ heavy-ion collisions
  - o How does the proton get its spin? ⇒ polarized proton collisions
  - o Does the gluon density saturate in a heavy nucleus? ⇒ d+Au/p+Au collisions

What have we learned from 10 years of RHIC spin?
Transverse Spin



B.I.Abelev (STAR), Phys. Rev. Lett. 101 (2008).



I. Arsene (BRAHMS), Phys. Rev. Lett. 98 (2007).

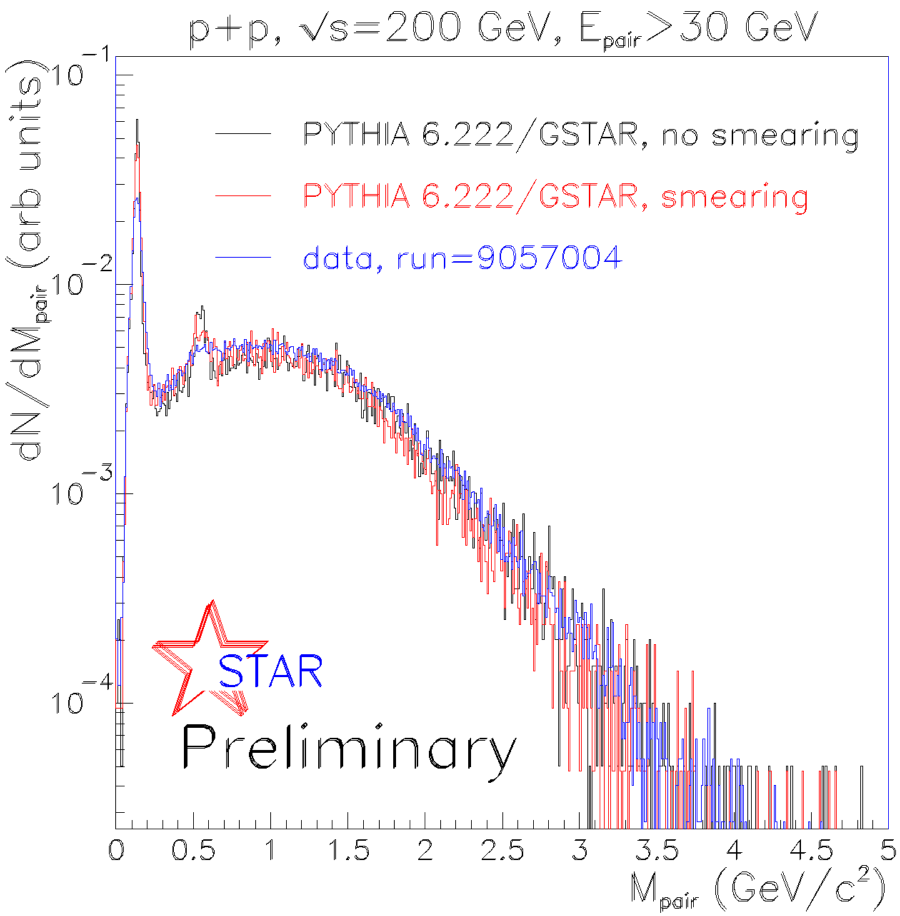
Why A_NDY?

- Largest spin effects are found at RHIC when Feynman-x > 0.1
- Predicted change of sign for Sivers function between transverse single spin measurements for semi-inclusive deep inelastic scattering and the analyzing power for Drell Yan is likely best done in this range, but limited to $x_F < 0.3$ to match HERMES kinematics as closely as possible
- Forward upgrades of STAR and PHENIX are major undertakings and would benefit from a feasibility demonstration of forward DY production (i.e., A_NDY). Forward DY production is of interest for more than just the analyzing power, e.g. most robust observable to low-x parton distributions for intercomparison to a future electron-ion collider. A_NDY can run in parallel with RHIC W program.

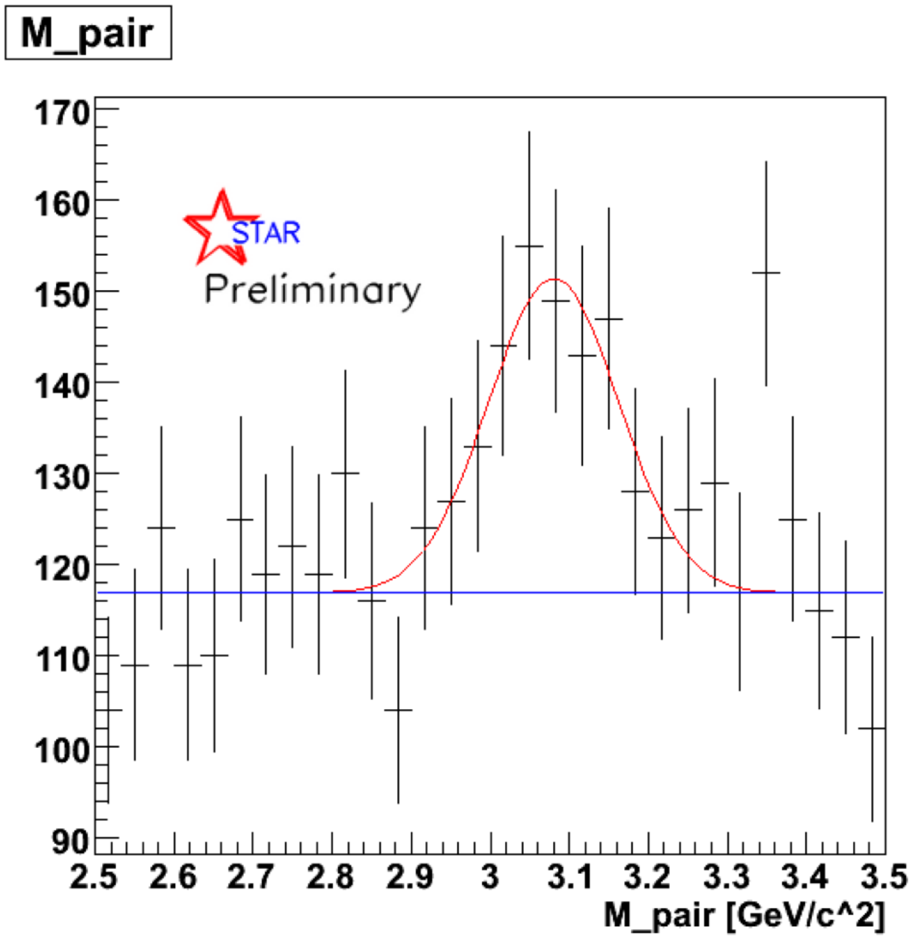
What is A_NDY?

Basic ingredients to forward DY at a collider

Pair mass from bare EMcal



arXiv:0906.2332



arXiv:0907.4396

- pair mass backgrounds well modeled
- $J/\psi \rightarrow e^+e^-$ observation with bare ECal at $\langle x_F \rangle \sim 0.67$ emboldens DY consideration

Previous Work on Low-Mass DY at a Collider

p+p DY at ISR, √s=53,63 GeV
Phys. Lett. B91 (1980) 475

STUDY OF MASSIVE ELECTRON PAIR PRODUCTION AT THE CERN INTERSECTING STORAGE RINGS

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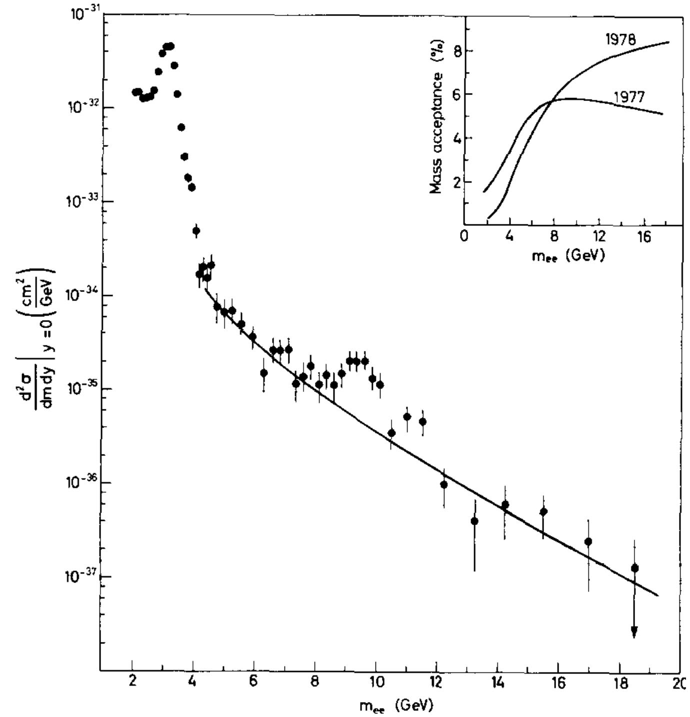


Fig. 1. The cross section $(d^2\sigma/dm\,dy)_{y=0}$ versus mass for the data at $\sqrt{s}$ = 53 and 63 GeV combined. The curve is a result of the fit to the continuum displayed in fig. 2. The inset show the mass acceptance for "1977" and "1978" triggers and geometrical configurations calculated for isotropic decay distributions and production uniform in rapidity with p_T dependence $d\sigma/dp_T^2 \sim \exp(-bp_T)$, where b = 1.4 GeV^{-1}. The mass acceptance changes by ± 15% when the helicity decay distribution follows $dN/d\cos\theta = 1 + \alpha\cos^2\theta$ when $\alpha = \pm 1$, where θ is measured in the s-channel helicity frame.

