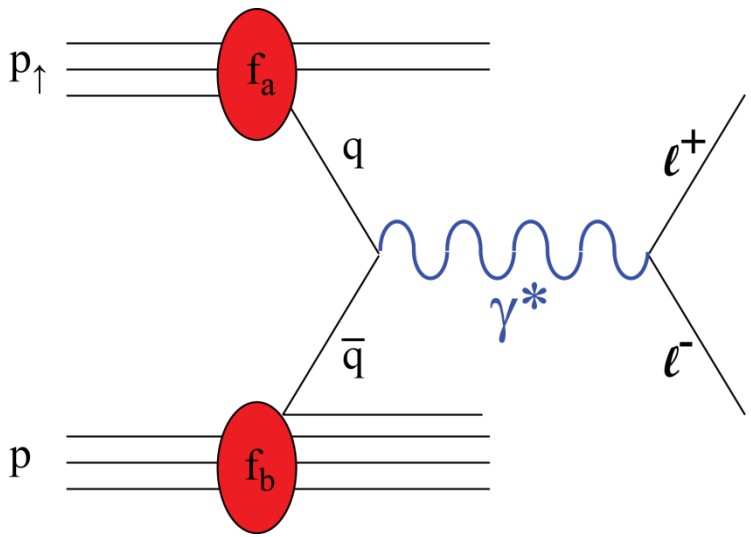
A_NDY in RHIC run-12



L. Nogach, IHEP (Protvino)
for A_NDY

RHIC & AGS Annual Users' Meeting
Jun-12-2012

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

S. Abrahamyan[1], A. Bazilevsky[2], L. C. Bland[2], E. J. Brash[4,3], E. Cisbani[5], H. J. Crawford[6], A. Derevshchikov[7], K. Drees[2], J. Engelage[6], K. O. Eyser[2], C. Folz[2], K. Gnanvo[8], G. Igo[9], E. G. Judd[6], X. Li[10], M. X. Liu[11], N. K. Liyanage[8], Y. Makdisi[2], N. Minaev[7], D. Morozov[7], L. Nogach[7], A. Ogawa[2], C. F. Perdrisat[12], C. Perkins[6,13], P. Pile[2], M. Planinic[14], V. Punjabi[15], G. Schnell[16], A. Shahinyan[1], T. G. Throwe[2], C.Van Hulse[16], and A. Vossen[17]

[1]Yerevan Physics Institute, Armenia
[2]Brookhaven National Laboratory
[3]Thomas Jefferson National Accelerator Facility
[4]Christopher Newport University
[5]INFN Roma, Italy
[6]University of California, Berkeley/Space Sciences Laboratory
[7]Institute for High Energy Physics, Protvino
[8]University of Virgina
[9]University of California, Los Angeles
[10]Shandong University, China
[11]Los Alamos National Laboratory
[12]College of William and Mary
[13]Stony Brook University
[14]University of Zagreb, Croatia
[15]Norfolk State University
[16]University of the Basque Country and IKERBASQUE, Spain
[17]Indiana University

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

2011 PAC recommendations:

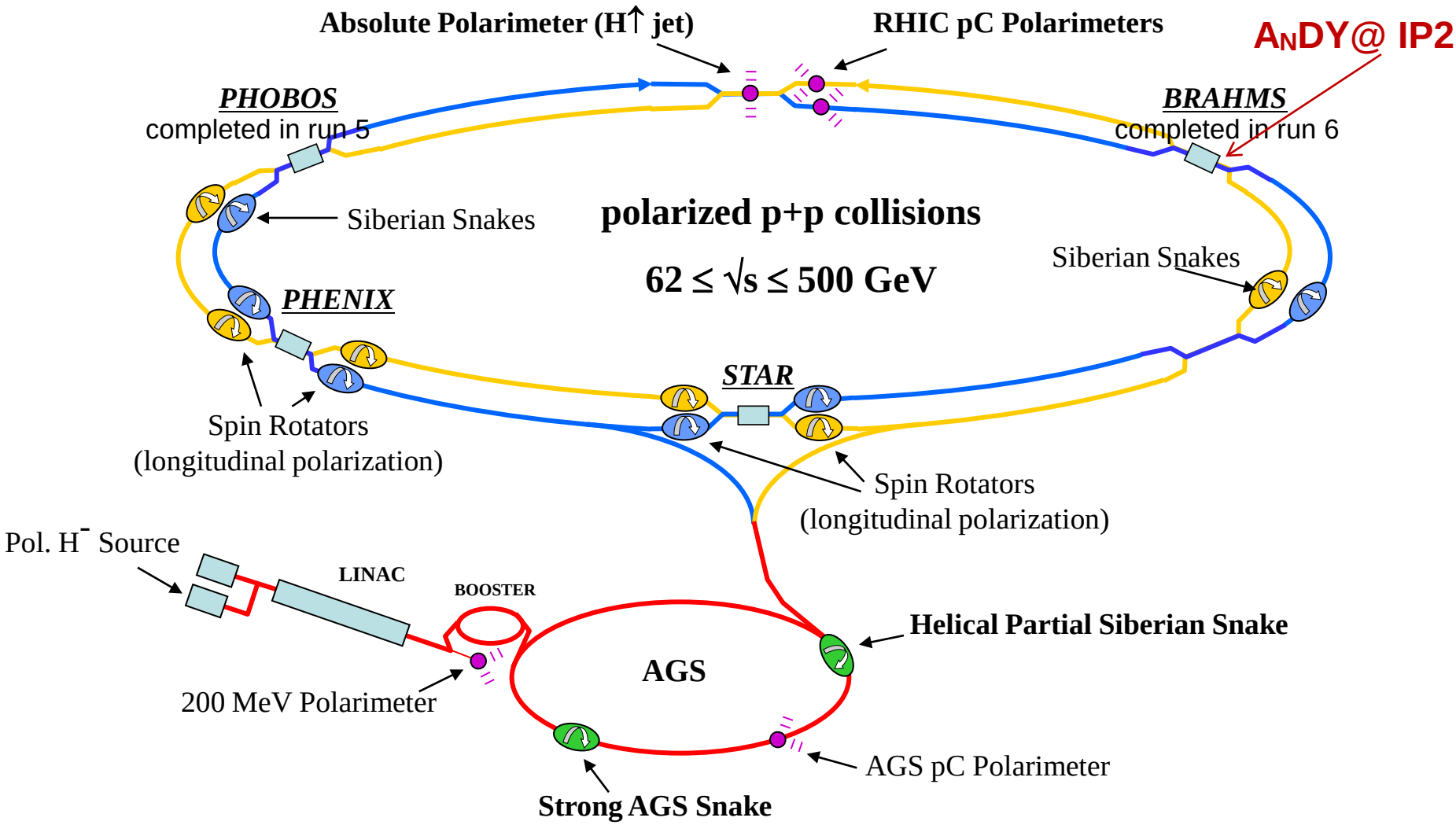
http://www.bnl.gov/npp/docs/pac0610/Finalrecommendations.pdf

Proposal for funding review 30 March 2012:

