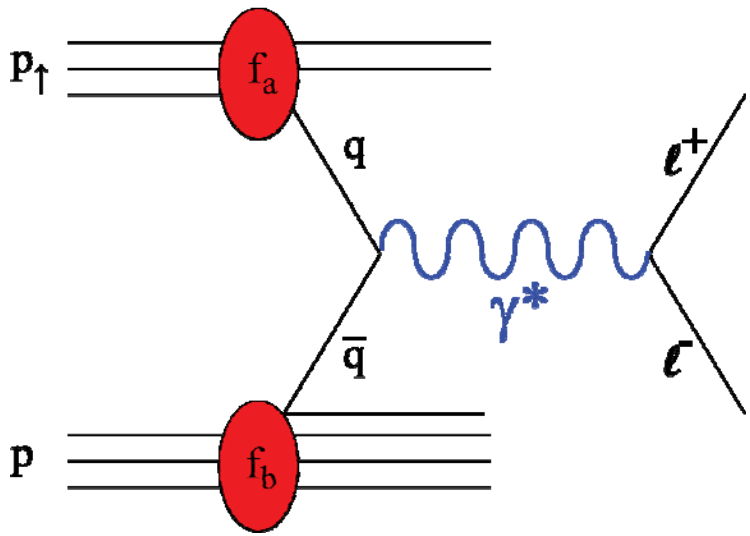
A_NDY Report



L.C. Bland
Brookhaven National Lab
RHIC/AGS Users Meeting
14 June 2012

A_NDY

A_NDY: Measurement of the Analyzing Power for Large Rapidity Drell-Yan Production

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[13]Stony Brook University
[14]University of Zagreb, Croatia
[15]Norfolk State University
[16]University of the Basque Country and IKERBASQUE, Spain
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February 28, 2012

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

BNL Review of A_NDY 30 March 2012:

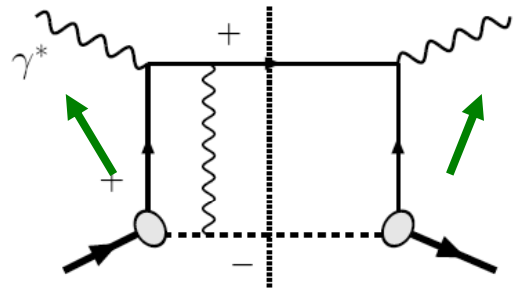
http://hena.lbl.gov/IP2/Business/review/0-proposal_120229.pdf

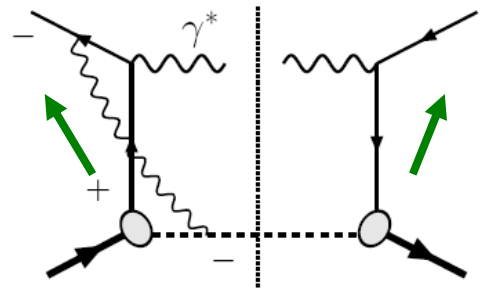
Review Report 10 May 2012

Attractive vs Repulsive Sivers Effects

Unique Prediction of Gauge Theory !

Simple QED example:

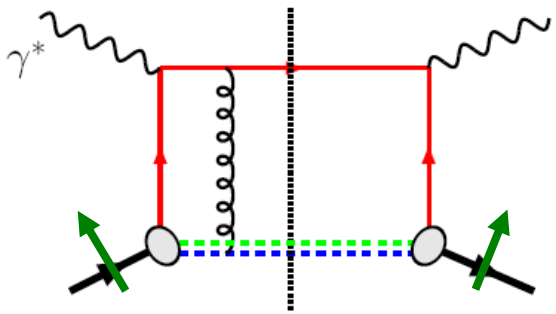


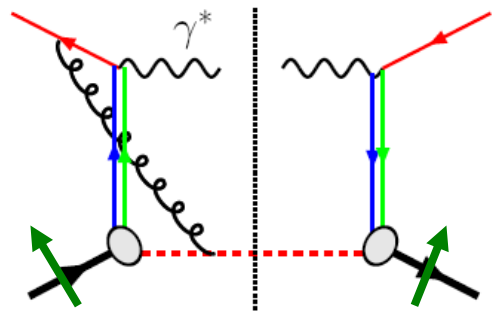


DIS: attractive

Drell-Yan: repulsive

Same in QCD:





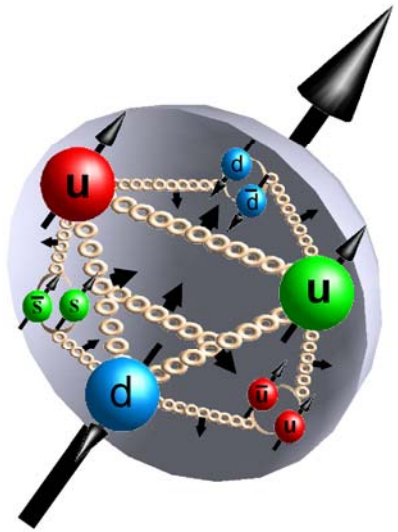
As a result:

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

Transverse Spin Drell-Yan Physics at RHIC (2007)

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

Where is the spin of the proton?



Present understanding:

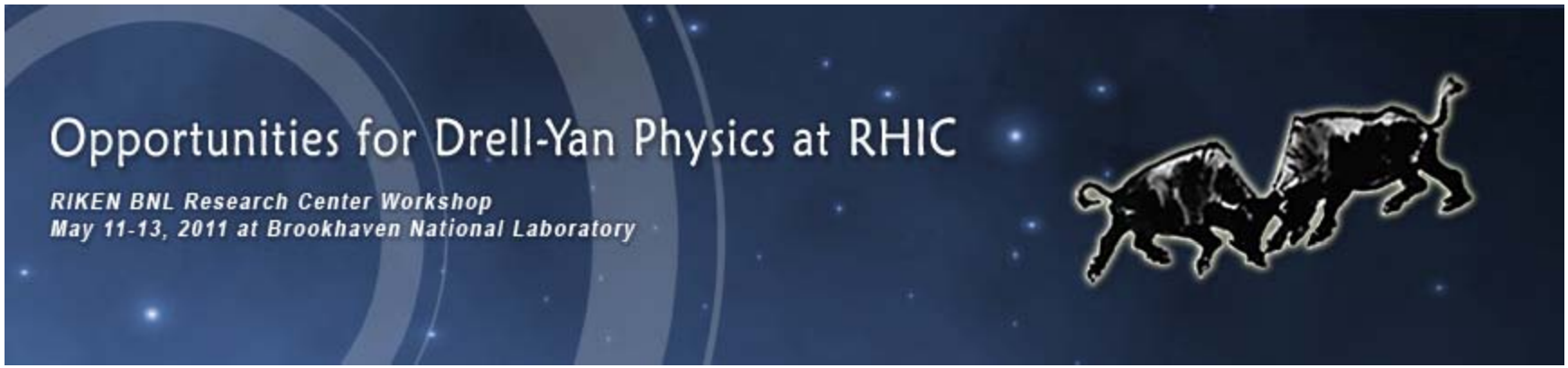
substantial contributions to the proton spin from orbital angular momentum

e.g. **INT Workshop INT-12-49W** ***Orbital Angular Momentum in QCD***

6-17 February 2012 http://www.int.washington.edu/PROGRAMS/12-49w/

Why polarized Drell Yan?

Best answer: RBRC workshop in May, 2011 had 31 talks and ~80 participants from all over the world due to the intense interest in measuring transverse SSA, and other aspects, for Drell-Yan production



John Collins, in his *Workshop Summary*, concluded with these words…

Conclusions

- Sivers function gives stress test of our understanding of QCD parton dynamics in hard scattering, especially of space-time locations of color flows

  (Key issues were hidden until recently!)

- SSA in Drell-Yan is clean test case with predictions deduced from SIDIS data and unpolarized Drell-Yan

  But remember CSS evolution (or equivalent) in making predictions.