Comments (note: large x_F at collider breaks new ground)

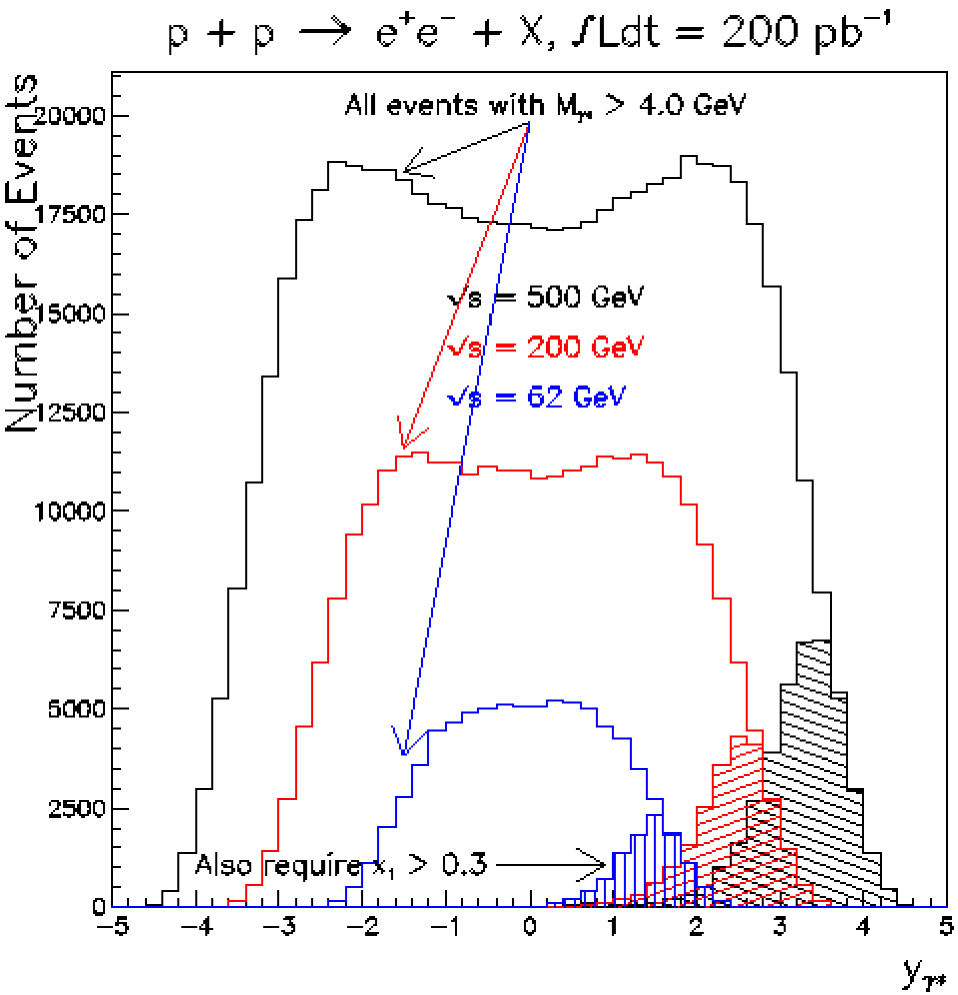
- e+e- low-mass DY done at ISR and by UA2 [see review J.Phys. G19 (1993) D1]
- UA2 [PLB275 (1992) 202] did not use magnet / CCOR did [PLB79 (1979) 398]
- most fixed target experiments do μ+μ- DY

Requirements for DY

- Luminosity

- Background Reduction
  - electron/hadron discrimination
  - Charged/Neutral discrimination and photon conversion background
  - Open heavy flavor (c,b) production
  - Is a magnet plus tracking required for forward DY?

Collision Energy Dependence of Drell Yan Production



Comments…

- RHIC pp luminosity largest at √s=500 GeV
- partonic luminosities increase with √s
- net result is that DY grows with √s
- in any case, largest √s probes lowest x

⇒ Consider large-x_F DY at √s=500 GeV

$$\text{large } x_F \Rightarrow x_1 \approx x_F \text{ and } x_2 \approx \frac{M^2}{x_F s}$$

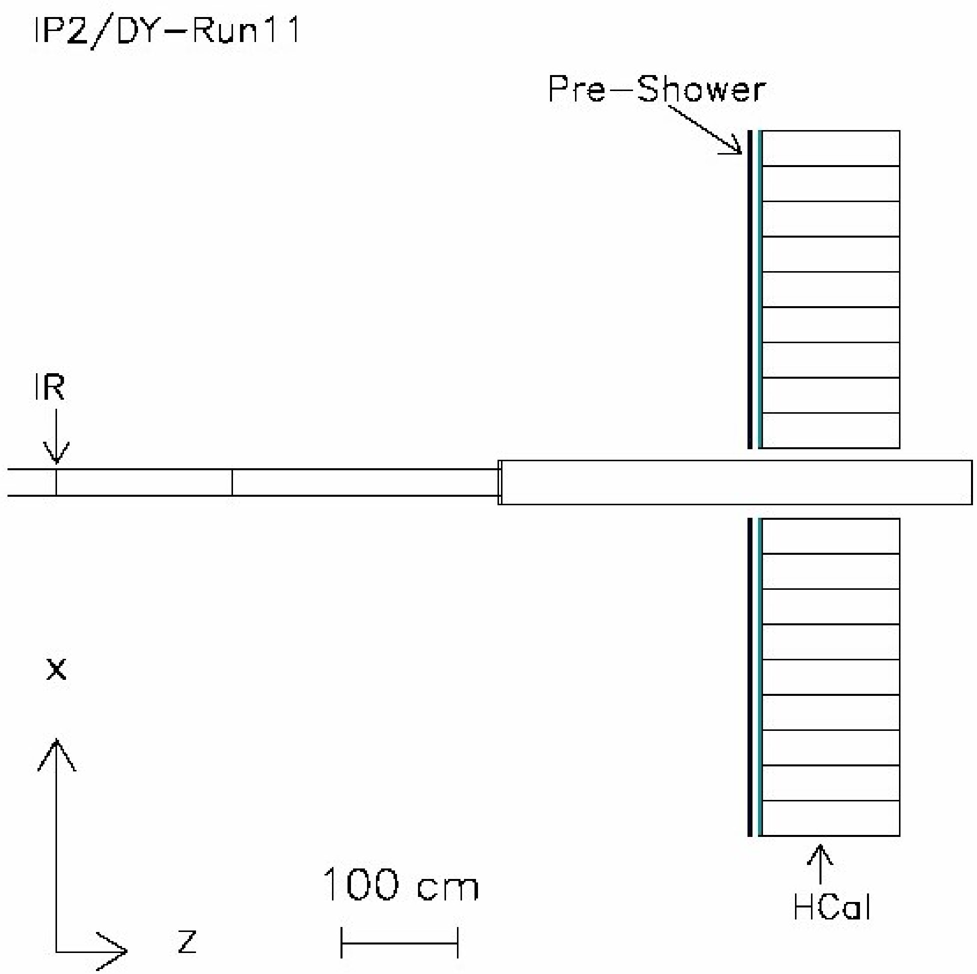
⇒ Forward DY production probes valence region for "beam" and $x_2 \approx 10^{-4}$ for "target" for √s=500 GeV (M>4 GeV/c²)

Transverse Spin Drell-Yan Physics at RHIC (2007)

http://spin.riken.bnl.gov/rsc/write-up/dy_final.pdf

Schematic of detector considered

Original Plan for Run-11 configuration



Equipment in place:

- Hcal is existing 2x9x12 modules from E864 (NIM406,227)
- BBC and ZDC

Goal:

- establish impact of 3 IR operation on PheniX and Star luminosity
- calibrate HCAL
  - absolute Energy scale with ρ, Φ, K_s
  - gains with cosmics
- measure the hadronic background to bench mark MCs further