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

Report received 10 May 2012

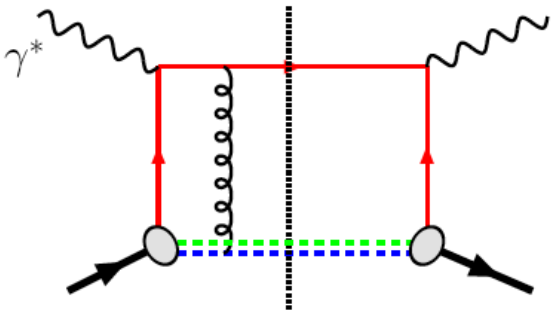
RHIC as a polarized proton collider



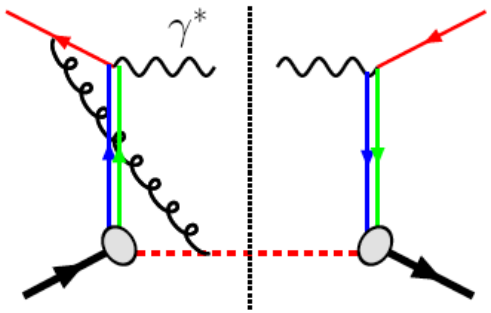
Theory prediction for Drell-Yan process

- Sivers function: $\hat{S}_T \bullet \left(\hat{P} \times \hat{k}_\perp\right) f_{1T}^{\perp}(x, k_\perp)$
- In QCD

DIS: attractive



Drell-Yan: repulsive



As a result:

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

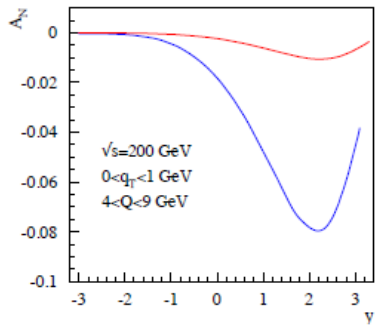
Test of this relation is a test of TMD factorization

Theory prediction for DY – new development

Sivers effect of DY production at RHIC

- Blue curve: bare parton model (using Torino TMD with Gaussian ansatz from SIDIS)
- Red curve: resummed formalism (using Torino TMD to calculate $T_F(x, x)$ as the initial input function, then evolve)

$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)|_{\rm SIDIS}$$



- caution: non-perturbative part could be different for Sivers asymmetry

May 14, 2012 Zhongbo Kang, LANL 28

Combined analysis of SIDIS and inclusive pion production leads to the conclusion that the u-quark Sivers function has a node at x~0.4

⇒

Essential to test predicted sign change for DY in same kinematics as SIDIS

QCD evolution for TMDs is important; evolution leads to the suppression of the Sivers function with increasing scale

⇒

scale is important (M_{γ^*} < 4 GeV/c^2?)

Z. Kang, QCD Evolution Workshop (May, 2012)
http://www.jlab.org/conferences/qcd2012/talks/monday/Kang.pdf

Motivation for A_NDY

- Drell-Yan production is believed to be well understood by theory for transverse momentum-dependent effects
- DY measurements are planned at several facilities (CERN, FAIR, NICA) , starting in 2014 by Compass
- To measure DY at forward rapidity STAR and PHENIX would require significant upgrades $\Rightarrow$ not before 2016. Major engineering efforts to instrument the forward direction at STAR and PHENIX would benefit from a feasibility demonstration of DY production at RHIC.
- 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.
- 3 IR operation was demonstrated in run-11/12 $\Rightarrow$ A_NDY can run in parallel with RHIC W program.

A_NDY goals

- To establish that large-x_F low-mass dileptons from the DY process can be discriminated from background in $\sqrt{s}$=500 GeV p↑+p collisions.

- To provide sufficient statistical precision for the analyzing power for DY production to test the theoretical prediction of a sign change compared to transverse single spin asymmetries for semi inclusive deep inelastic scattering.

Requirement for DY

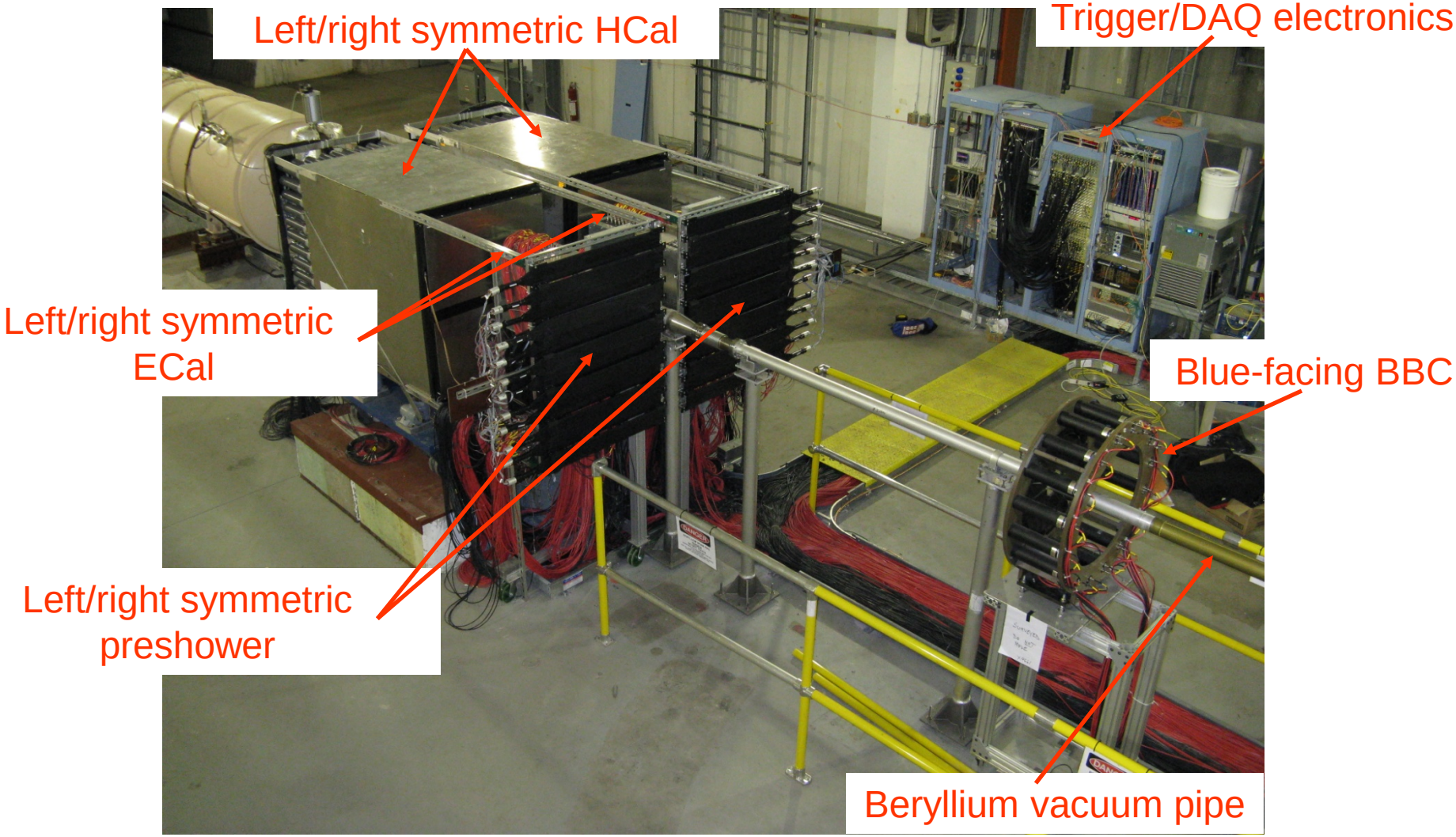
- Luminosity (L_{int} ~150/pb required) – 10/pb per week is achievable if A_NDY goes into collisions early in a store or assuming an average of 14 stores per week (one store is ~8 hr)

- 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?