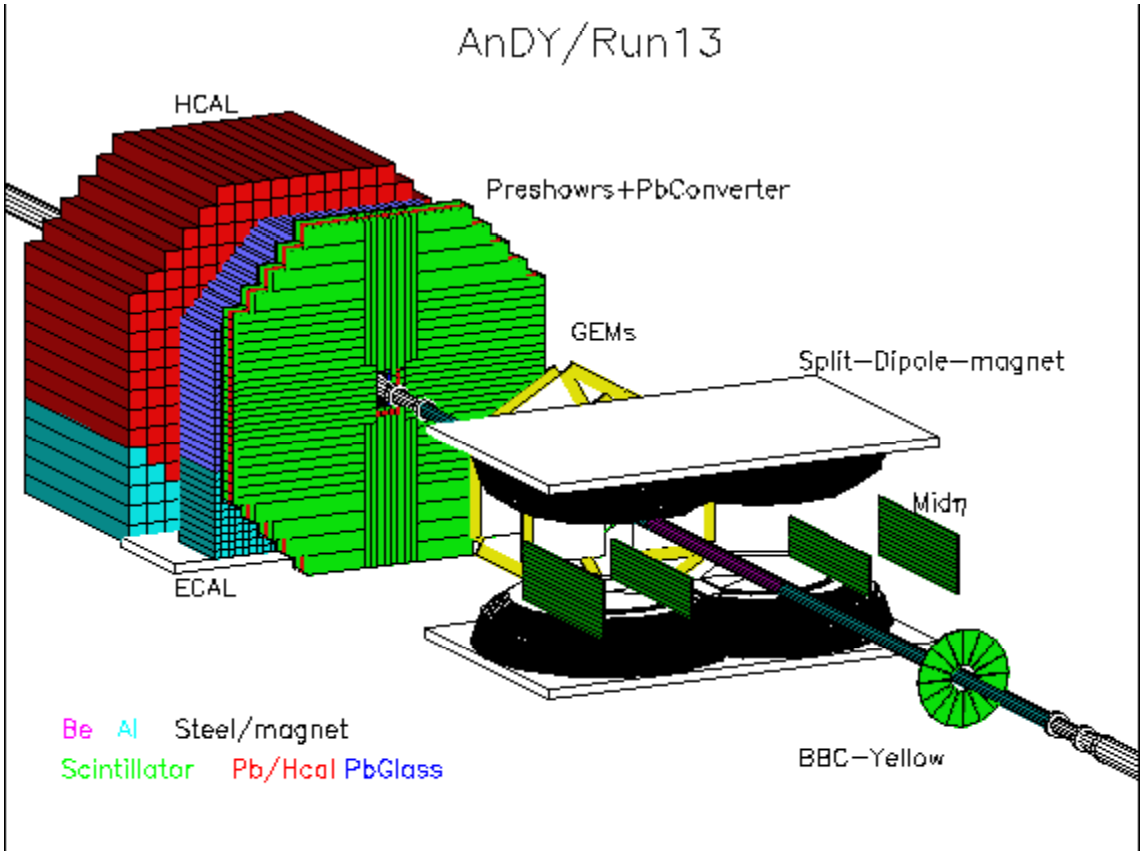
- Disquieting data for $p^{\uparrow}p \to \pi X$
- But than $p^{\uparrow}p \to \pi X$ is harder for theory than Drell-Yan

Why A_NDY?

- Drell-Yan production is believed to be best understood by theory for transverse momentum-dependent effects, such as the Sivers function.
- Suggested surrogates for DY production, such as di-jets, have led to confusing results. The best way to test the sign-change prediction from theory is DY.
- Forward DY is important, to ensure kinematic overlap between DY and SIDIS.
- It is expected that future efforts in forward DY will provide the most robust connections to the low-x physics program of an EIC, so developing capabilities at RHIC are essential.
- Forward instrumentation at RHIC is limited, as is available space at STAR and PHENIX. The major engineering efforts to instrument the forward direction at STAR and PHENIX are best done after demonstrating the basic requirements for DY.
- Run-11 demonstrated that RHIC can collide polarized proton beams at 3 IR, albeit with the need to further reduce backgrounds. Consequently, A_NDY can run in parallel with the W program and be done in parallel with COMPASS-DY, planned for 2014.

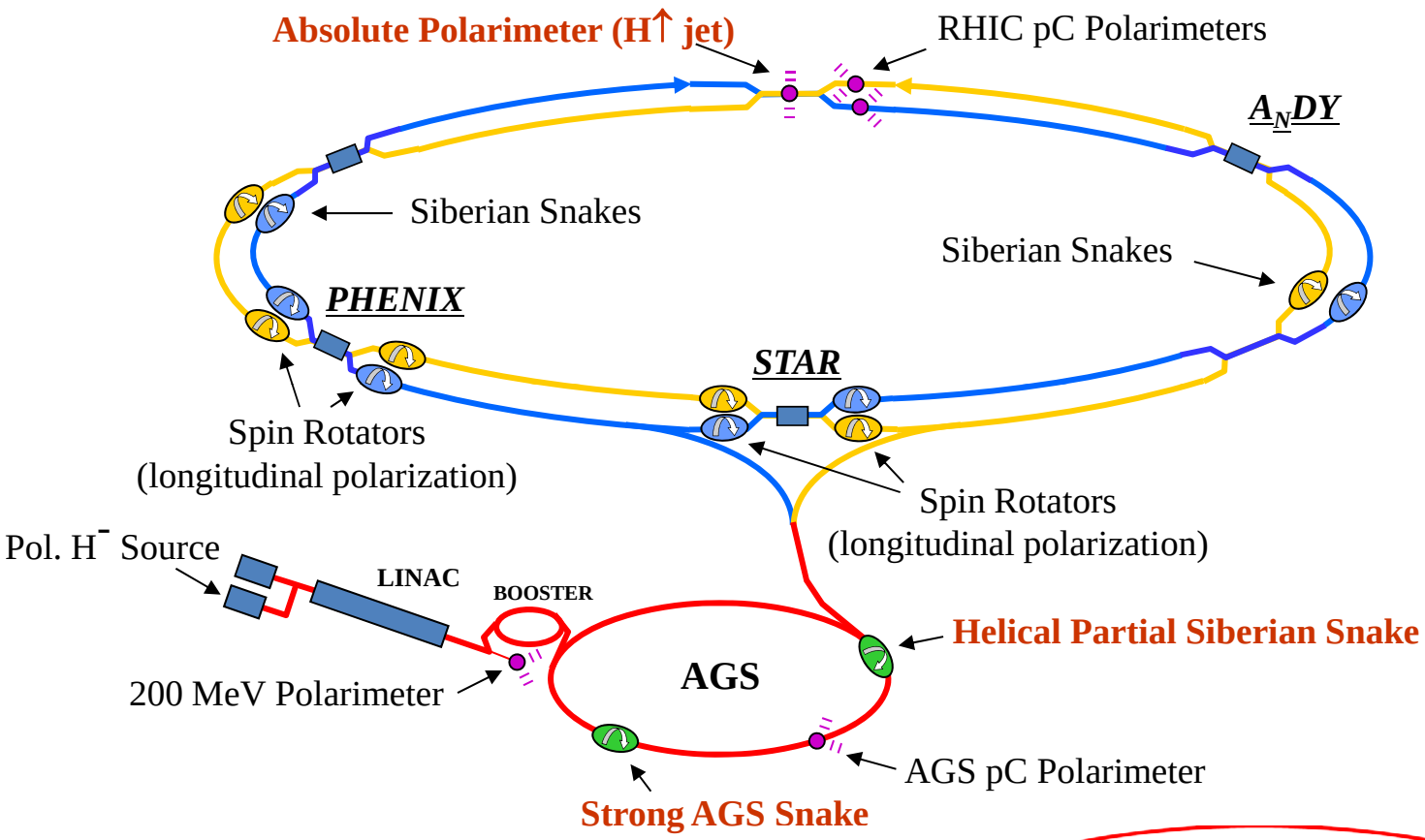
Goal of A_NDY Project

Measure the analyzing power for forward Drell-Yan production to test the predicted change in sign from semi-inclusive deep inelastic scattering to DY associated with the Sivers function

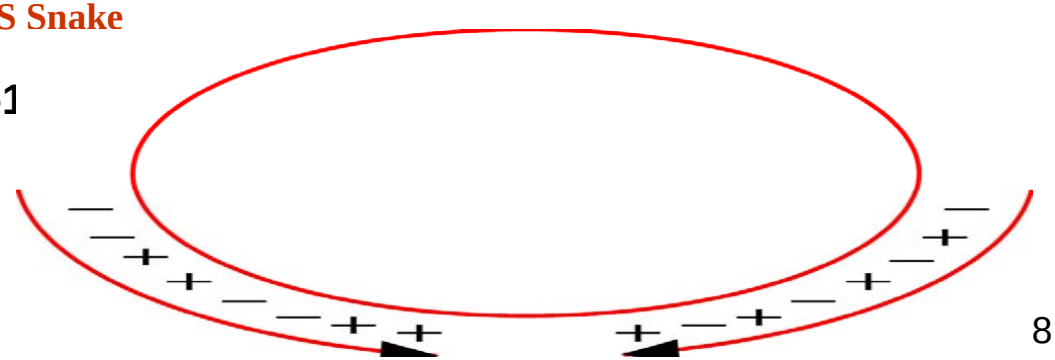


GEANT model of proposed A_NDY apparatus (run-13)