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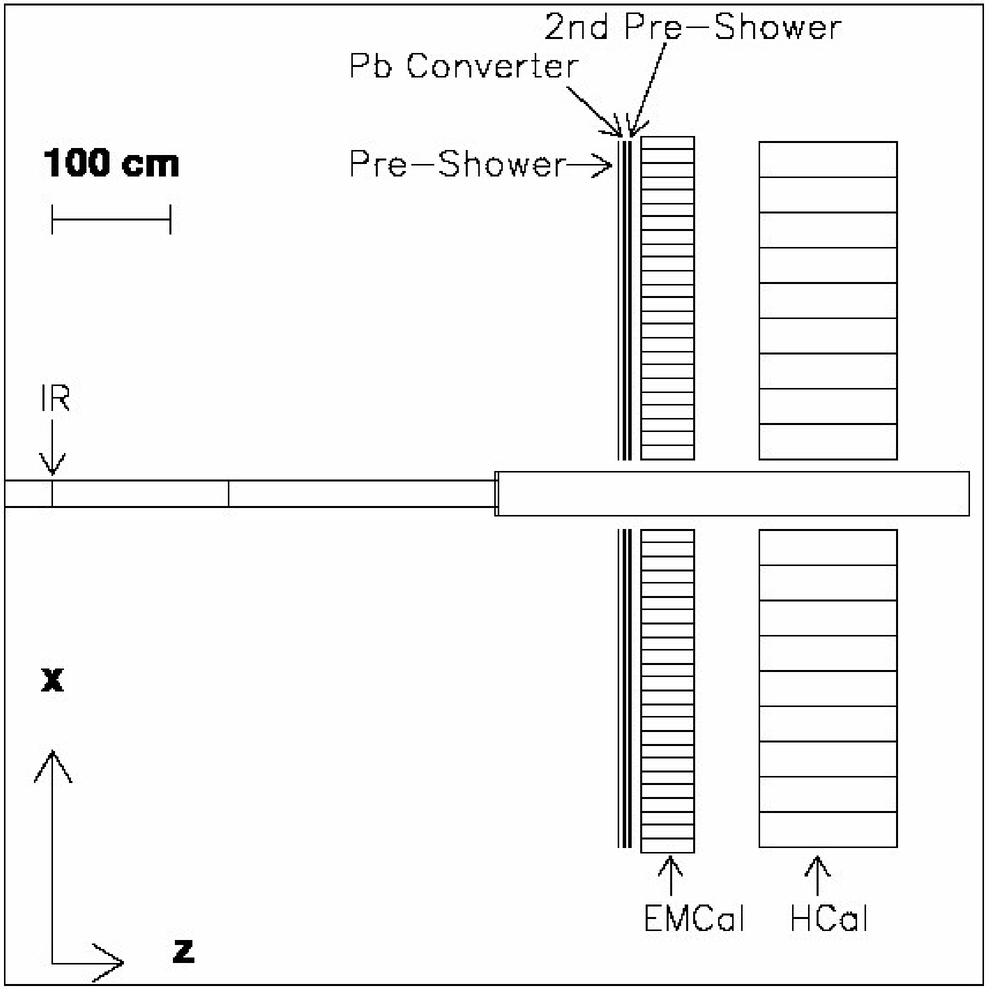
Schematic of detector considered

Run-12 configuration

(PHOBOS split-dipole expected to be in place, but not used)

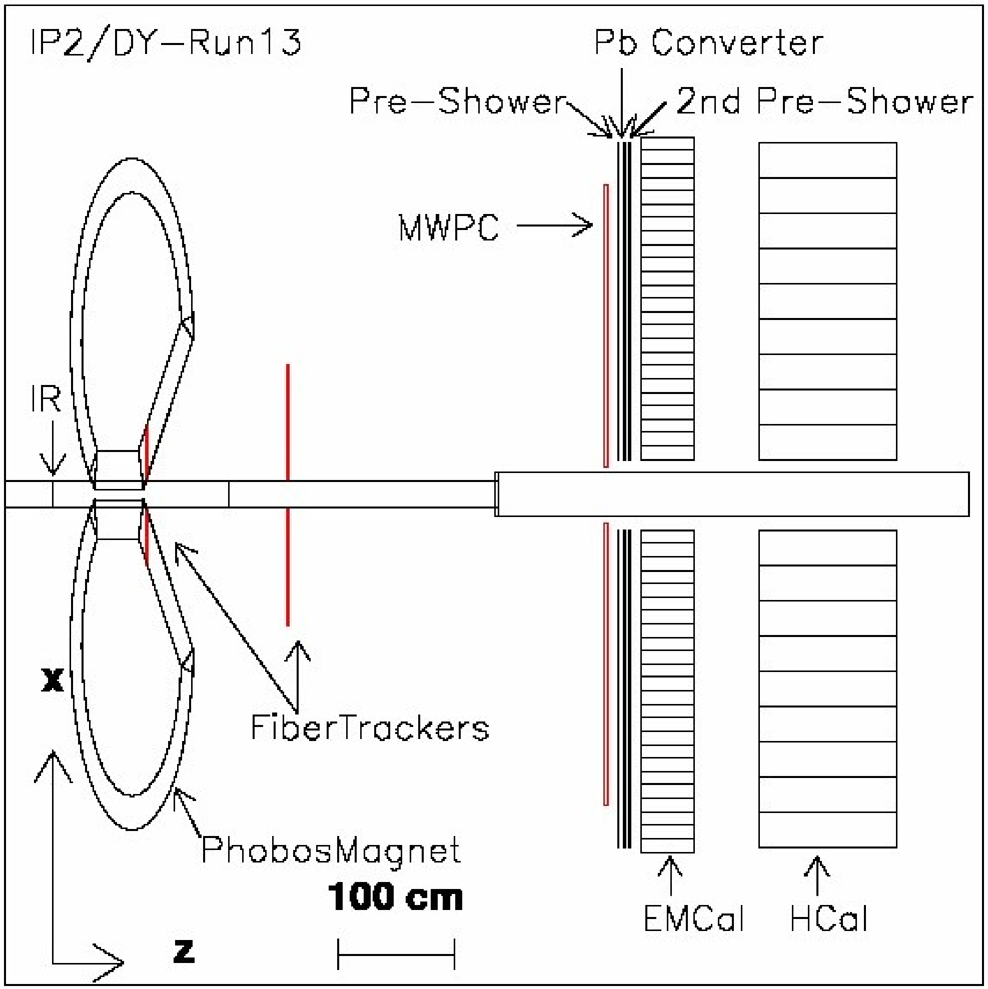


- Hcal is existing 9x12 modules from E864 (NIM406,227)
- EMcal is modeled as only $(3.8cm)^2$x(45cm) lead glass
- Preshower would require construction

http://www.star.bnl.gov/~akio/ip2/topview2.jpeg

Schematic of detector considered

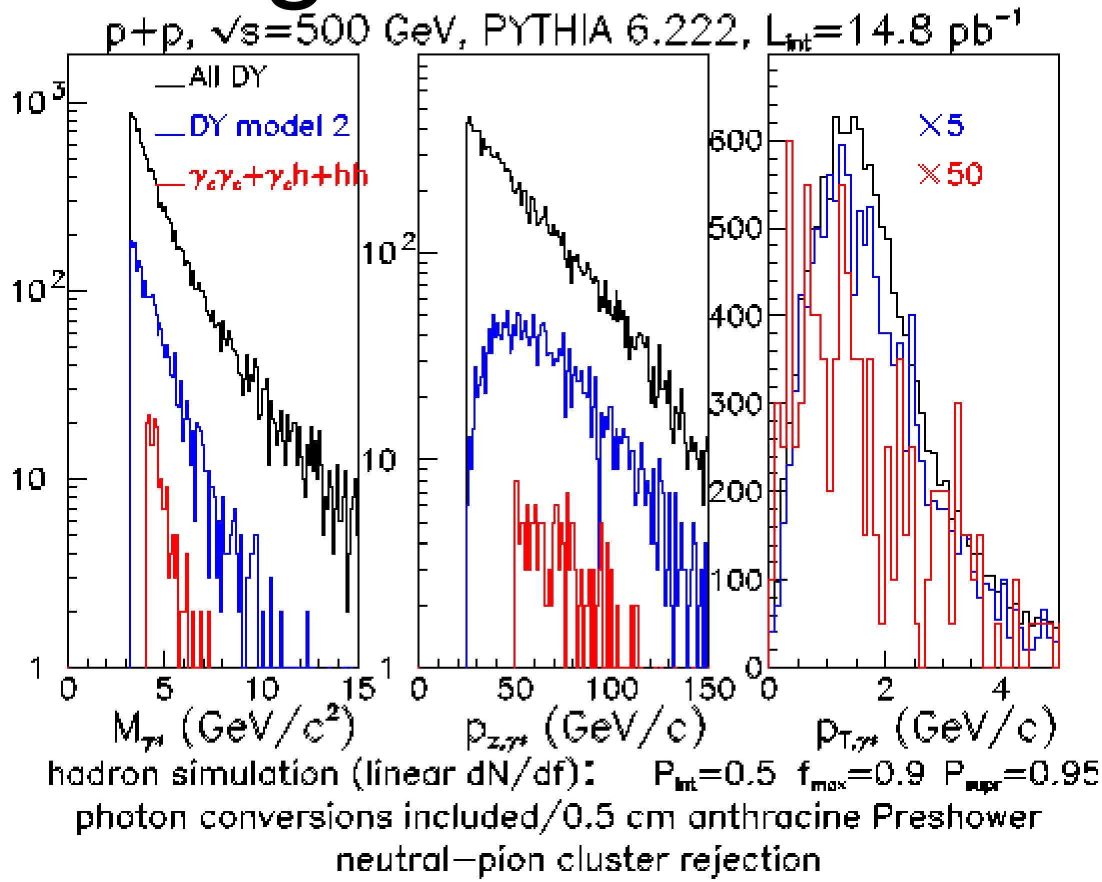
Run-13 configuration
(Uses PHOBOS Split Dipole for charge sign)