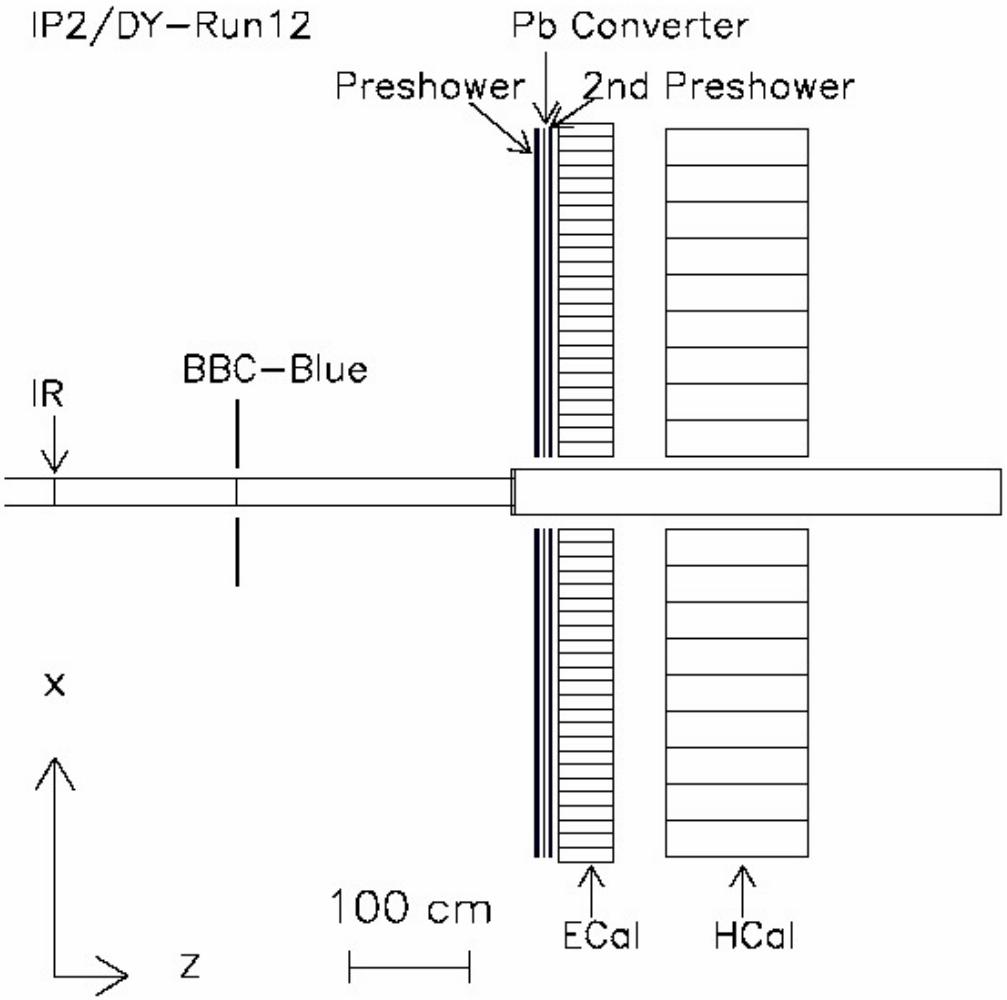
reducible, <10%

irreducible, ~5% from open-b

Run-11 setup


Left/right symmetric HCal
Trigger/DAQ electronics
Left/right symmetric ECal
Blue-facing BBC
Left/right symmetric preshower
Beryllium vacuum pipe

Schematic of detector considered for run-12

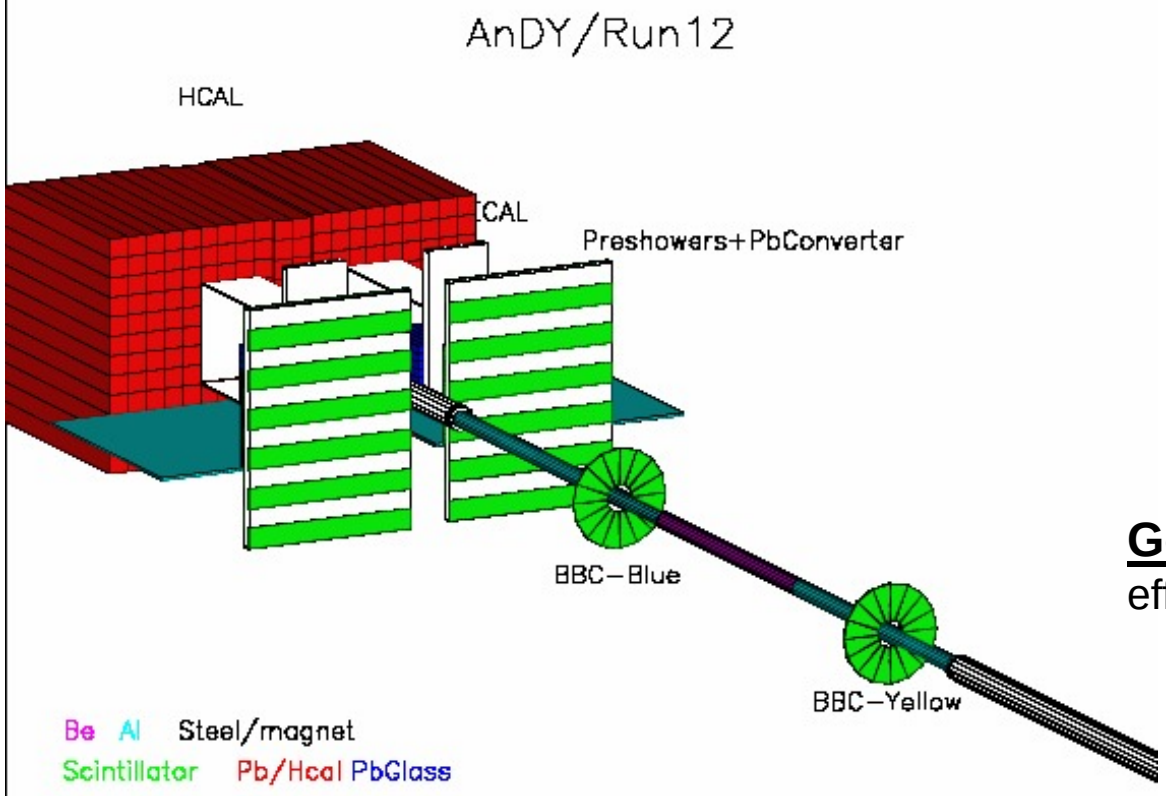


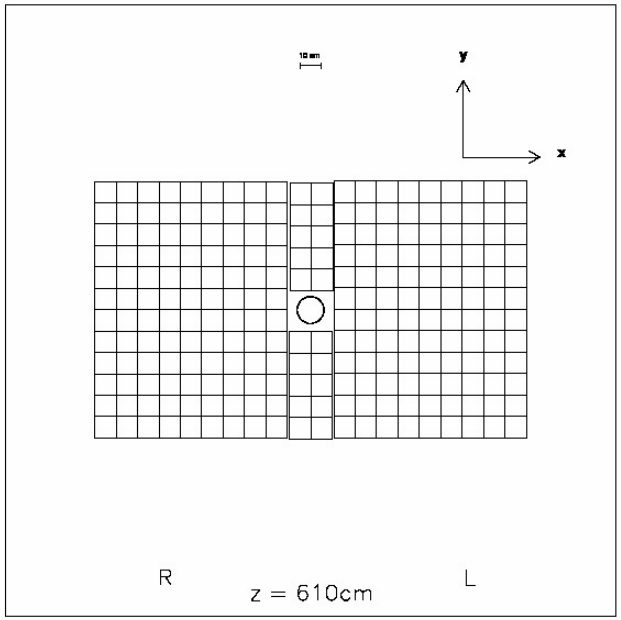
- HCal is existing 9x12 modules from E864
- ECal is existing lead glass from BigCal (modeled as $(3.8cm)^2$x45cm cells only)
- Preshower would require construction
- PHOBOS split dipole expected to be in place, but not used