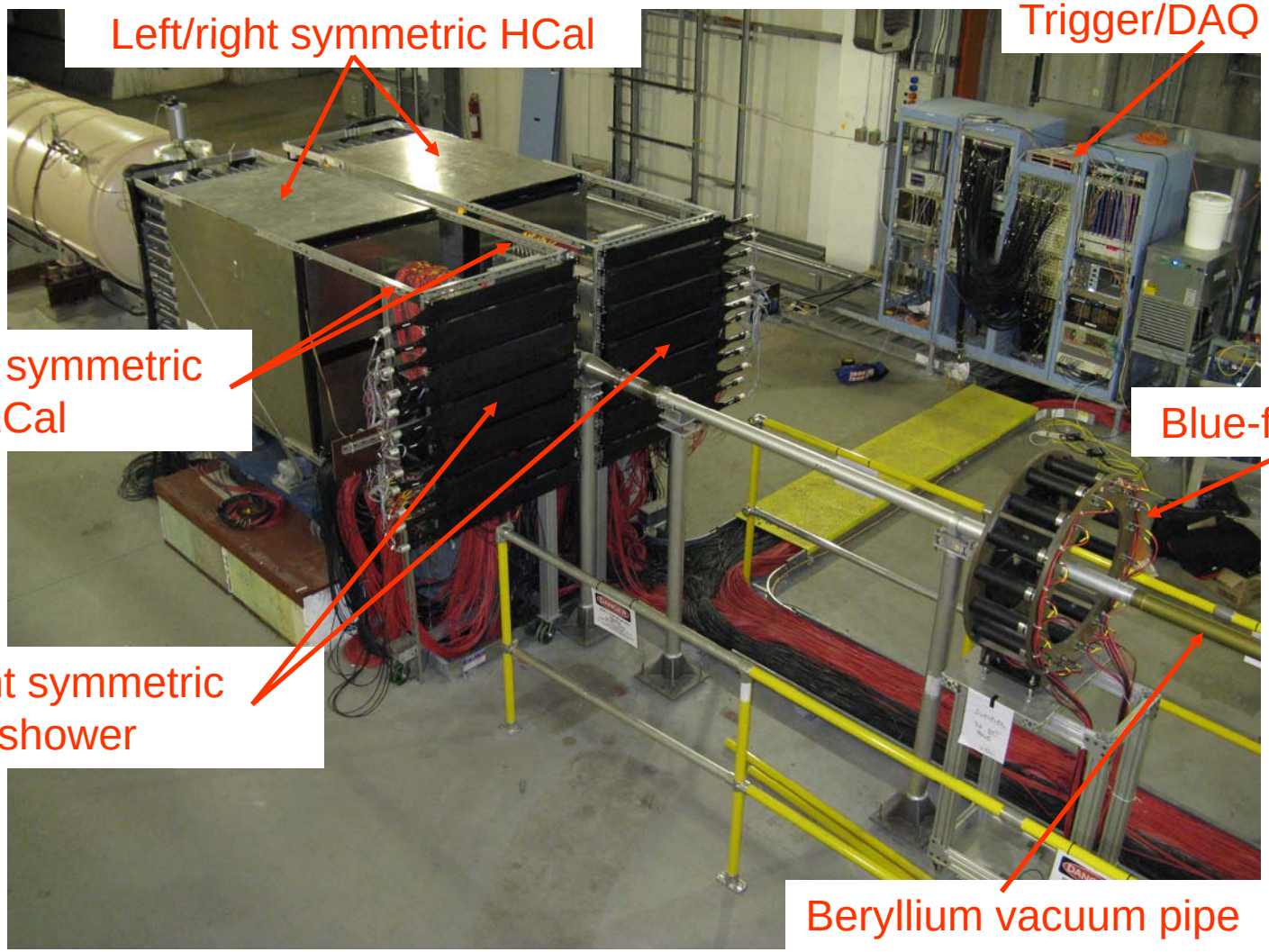
RHIC Polarized Proton Collider



2012: L_{peak}~1.6×10^{32} cm^{-2} s^{-1}
Polarization~0.52
$\sqrt{s}$ = 510 GeV



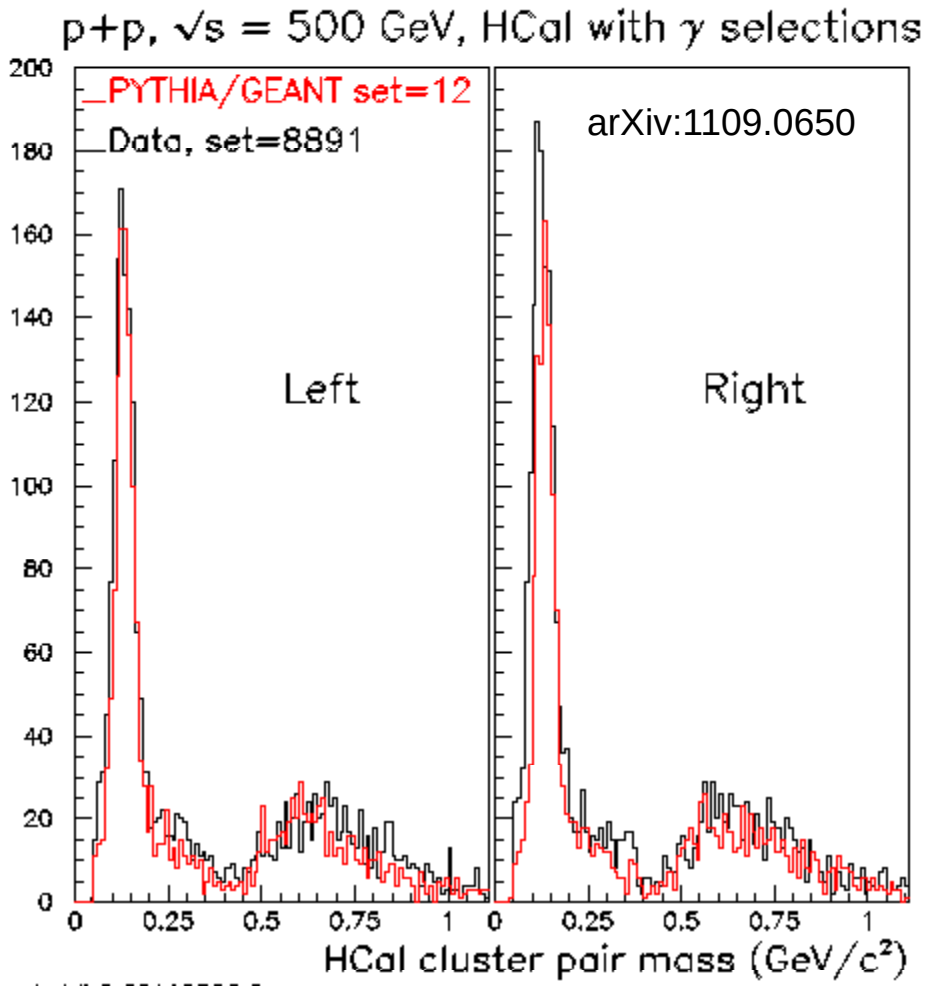
Run-11 A_NDY



Stage-1 prototype of forward Drell-Yan experiment

Calibration of Hadron Calorimeter

Based on $\pi^0 \rightarrow \gamma\gamma$ reconstruction, Run-11 A_NDY

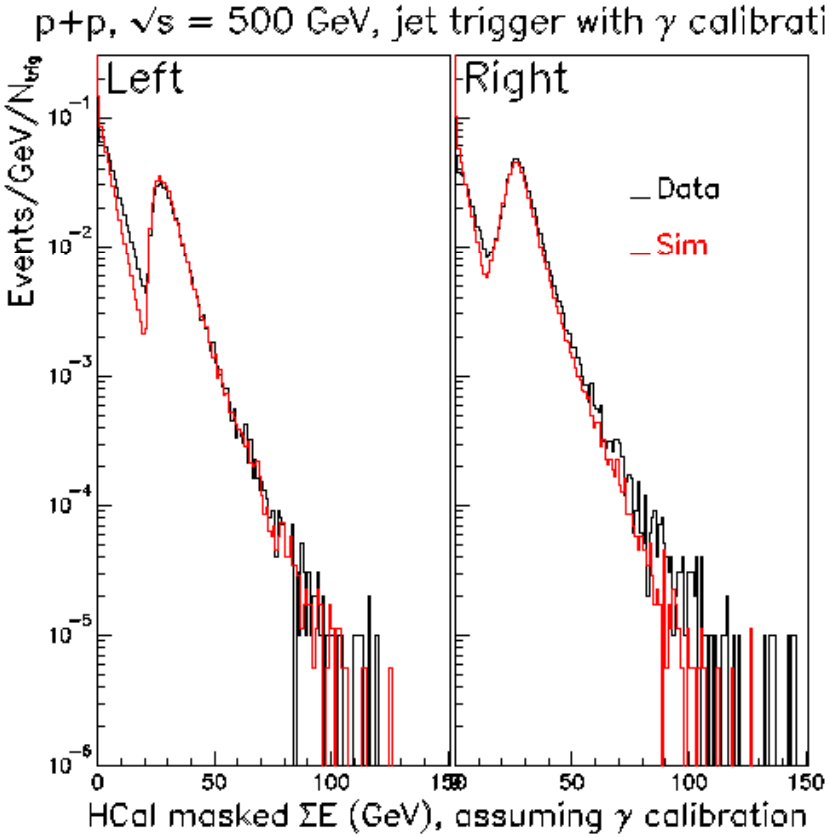


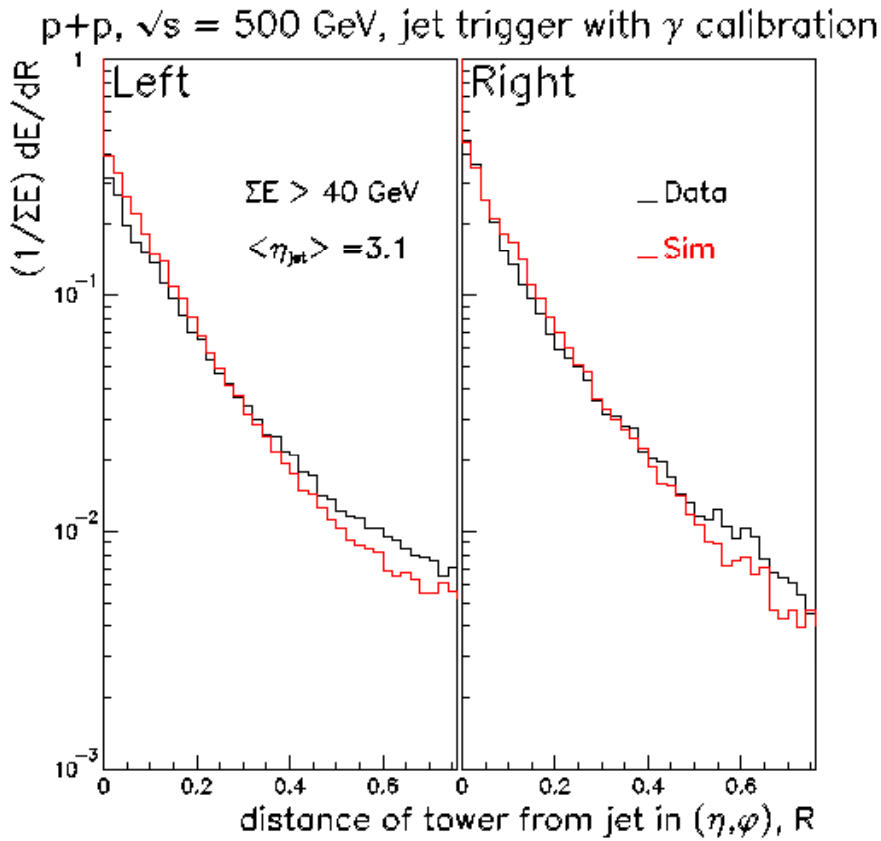
- require: (1) 1-tower clusters; (2) E>1.8 GeV; (3) |x|>50 cm to avoid ECal shadow; (4) >1 clusters to form pairs; (5) E_{pair}>5 GeV; (6) M_{pair}<0.5 GeV; and (7) z_{pair}<0.5.