- Hcal is existing 9x12 modules from E864 (NIM406,227)
- EMcal is modeled as only $(3.8cm)^2x(45cm)$ lead glass
- Preshower would require construction
- PHOBOS split-dipole magnetic field in GEANT model
- Fiber tracker stations and MWPC require construction

http://www.star.bnl.gov/~akio/ip2/topview_run13.jpeg

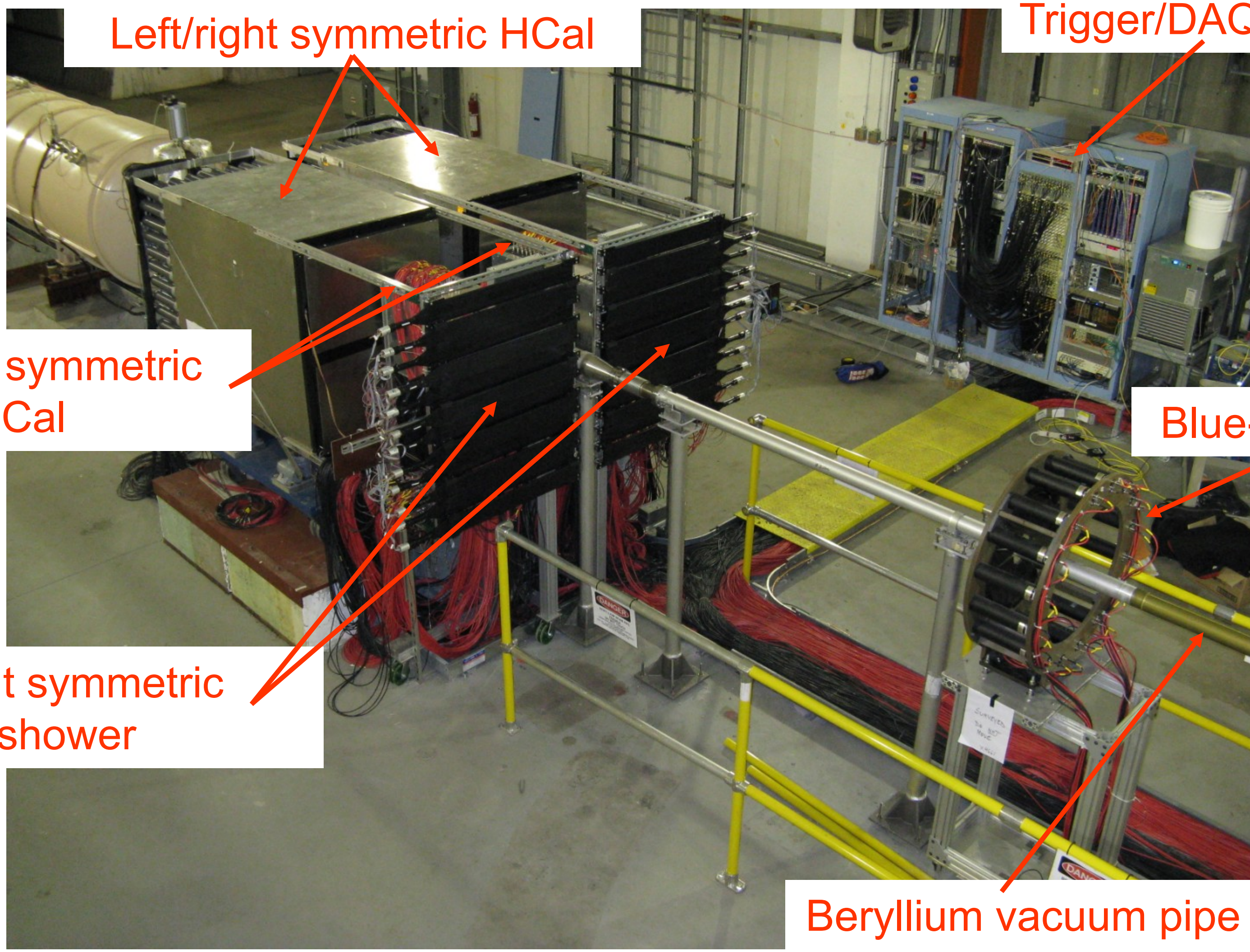
Background Estimate



Comments:

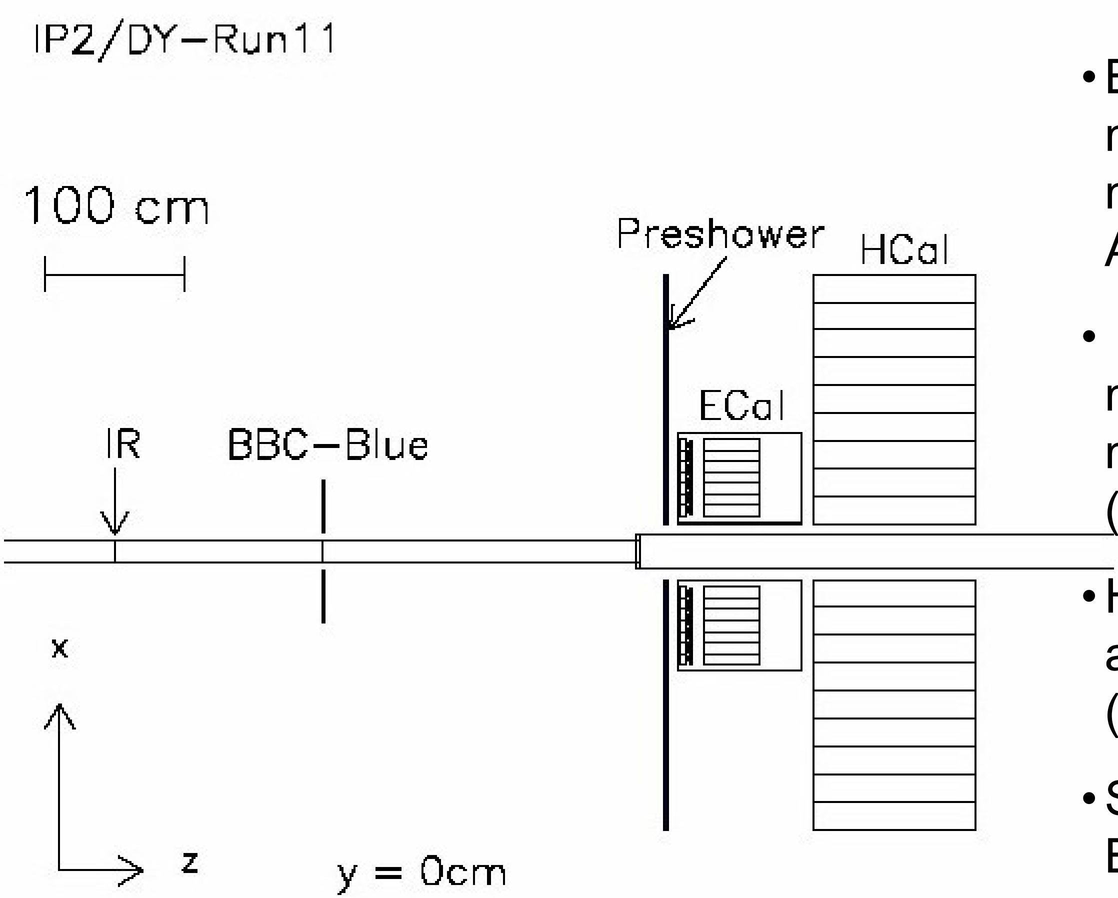
- Conversion photons significantly reduced by $\pi^0 \rightarrow \gamma\gamma$ veto
- Preshower thickness tuned, although perhaps is not so critical given photon veto
- Linearly decreasing dN/df (fast-simulation model for hadronic response of ECal) estimates smaller hadronic background $\Rightarrow$ increased sophistication needed for reliable estimates, although other model uncertainties could easily dominate.
- Open heavy flavor backgrounds also estimated and found small due to large rapidity

What did we learn from run-11 A_NDY?