<u>Goal</u>: to acquire data sample to observe $J/\psi \rightarrow e+e-$, $\Upsilon \rightarrow e+e-$ and dilepton continuum between these signals as a benchmark for DY feasibility

Run-12 implementation

HCal Left/Right modules used in run-11 were modified into annular 20x12 detector with 2x2 hole for the beam pipe





Goal: to establish from measurement effects from trigger bias on run-11 jets

Data taken in run-12

Requests for run-12:

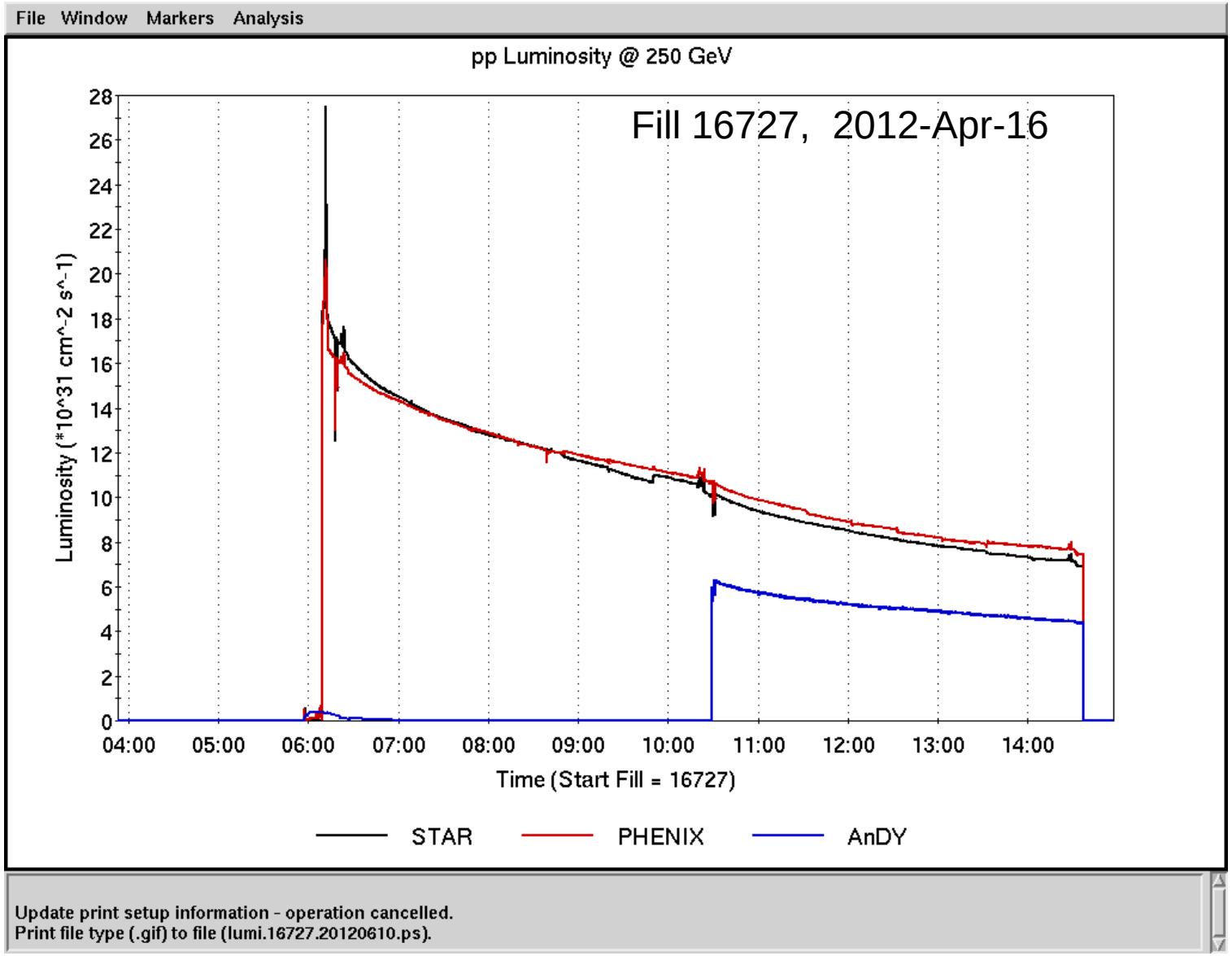
- Complete end-of-store measurements to tune-up IP2 bump removal and collimation optimization to reduce backgrounds when IP2 goes into collisions.
- > 2 fills with IP2 collisions. 1 fill needed for final timing checks of separated-beam tuneup of run-12 apparatus. 2 fills needed with ECal in its out position to establish from measurement effects from trigger bias on run-11 jets.

Integrated luminosity: 2.5/pb

6 fills on Apr/15-18 when IP2 collisions began at ~mid-store:
- one fill for commissioning
- two fills with ECal-out (in the “far” position not to shadow HCal)
- three fills with ECal-in (in the “near” position)

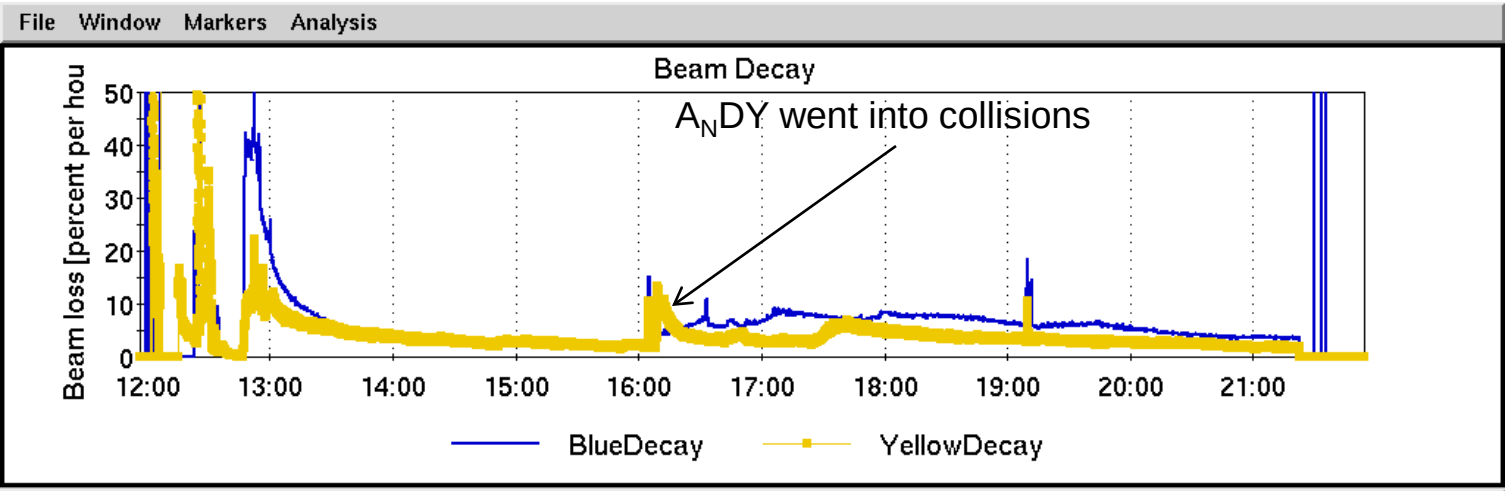
Triggers:
- minimum-bias (BBC coincidence)
- ECal ADC sum in L/R module
- HCal masked ADC sum in L/R module (“jet” trigger)
- ZDC coincidence
- LED