- Apply to 20M minimum-bias events from run-11 data
- Apply to 20M PYTHIA events subjected to BBC charge sum trigger emulation (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

Run-11 A_NDY

arXiv:1112.1812

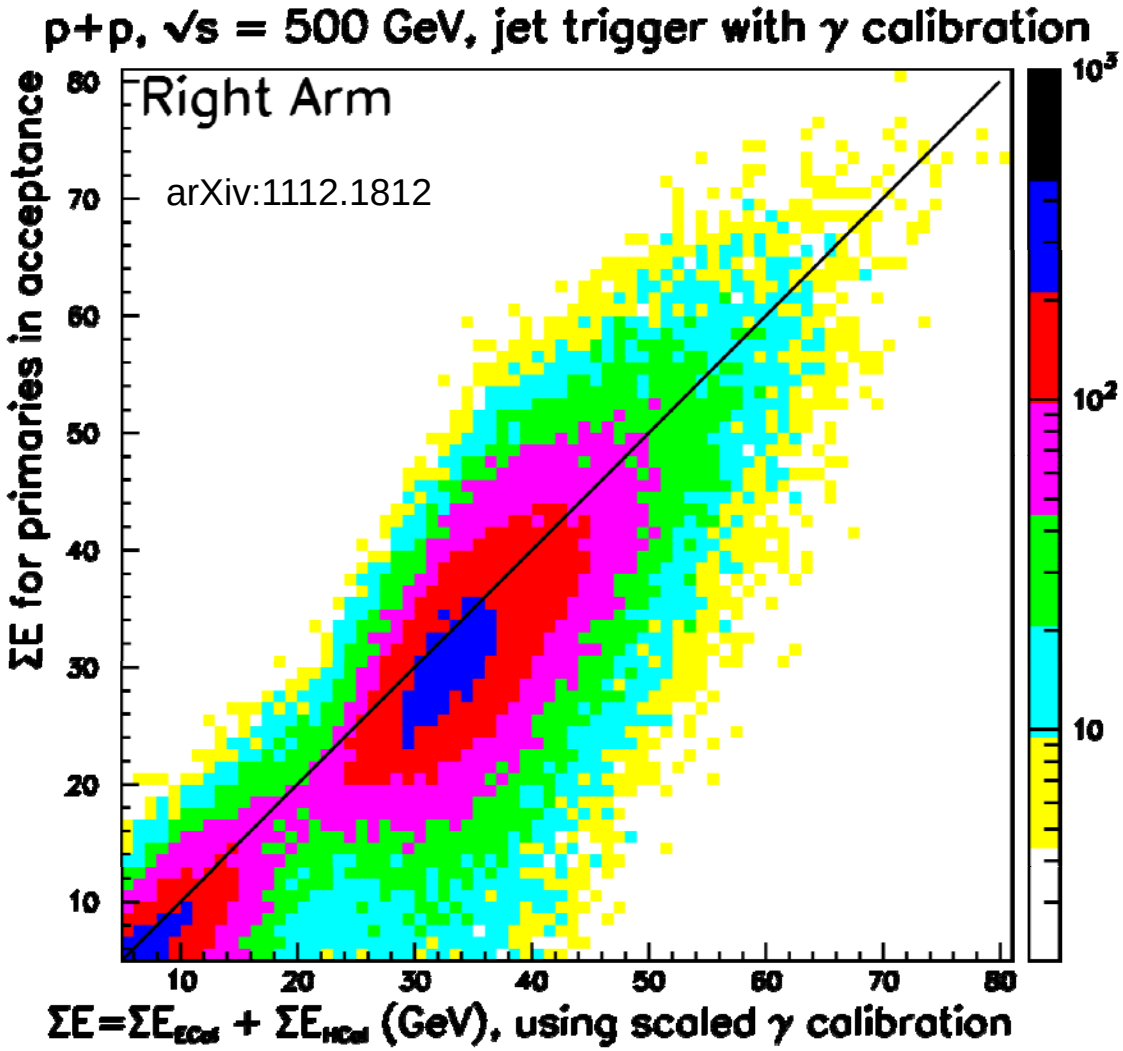


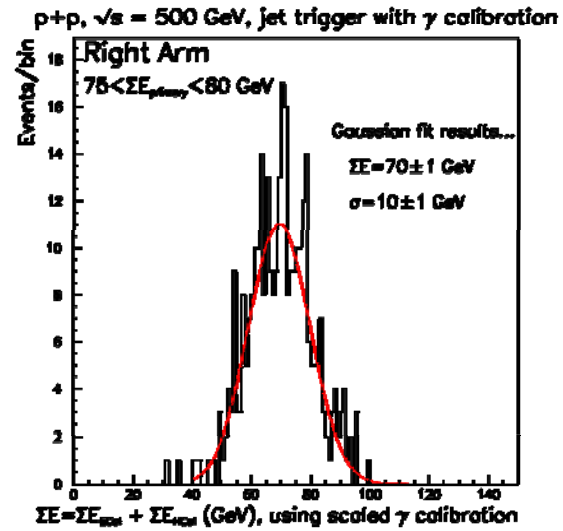


- Good agreement between data and PYTHIA/GEANT simulation for summed HCal response excluding outer two perimeters of cells ⇒ QCD backgrounds can be modeled
- Good agreement between data and simulation for jet shape
- Next up: forward jet analyzing power