Schematic of detector for Run-11

Polarized proton collisions at √s=500 GeV from February to April 2011



- Beam-beam counter (BBC) for minimum-bias trigger and luminosity measurement from PHOBOS [NIM A474 (2001) 38]
- Zero-degree calorimeter and shower maximum detector for luminosity measurement and local polarimetry (ZDC/ZDC-SMD, not shown)
- Hadron calorimeter modules (HCal) are 9x12 modules from AGS-E864 (NIM406,227)
- Small (~120 cells) ECal loaned from BigCal at JLab
- Pre-shower detector

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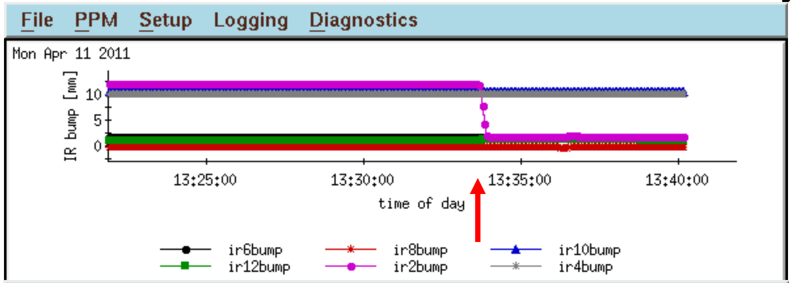
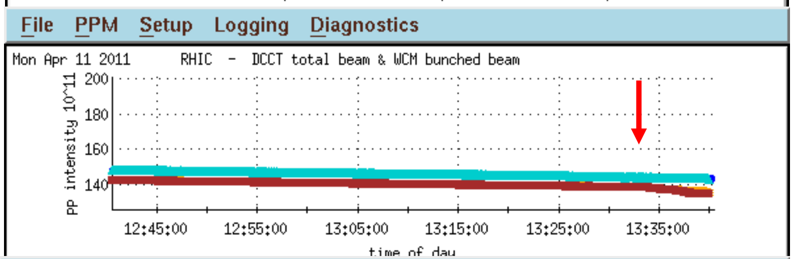
Impact of Collisions at IP2

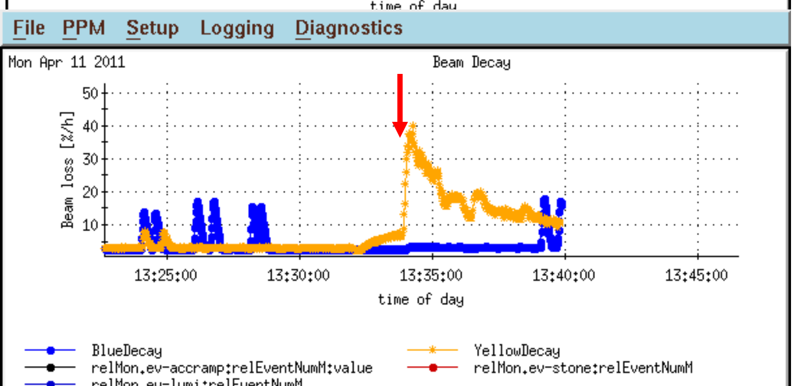
The anatomy of initiating collisions at IP2



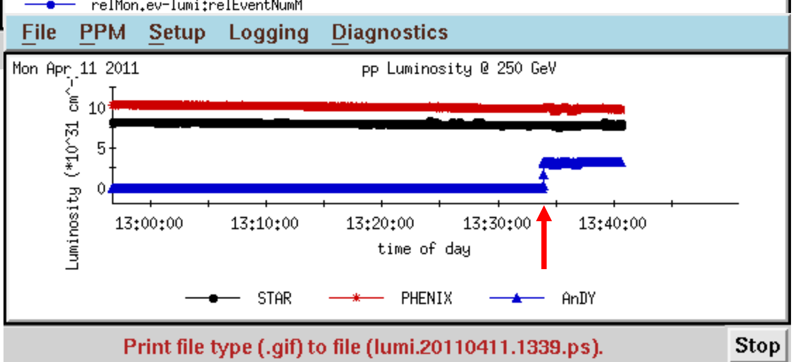
Early after a RHIC store is set up, beams are colliding at IP6 (STAR) and IP8 (PHENIX). Beams are transversely separated at IP2 (A_NDY). The arrow indicates when collisions begin at IP2



After the beam intensity decays to a threshold (here, 1.3 $\times 10^{11}$ ions/bunch), collisions begin at IP2. There is loss of beam in the Yellow ring.

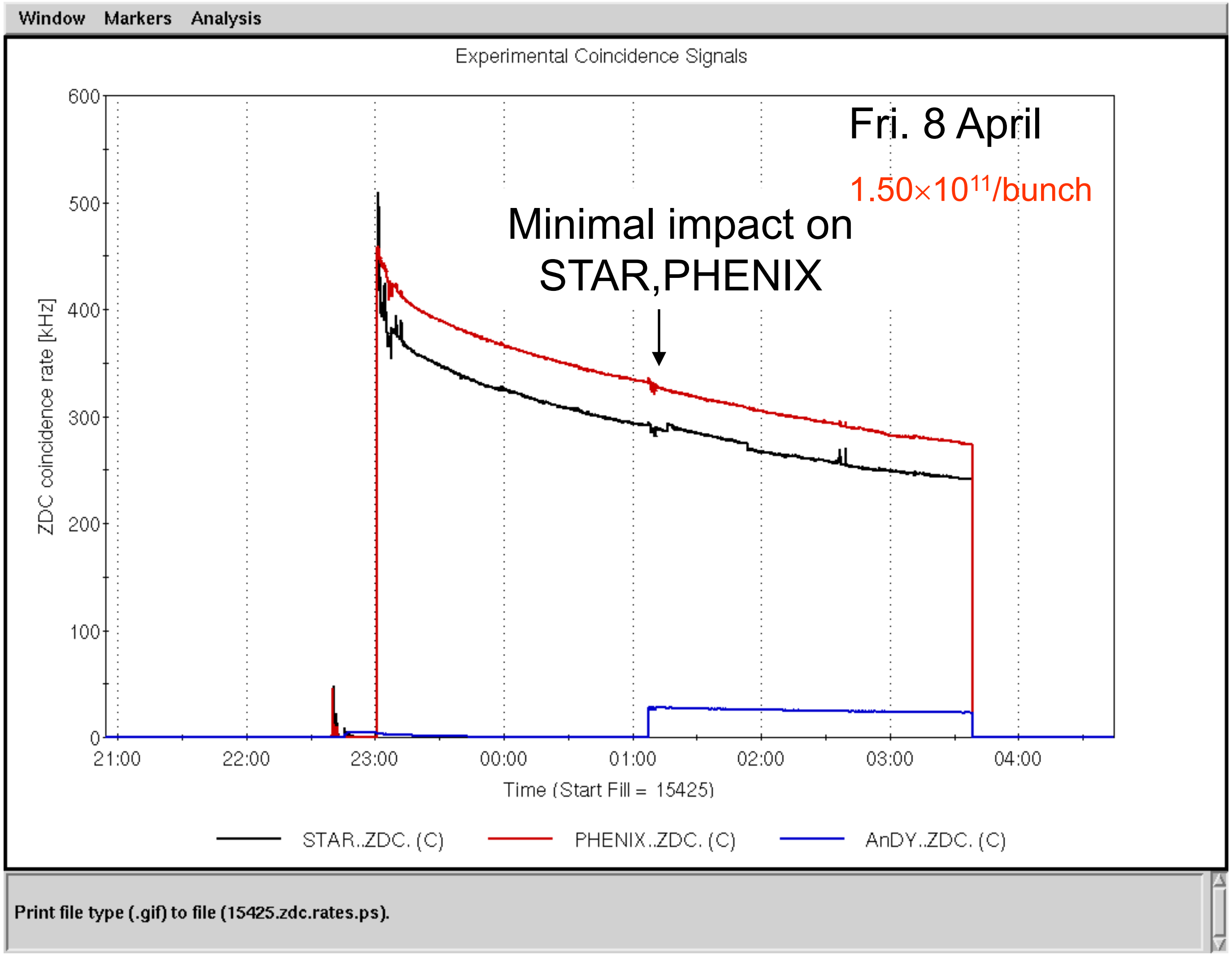


The beam loss is monitored. The spikes in the Blue ring are due to insertions of carbon ribbons for measuring the beam polarization. Beam-beam tune shift causes loss of ions in Yellow when collisions begin at IP2. This loss typically decays with time, as shown.