Impact of IP2 collisions

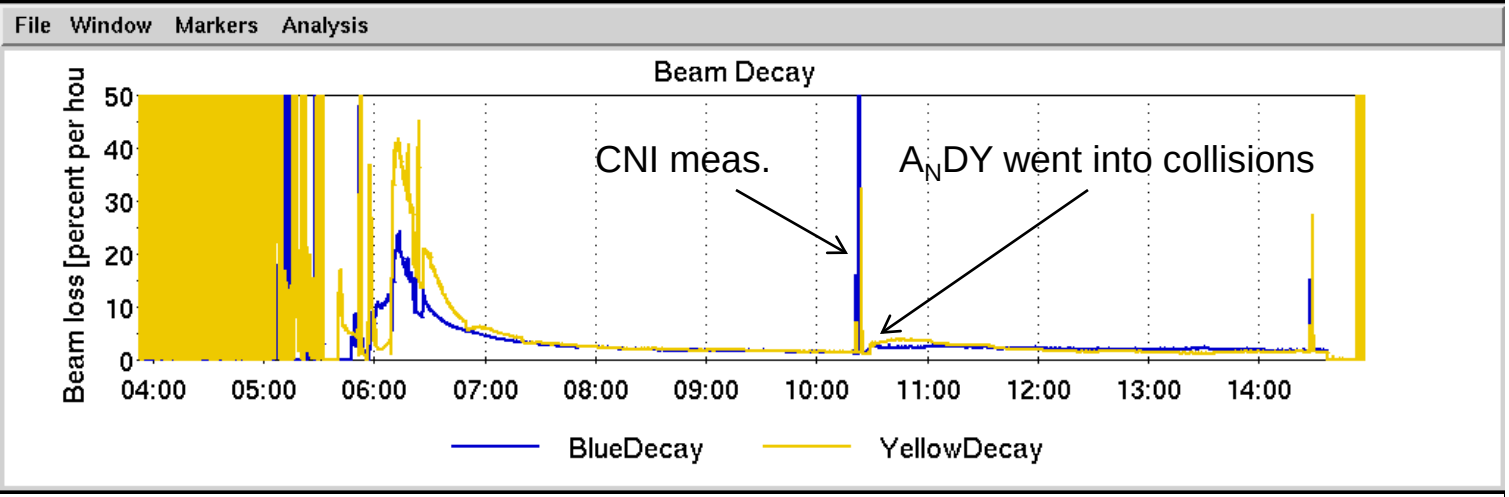


IP2 collisions began around mid-store with minimal impact on IP6 & IP8.
2x higher luminosity at IP2 compare to run-11 (decreased β*).

Impact of IP2 collisions



Fill 15470
2011-Apr-17



Fill 16727
2012-Apr-16

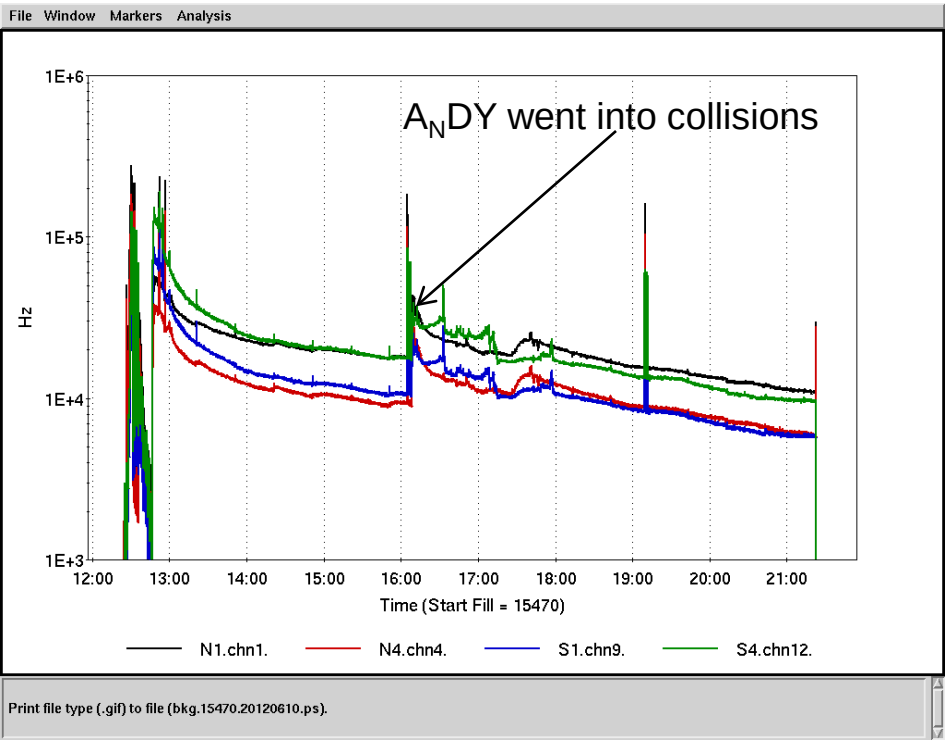
Transient beam losses were essentially eliminated in run-12