Forward Jet Energy Scale

Run-11 A_NDY

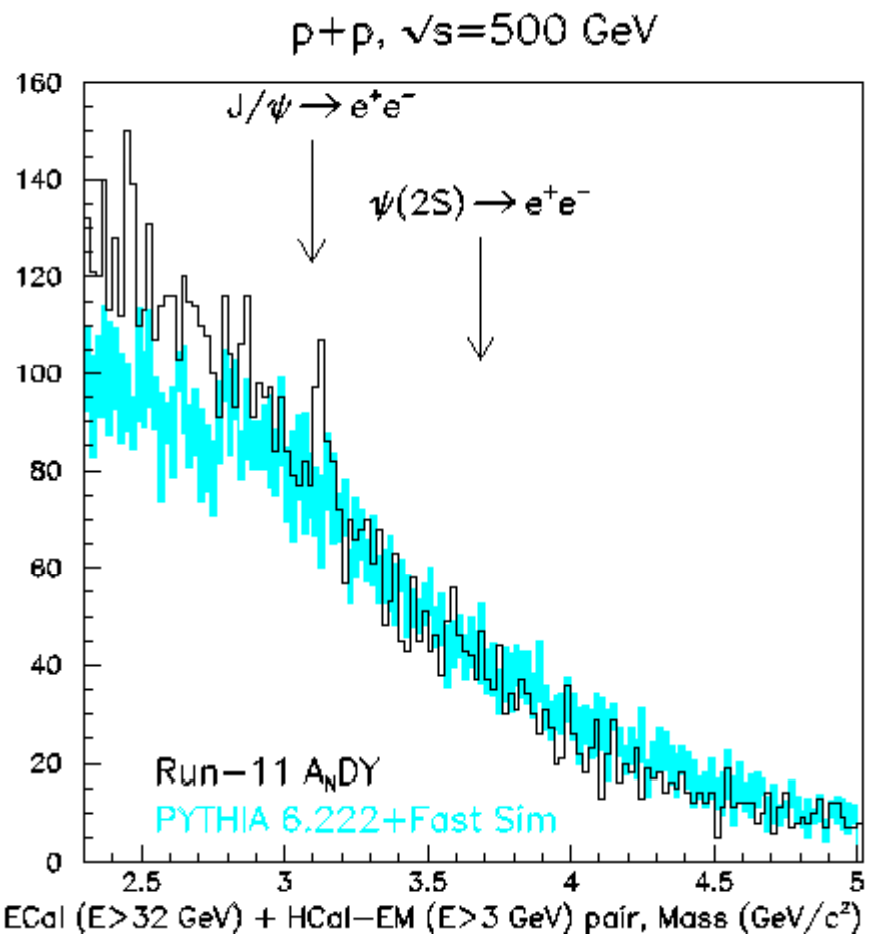




- Jet energy scale determined by association analysis of simulation
- Required to add ECal energy deposition to masked summed HCal response
- Small rescaling (<10%) of HCal energy scale is applied, likely to account for hadronic corrections

Dileptons from Run 11 Data versus Simulation

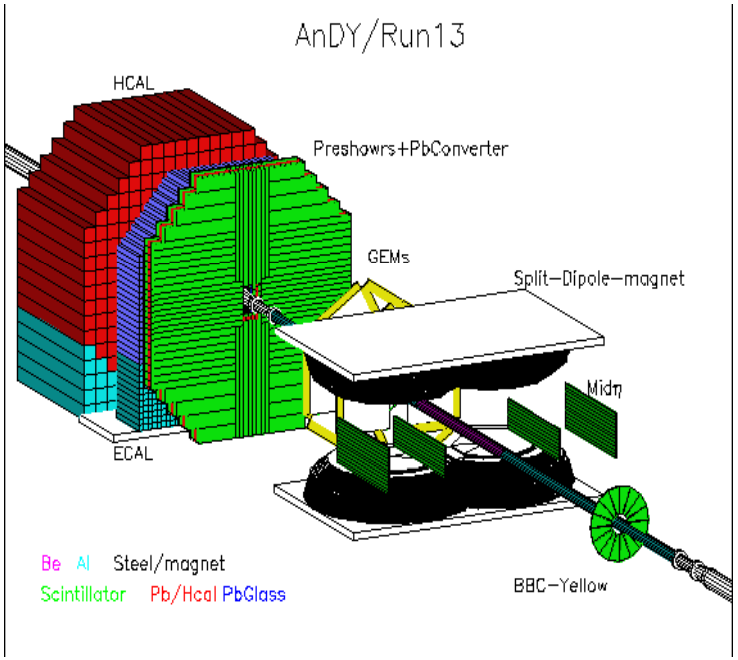
See http://hena.lbl.gov/IP2/Business/review/0-proposal_120229.pdf



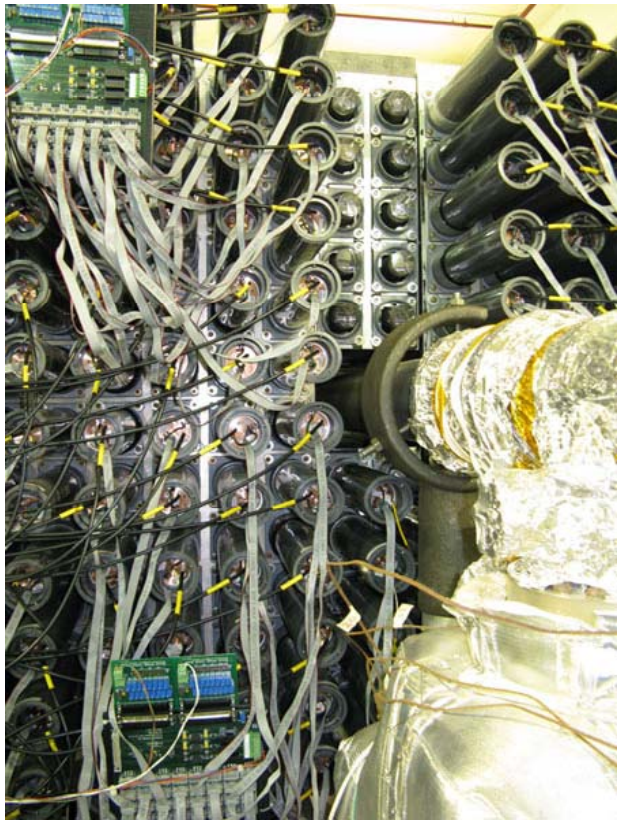
- Compare run-11 mass distribution to model used to make background estimates for DY
- Large-mass background found to be well-represented by fast-simulator model in both magnitude and shape

⇒ Expect signal:background ratio of ~6:1 for DY (~10% from reducible QCD background and ~5% from irreducible heavy flavor background)

Changes to A_NDY for Run-12



GEANT model of proposed A_NDY apparatus (run-13)