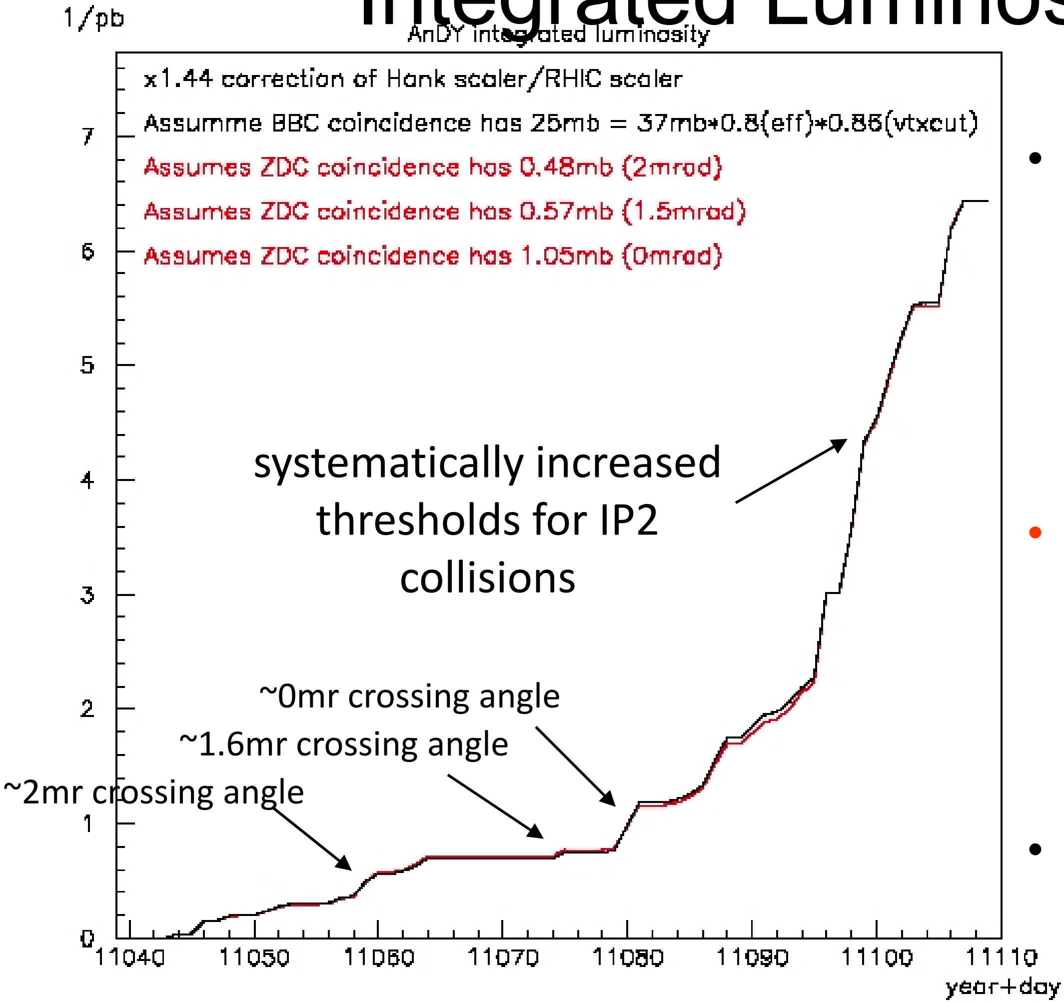
Luminosity at IP6 (STAR) and IP8 (PHENIX) is mostly constant when collisions are initiated at IP2 (A_NDY).

Impact of IP2 Collisions



IP2 collisions have begun <3 hours after physics ON with minimal impact on IP6,IP8. Adequate luminosity for A_NDY (10 pb^{-1}/week for $\sqrt{s}$=500 GeV polarized proton collisions) is projected for subsequent runs.

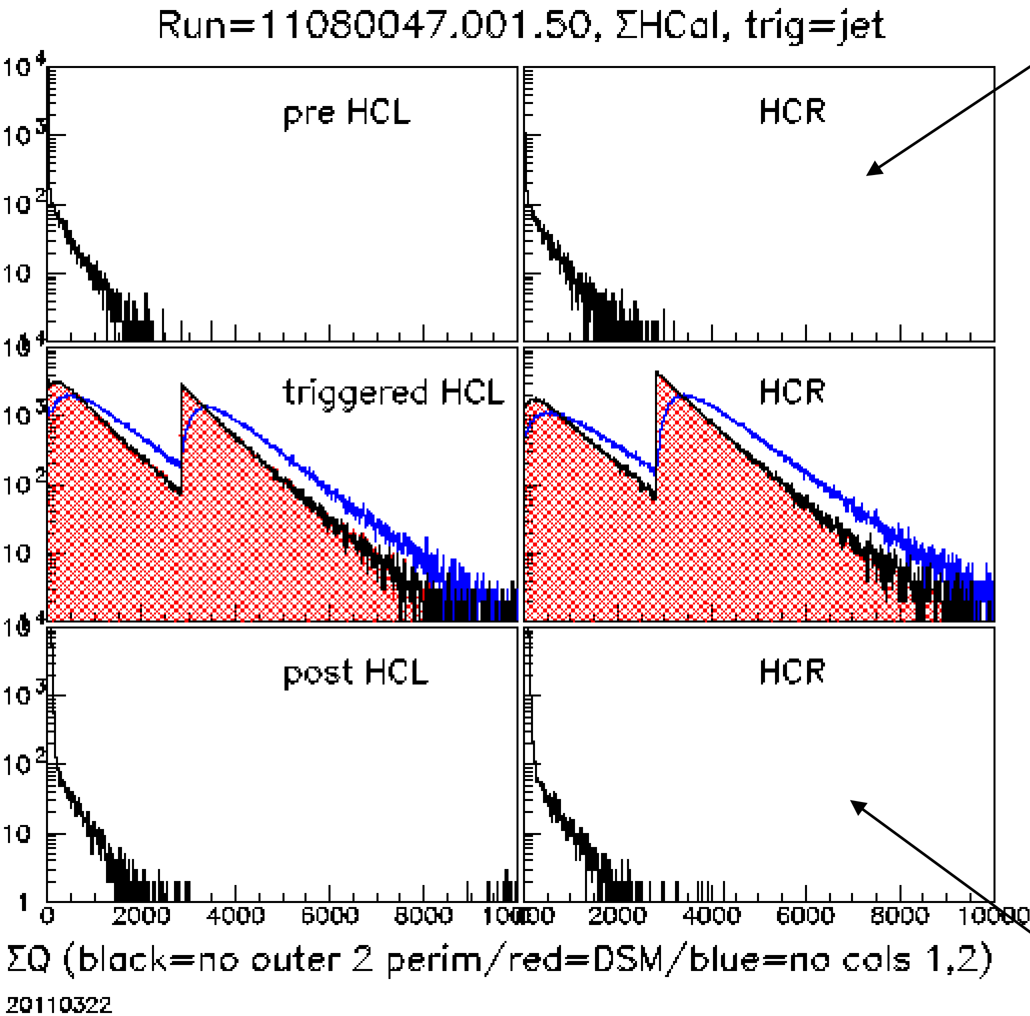
Integrated Luminosity in Run-11



- Presently, no accidentals correction (found to be large in some stores for ZDC). All rates are scaled by bunch-crossing scalers, following 20110330 access and subsequent timing adjustments.
- Effective BBC cross section has been revisited through full simulations and now is in better agreement with vernier scan measurements (e.g., fill=15457)
- Jet analyzing power measurement sets goal of 10 / pb for run 11.