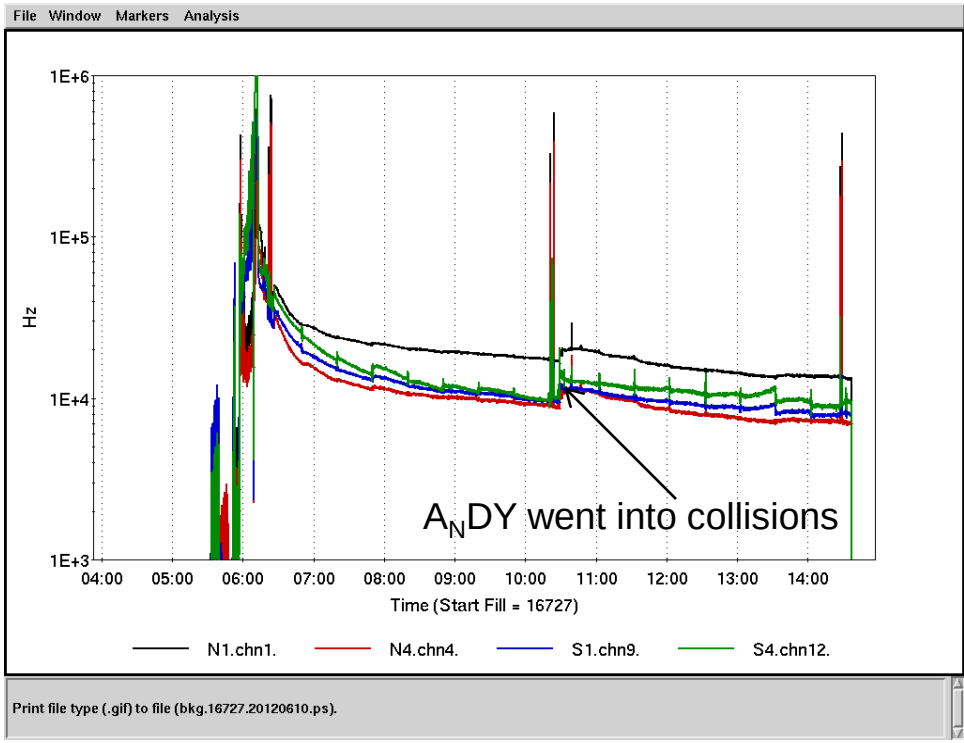
Impact of IP2 collisions

Background in Phenix muon arms

Fill 15470
2011-Apr-17

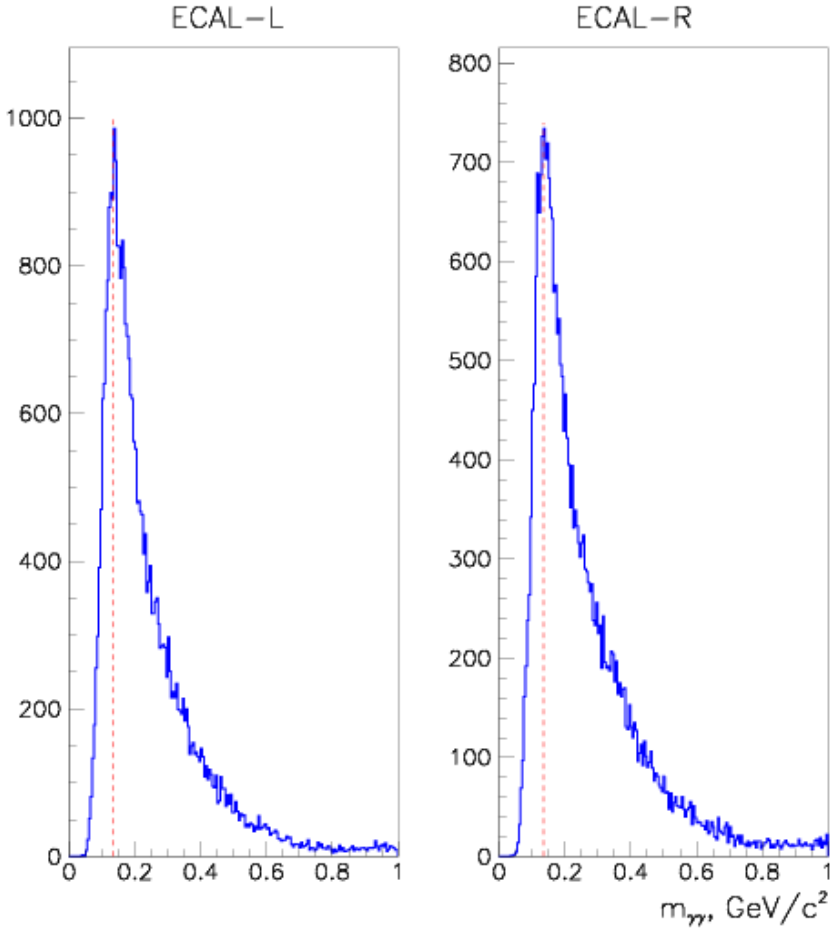
Fill 16727
2012-Apr-16





Background at IP8 from bringing into collisions IP2 is reduced

Analysis status: ECal calibration



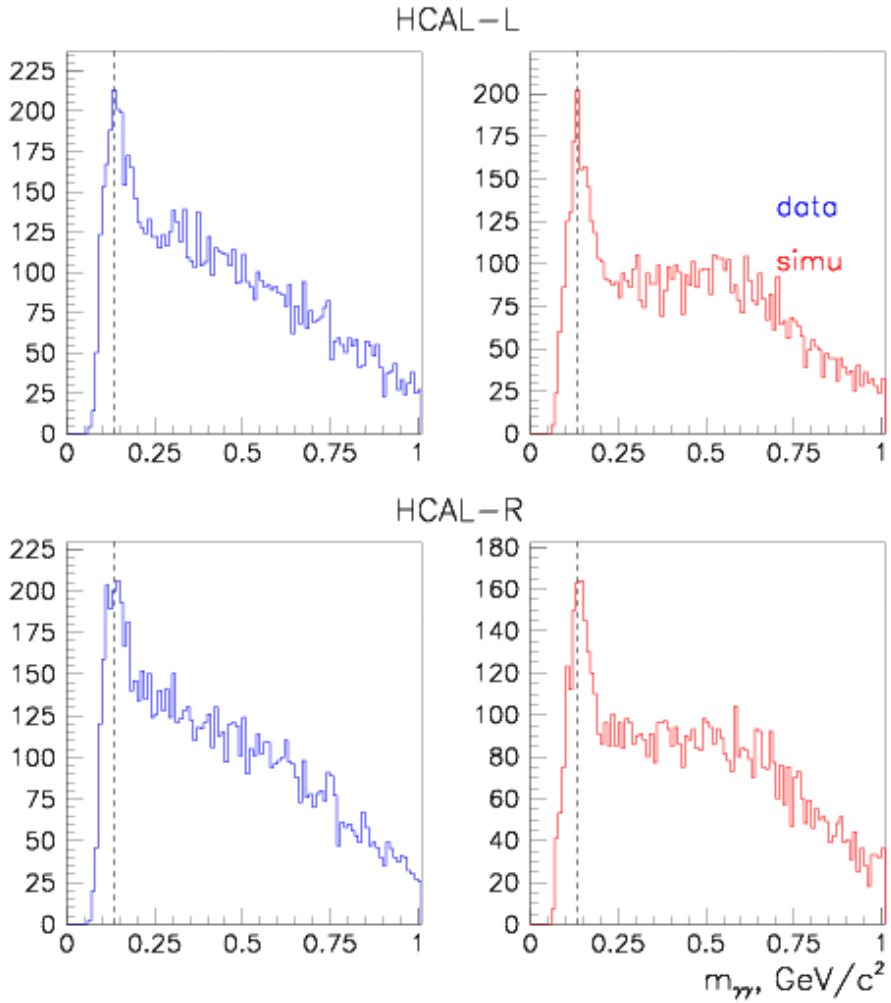
Di-photon invariant mass distribution in ECal modules

Calibration based on $\pi^0 \rightarrow \gamma\gamma$ reconstruction – iterative procedure to scale the gain to put the peak at the known π^0 mass

Event selection:
(1) $N_\gamma \geq 2$; (2) $E_{\gamma\gamma} > 15$ GeV; (3) $z_{\gamma\gamma} < 0.8$; (4) fiducial volume cut 1/2 cell.

π^0 peaks are at the right place, but work is ongoing to finalize cell-by-cell calibration

Analysis status: HCal calibration



Cluster pair mass distributions in HCal modules

Two steps:

1) slope matching of energy distributions from minimum-bias data and simulation;
2) reconstruction of $\pi^0 \rightarrow \gamma\gamma$ from HCal clusters

"Jet-triggered" data and simulation with trigger emulation

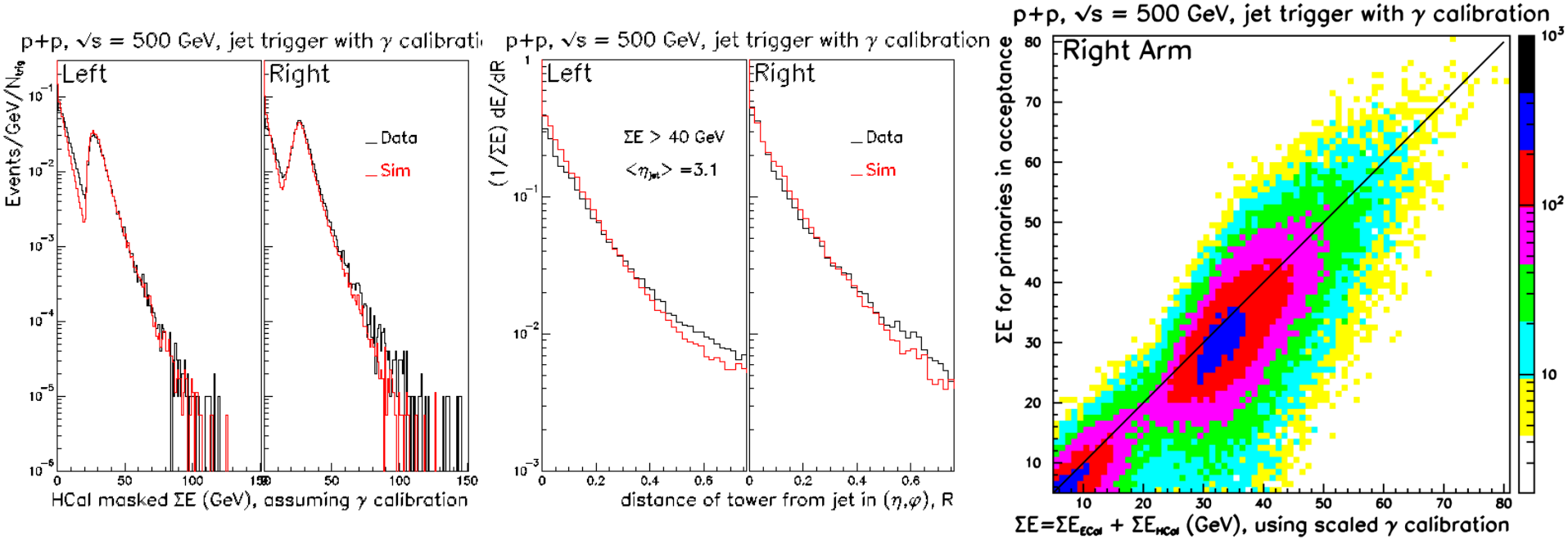
Cuts applied to select "electromagmetic" clusters:

- 1-tower clusters
- Ecl > 1.8 GeV
- Epair > 5 GeV
- zpair < 0.5

Corrections to HCal calibration for hadron showers still need to be evaluated (expected ~20% from simulations)

Towards forward jets (run-11)

arXiv:1112.1812



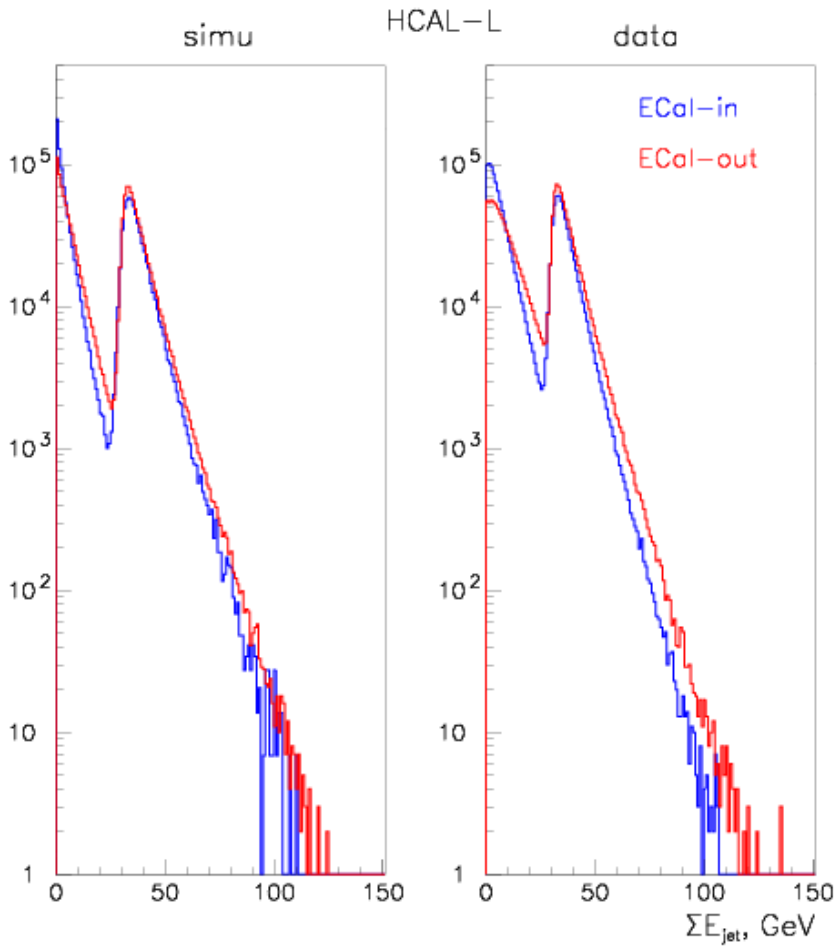
(a) (b) (c)

(a) Distribution of summed energy in HCal modules from the jet trigger.

(b) Distribution of fraction of energy in the jet as a function of distance in η-ϕ space from the jet center (jet shape).

(c) Jet energy from simulations versus reconstructed response in ECal+HCal.

Trigger bias for forward jets (run-12)



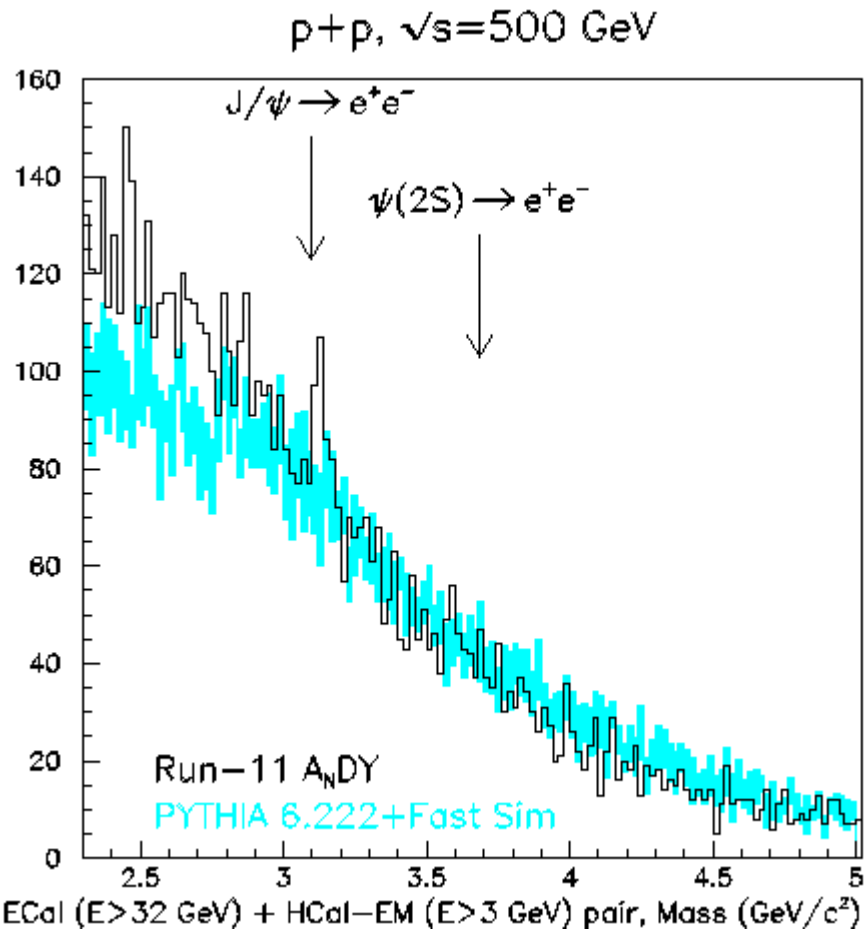
Summed energy in HCal module from the jet trigger