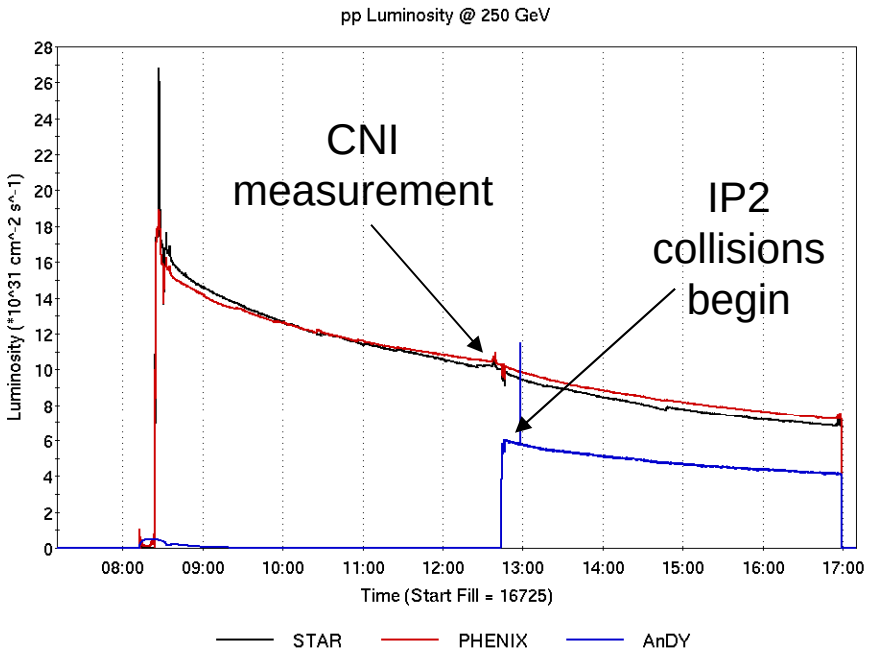


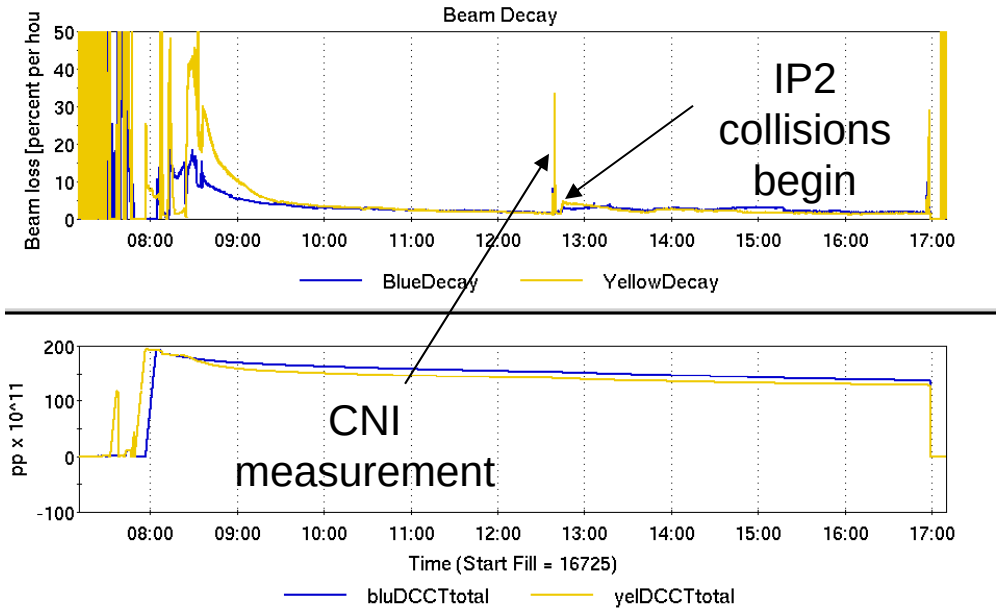
Thanks to C.Folz, et al.

- Proposed A_NDY detector (left) consists of annular ECal, annular HCal, preshower + tracking through the (modified) PHOBOS split-dipole
- The HCal module pair used in run 11 was modified to become an annular 12-row x 20 column HCal for run 12. The picture to the right shows the phototube (PMT) end of HCal upon completion of its installation in December, before installing all PMT.
- Run-11 ECal modules were mounted on rails to allow unobstructed view of IP by HCal

$\sqrt{s}$=510 GeV $p^{\uparrow}p^{\uparrow}$ Collisions at IP2 in Run 12

Fill 16725, first of six stores with IP2 collision start at mid-store

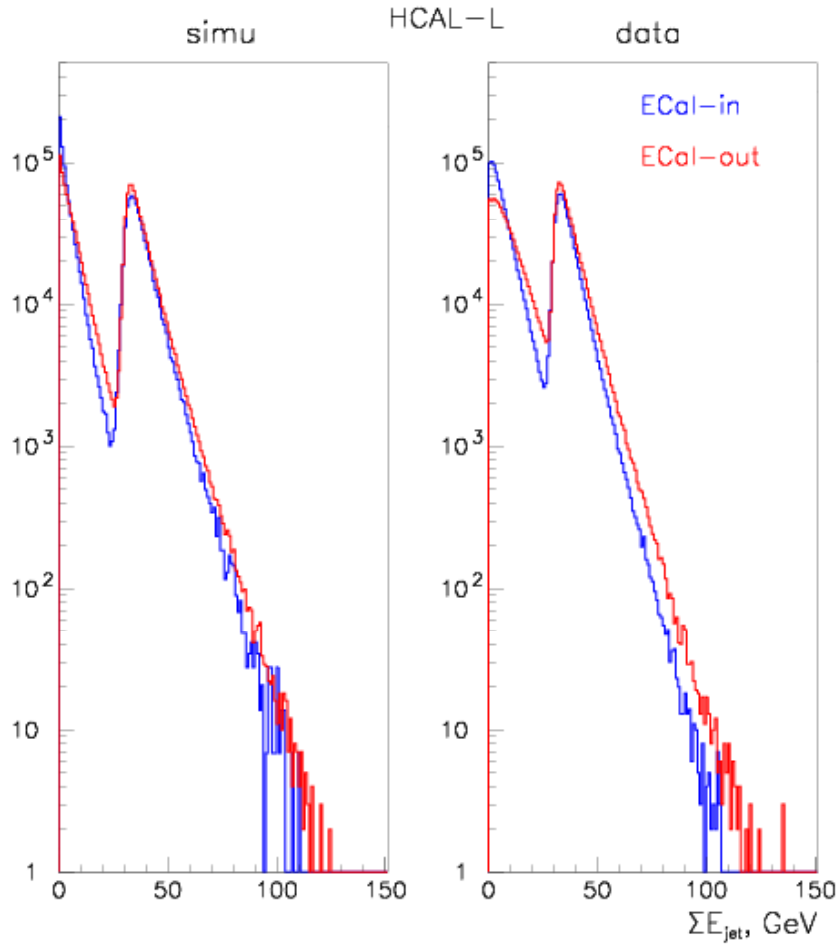




Run-12 Summary

- Significant reduction of transient beam loss that was observed in run 11
- Six stores demonstrated reproducibility when IP2 collisions begin
- L_{int}=2.5 pb^{-1} delivered to IP2 in six stores
- Higher instantaneous luminosity than run 11 $\Rightarrow$ 14 (8-hour) stores / week or earlier IP2 collision start to achieve 10 pb^{-1}/week

Trigger bias for forward jets (run-12)



Summed energy in HCal module from the jet trigger

- Measurement with ECal in (shadowing a part of HCal) and ECal out to establish effects from trigger bias on jets
- Filtered PYTHIA+GEANT simulation with trigger emulation and digitization using “real” gains
- ECal-in/ECal-out distributions are normalized by number of events

Good agreement between data and simulation above the threshold

Difference in slopes is noticeable for ECal-in vs ECal-out

As reported by L.Nogach at Users Meeting Spin Workshop on Tuesday. Ongoing effort…

Summary and Conclusions

- Polarized Drell Yan production is an important test of present understanding
  - o Sivers effect $\Leftrightarrow$ orbital angular momentum within the proton
  - o Repulsive like-color-charge interactions (DY) versus attractive unlike-color-charge interactions (semi-inclusive deep inelastic scattering)

- Luminosity and polarization at RHIC are sufficient to make first measurements of polarized DY on a time scale compatible with planned COMPASS measurement in 2014

- Dilepton observation in run 11, and additional statistics from run 12 data, can demonstrate background reduction as needed for DY