Many thanks to C-A for IP2 collisions

Jet Trigger

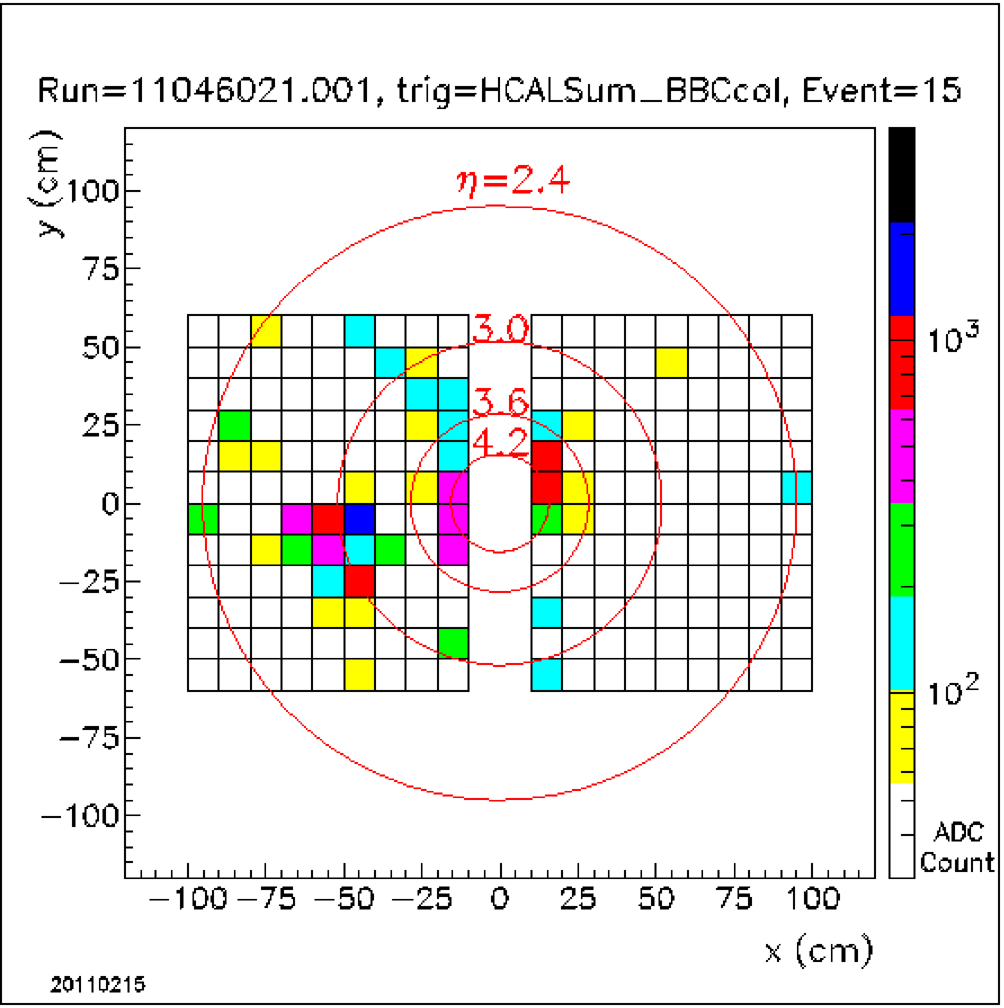


Hadron calorimeter is quiet ~107ns before jet event

- Jet trigger sums HCal response excluding outer two perimeters (rather than just two columns closest to beam)
- Definition is consistent with objective of having jet thrust axis centered in hadron calorimeter modules
- HCal energy scale is now determined
- >750M jet-triggered events acquired during RHIC run 11

Hadron calorimeter is quiet again ~107ns after jet event

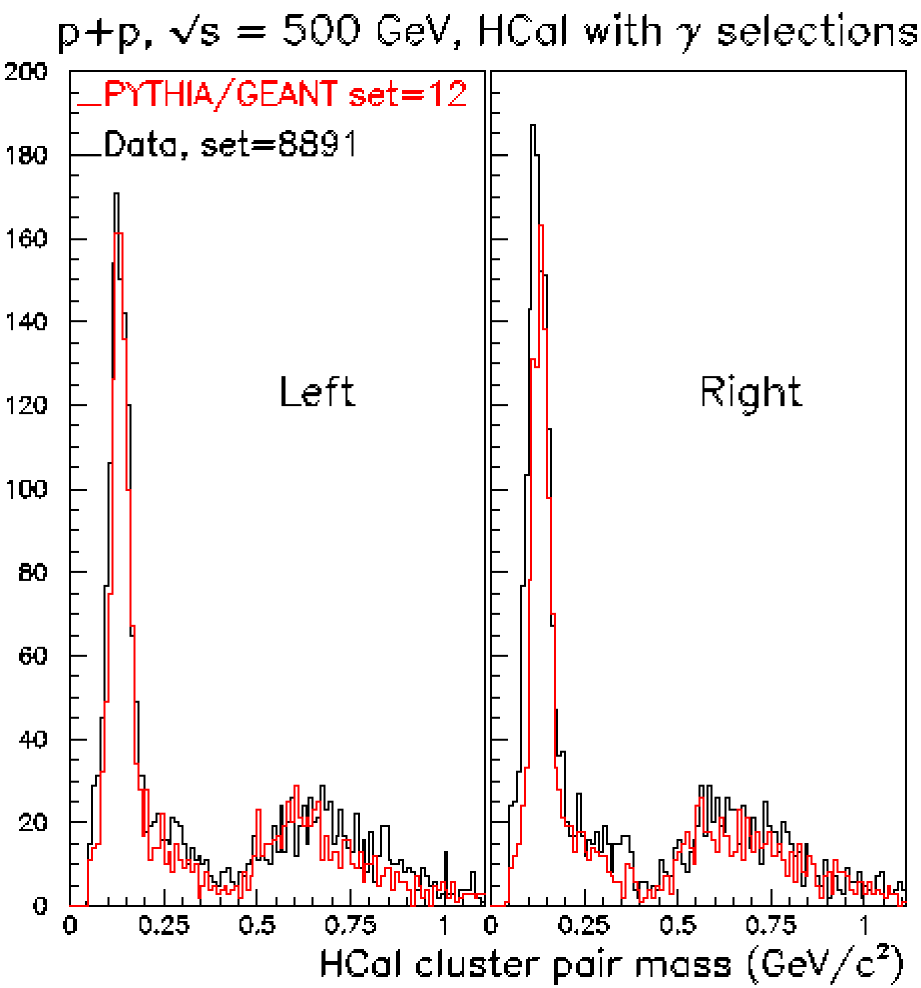
HCal Events



- Cosmic ray trigger is essentially the same as jet trigger, except that the threshold on the summed calorimeter response is set at 5 pC (20 counts)
- This is a trigger that will work without beam. We have other cosmic-ray triggers that will work with beam, when commissioned, for continuous monitoring.
- The tracks test noise, patterns, etc.

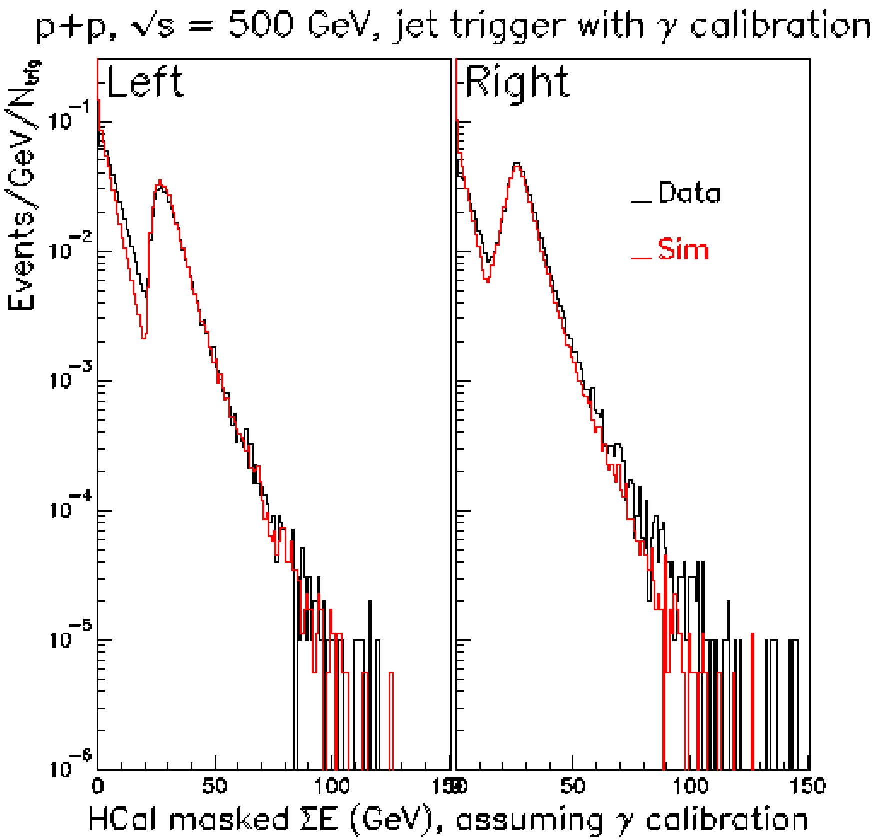
Calibration of Hadron Calorimeter

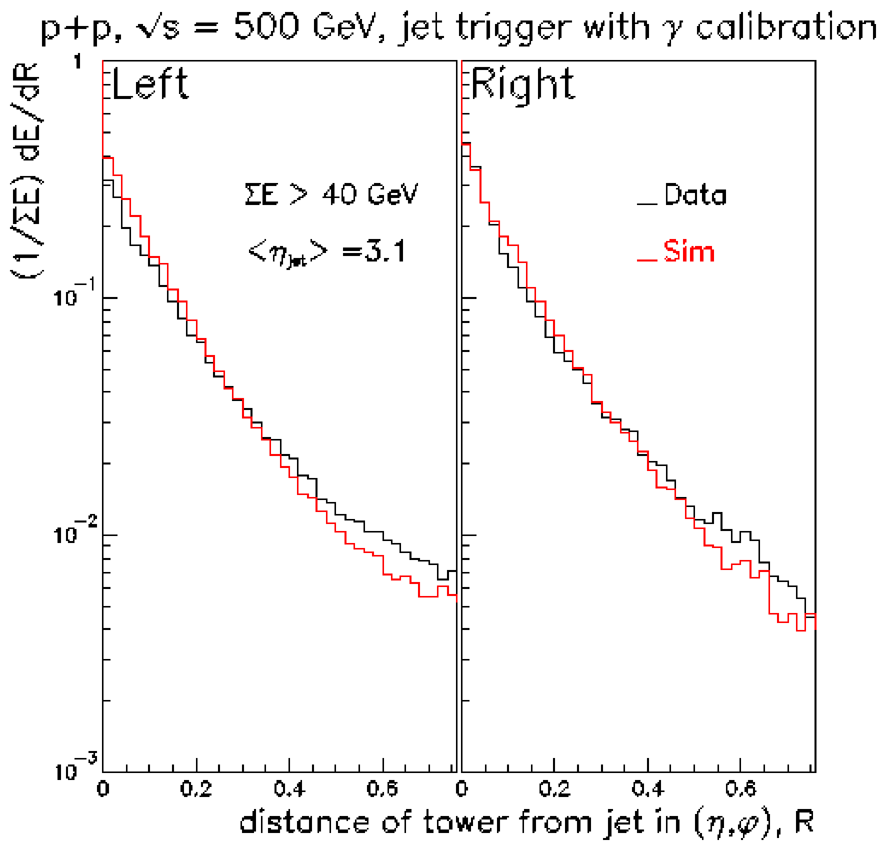
Based on $\pi^0 \rightarrow \gamma\gamma$ reconstruction



- require: (1) 1-tower clusters; (2) E>1.8 GeV; (3) |x|>50 cm to avoid ECal shadow; (4) >1 clusters to form pairs; (5) E_{pair}>5 GeV; (6) M_{pair}<0.5 GeV; and (7) z_{pair}<0.5.
- Apply to 20M minimum-bias events from run-11 data
- Apply to 20M PYTHIA events subjected to BBC charge sum trigger emulation (no vertex cut)
- Data and simulations are both absolutely normalized, so PYTHIA is expected to provide a good basis for QCD backgrounds to DY.
- Hadronic corrections expected to be small. Mass reconstructions to demonstrate this are underway.