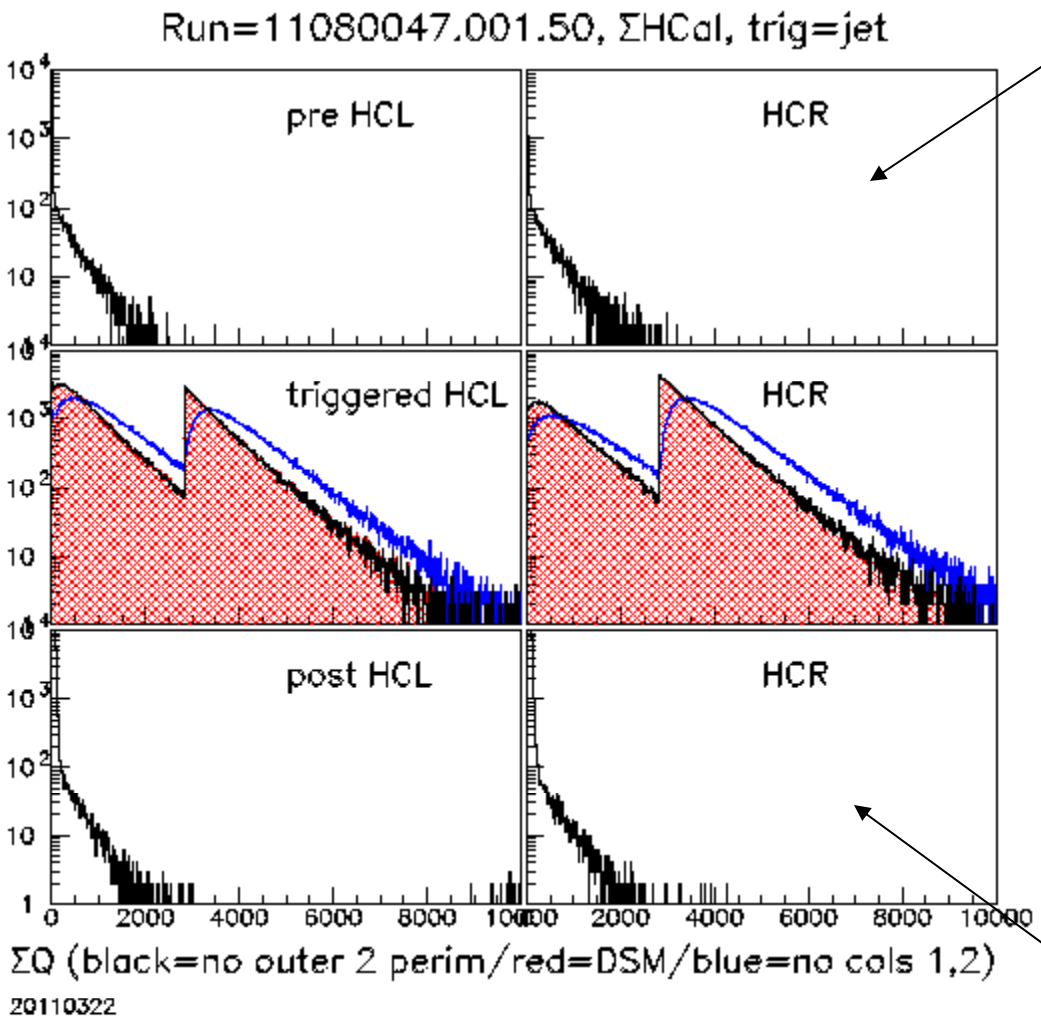
Status and Outlook

- 30 March 2012 A_NDY review identified:
  - Issue-1: timescale set by July, 2014 return of ECal
  - Issue-2: limited personnel

- It was decided that A_NDY will not proceed

Backup

Jet Trigger

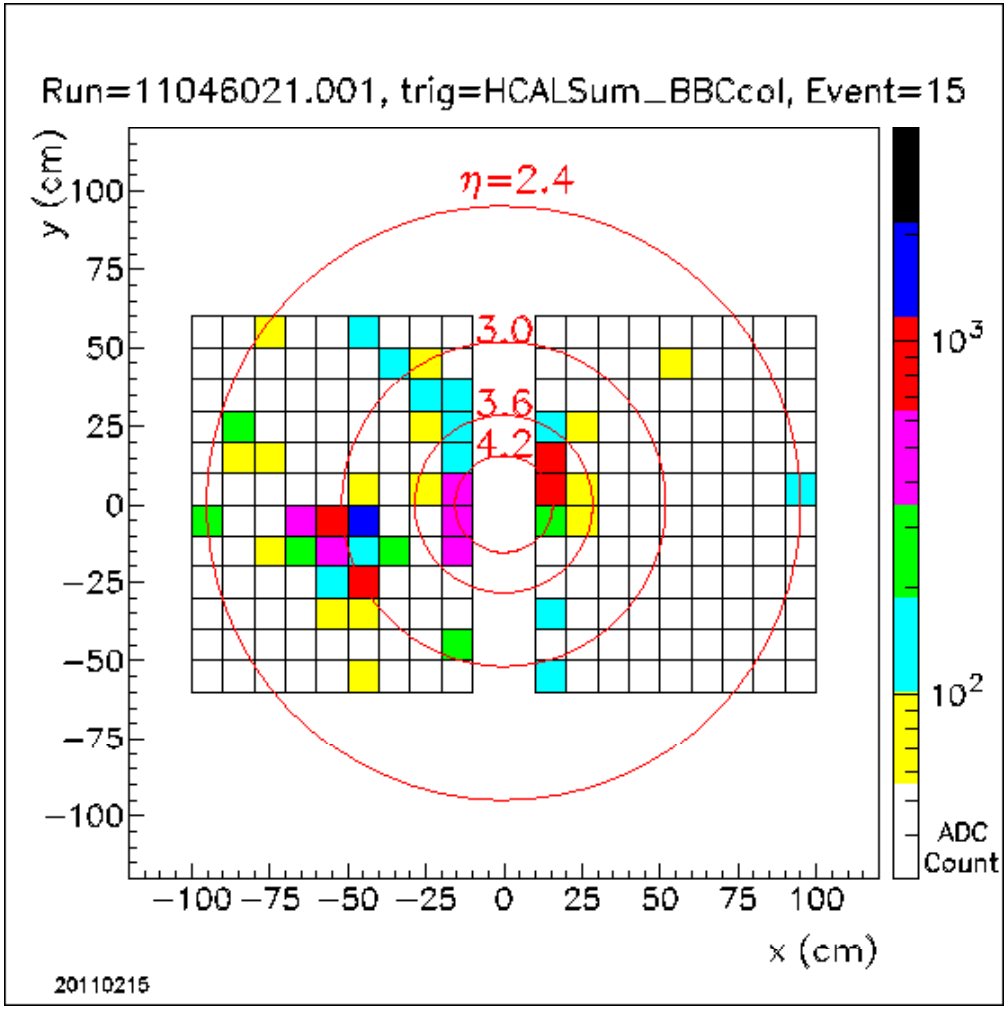


Hadron calorimeter is quiet ~107ns before jet event

- 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

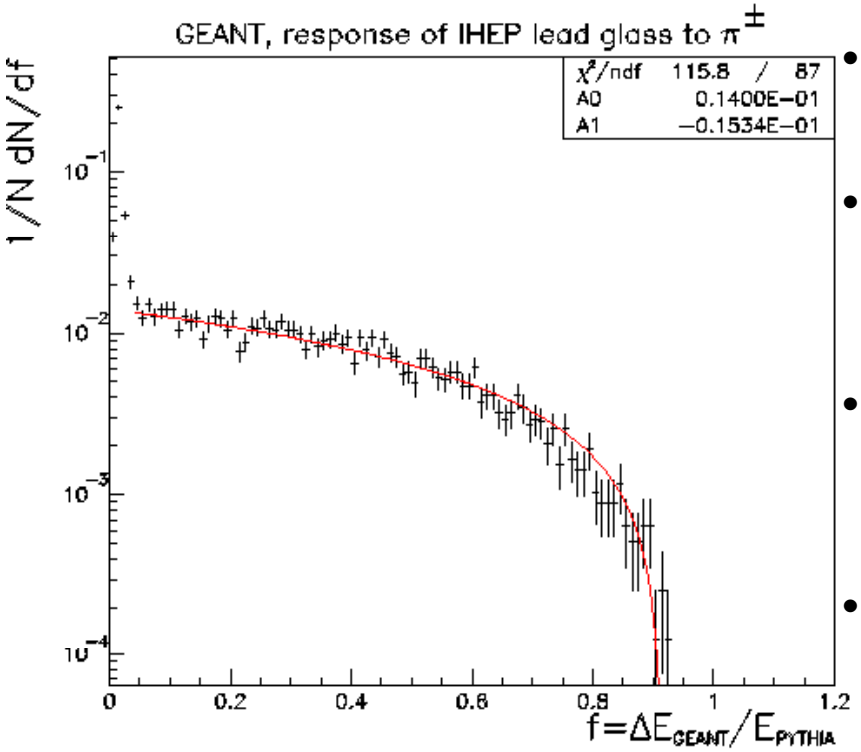
Hadron calorimeter is quiet again ~107ns after jet event

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.