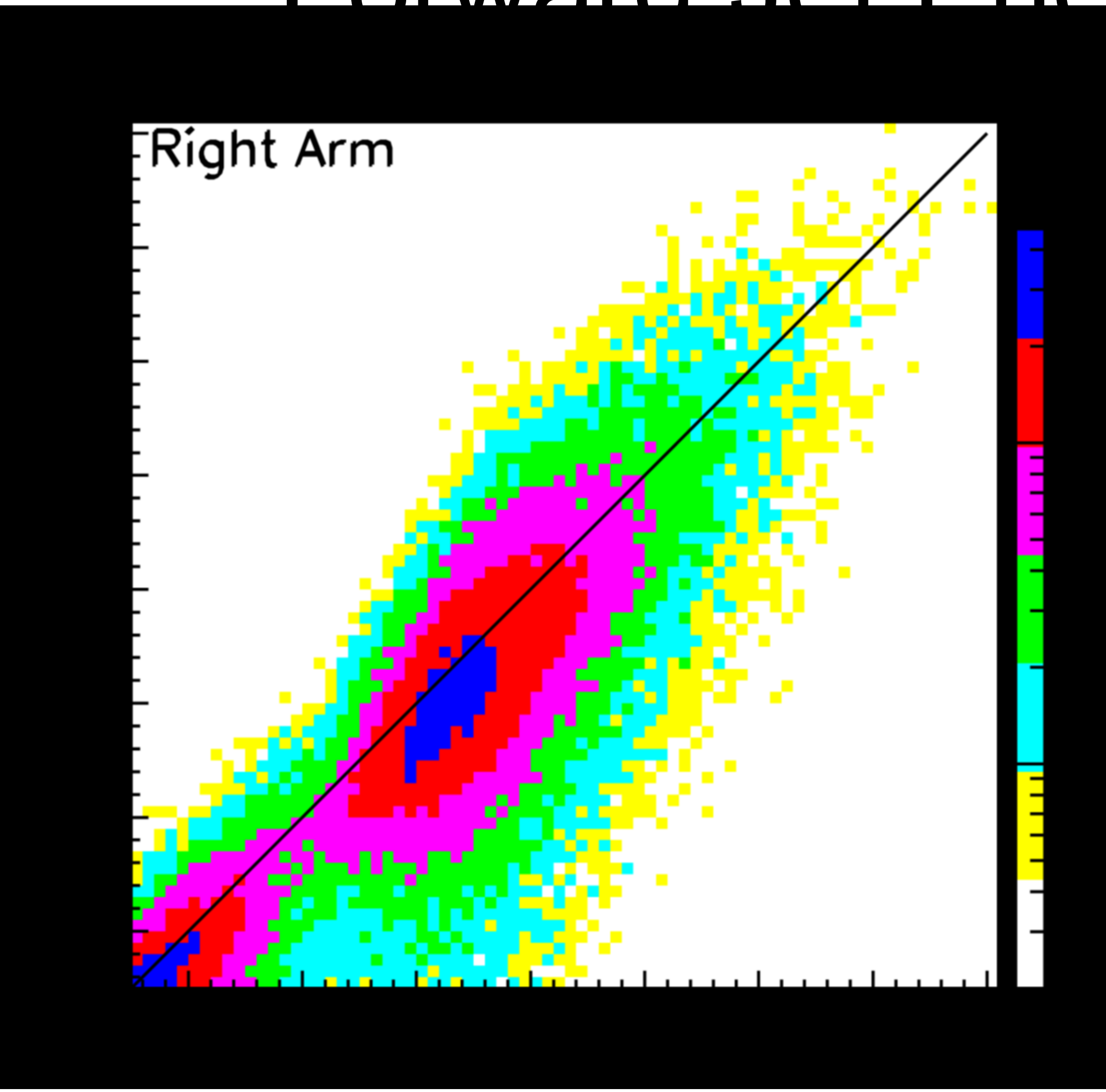
Towards Forward Jets

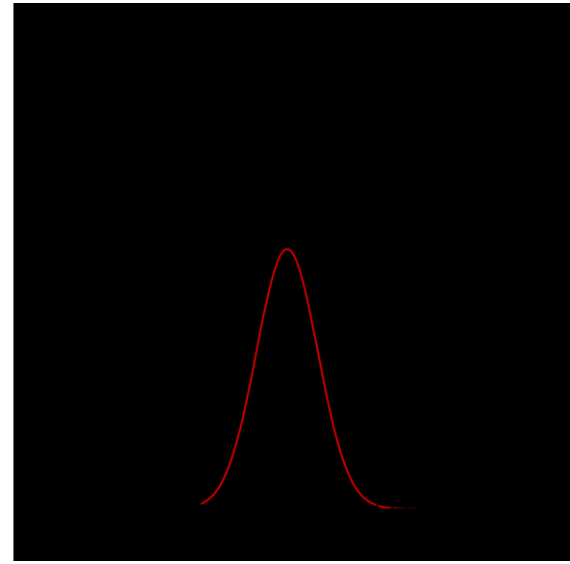




- Good agreement between data and PYTHIA/GEANT simulation for summed HCal response excluding outer two perimeters of cells ⇒ QCD backgrounds can be modeled
- Good agreement between data and simulation for jet shape
- Next up: forward jet analyzing power

Forward Jet Energy Scale

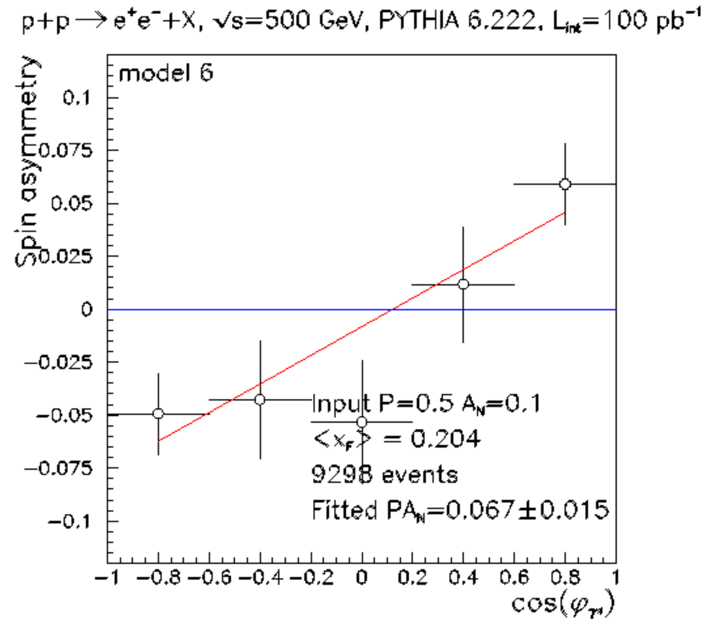




- Jet energy scale determined by association analysis of simulation
- Required to add ECal energy deposition to masked summed HCal response
- Small rescaling (<10%) of HCal energy scale is applied, likely to account for hadronic corrections

Status of A_NDY

- Calorimetry required for experiment is at BNL. It is on loan from JLab until July 2014.
- Layout for second stage (no magnet) is complete, with specification of azimuthally complete HCal, ECal and segmented preshower detector.
- Existing split dipole does require modification to match acceptance of final calorimetry plan.
- Staging of apparatus awaits funding review.
- At present, first attempt at transverse spin DY measurement will be in RHIC run 13



Projected sensitivity of A_NDY for L_{int}=100 pb^{-1} for $p^{\uparrow}$ $p^{\uparrow}$ collisions at $\sqrt{s}$=500 GeV requiring γ^* M>4 GeV/c^2, p_T<2 GeV/c and 0.1<x_F<0.3