Strategy for estimates

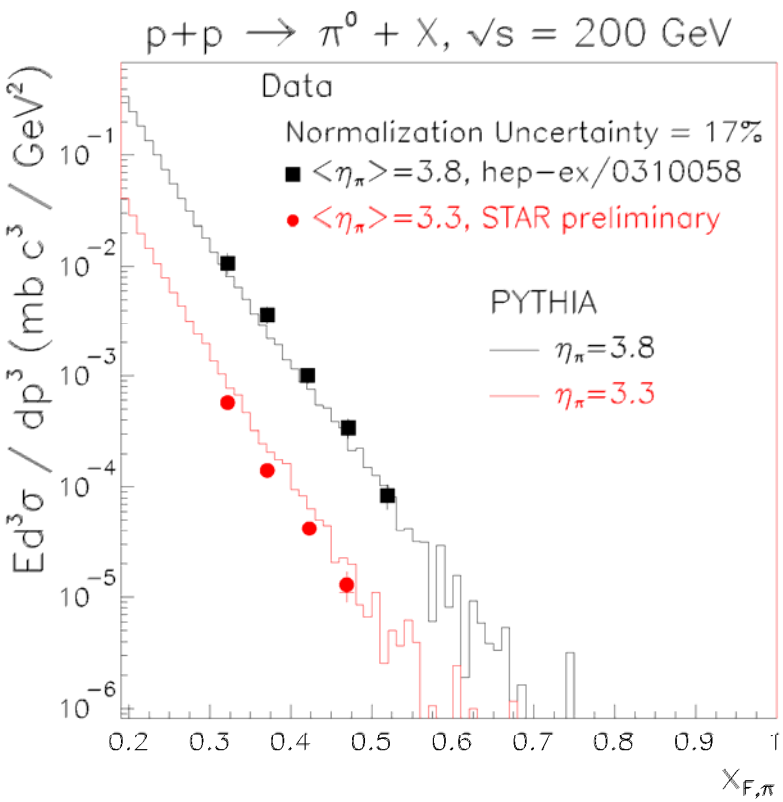


GEANT simulation of EMcal response to E>15 GeV $\pi^{\pm}$ from PYTHIA 6.222 incident on $(3.8cm)^2$x45cm lead glass calorimeter. GEANT response not so different from 57-GeV pion test beam data from CDF [hep-ex/0608081]

- ~10^{12} p+p interactions in 50 / pb at $\sqrt{s}$=500 GeV $\Rightarrow$ full PYTHIA/GEANT not practical
- Parameterize GEANT response of EMcal and use parameterized response in fast simulator applied to full PYTHIA events
- Estimate rejection factors from GEANT for hadron calorimeter and preshower detector (both critical to $h^{\pm}/e^{\pm}$ discrimination)
- Explicit treatment in fast simulator to estimate pathlengths through key elements (beam pipe and preshower), to simulate photon conversion to e+e- pair
- Estimate effects from cluster merging in EMcal ($d < \varepsilon d_{cell}$ / use ε=1 for estimates)
- Estimate/simulate EMcal cluster energy and position resolutions. σ_E=15%/$\sqrt{E}$ and $\sigma_{x(y)}=0.1d_{cell}$, used to date for $\pi^0\rightarrow\gamma\gamma$ rejection.

Backgrounds

- $h^{\pm}/e^{\pm}$ discrimination – requires estimates of p+p collisions and EMcal response
- charged/neutral discrimination
- photon conversion background – requires estimates of p+p collisions and materials



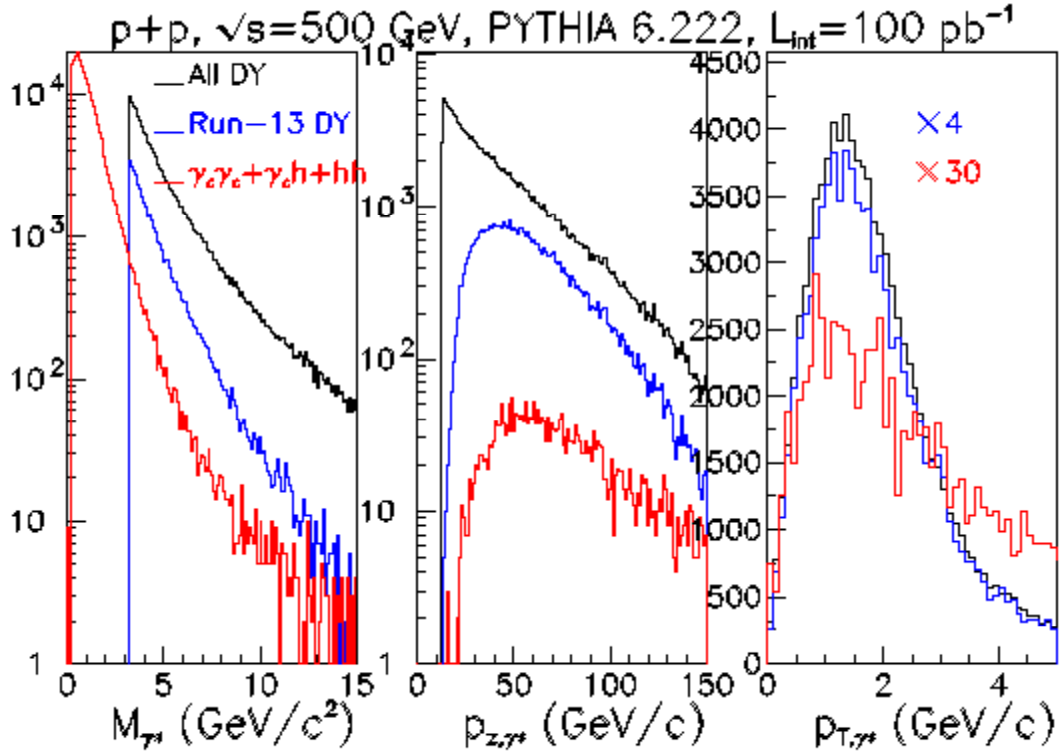
hep-ex/0403012

- PYTHIA 5.7 compared well to √s=200 GeV data [PRL 97 (2006) 152302]
- Little change until "underlying event" tunings for LHC created forward havoc

⇒ Stick to PYTHIA 6.222 for estimates

Reducible Backgrounds

See http://hena.lbl.gov/IP2/Business/review/0-proposal_120229.pdf

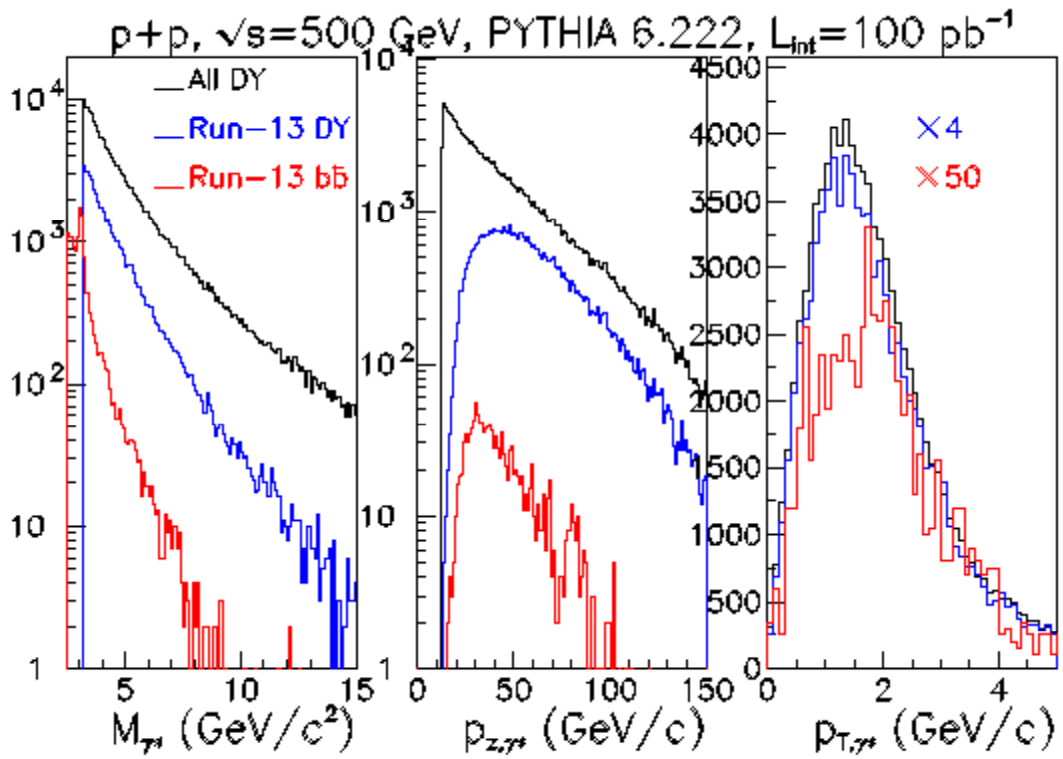


p_{z,γ^*} and p_{T,γ^*} require M_{γ^*}>4 GeV/c^2

Estimate that QCD backgrounds are <10% of the DY signal for $0.05<x_{F,\gamma^*}<0.3$ and $p_{T,\gamma^*}<2$ GeV/c (to overlap SIDIS).

Irreducible Backgrounds

See http://hena.lbl.gov/IP2/Business/review/0-proposal_120229.pdf



p_{z,γ^*} and p_{T,γ^*} require M_{γ^*}>4 GeV/c^2

Estimate that open-bottom backgrounds are ~5% of the DY signal for $0.05<x_{F,\gamma^*}<0.3$ and $p_{T,\gamma^*}<2$ GeV/c (to overlap SIDIS).