- 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

Dileptons from run-11 data versus simulation



- 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

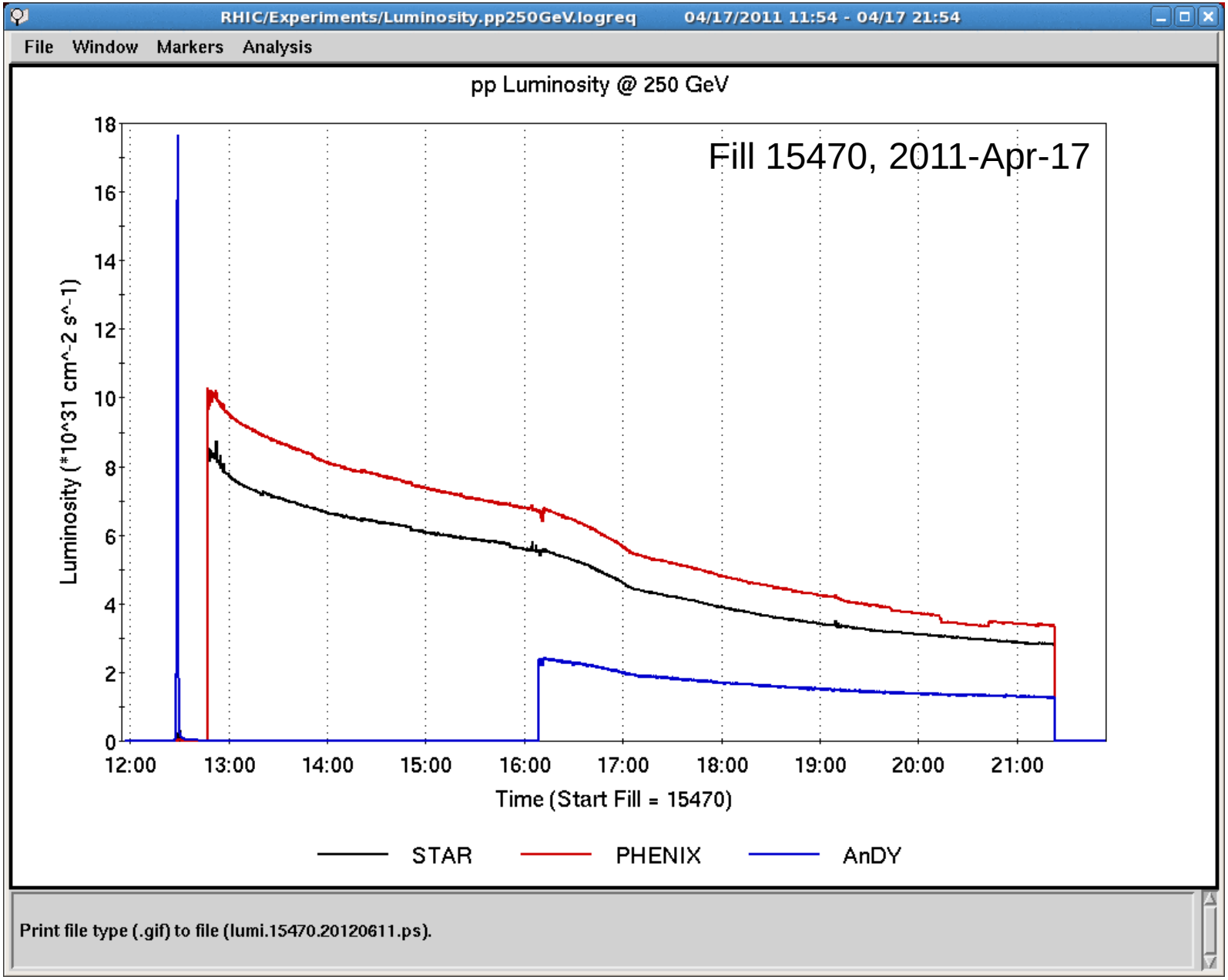
Additional ECal-triggered data in run-12: 1.5/pb, 3x run-11 statistics

Summary

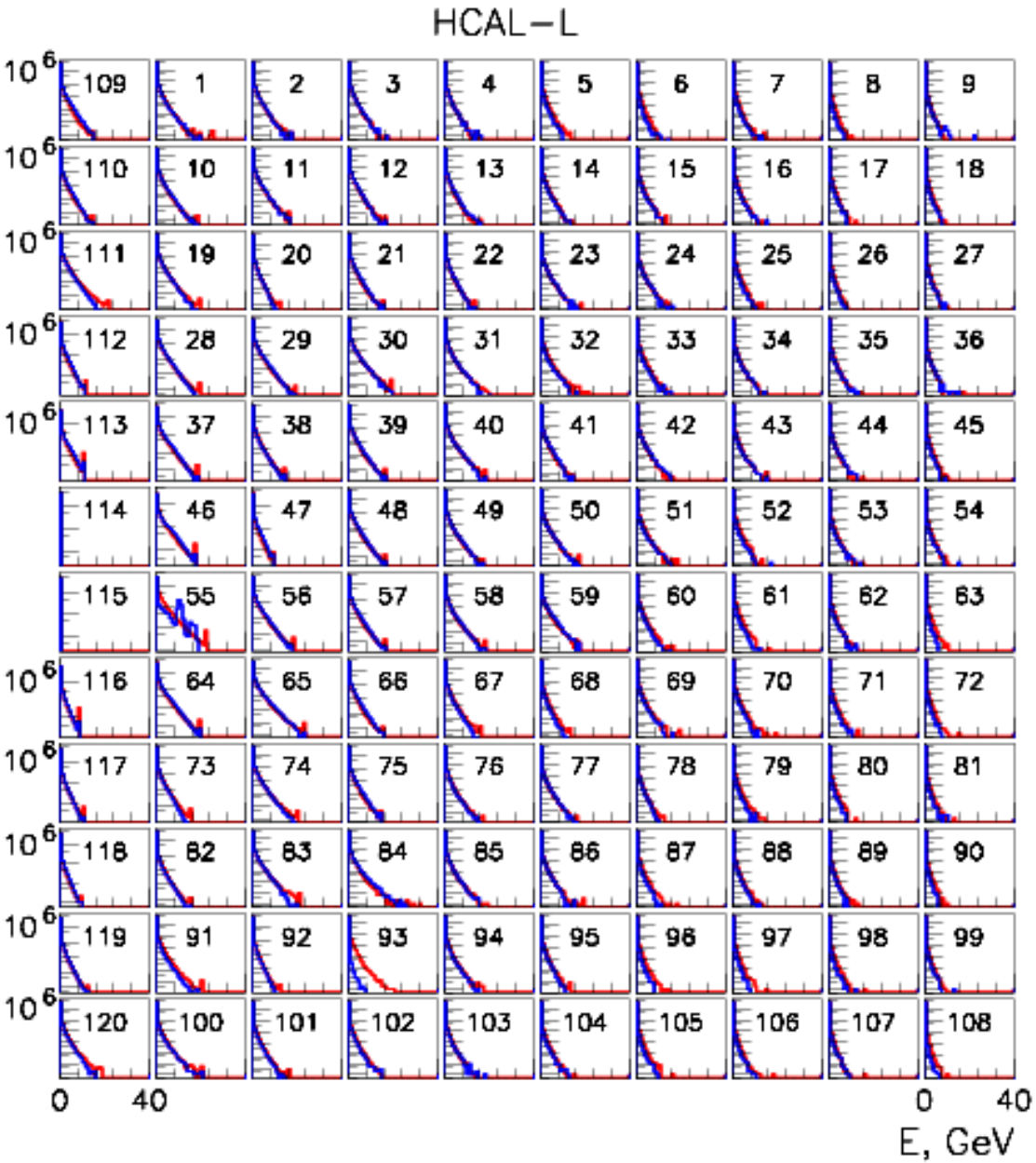
- Significant improvements in the procedure of bringing IP2 into collisions compare to run-11.
- 10/pb per week as needed for DY is realistic based on run-12 experience.
- Measurements were done to establish effects on jets from trigger bias. Analysis is ongoing.
- Current status of A_NDY: trying to resolve two basic issues mentioned in the review report (time scale and manpower).
- First attempt at transverse spin DY measurement at RHIC still could be competitive with Compass, but time is running out…

Backup

Impact of IP2 collisions



Calibration of HCal

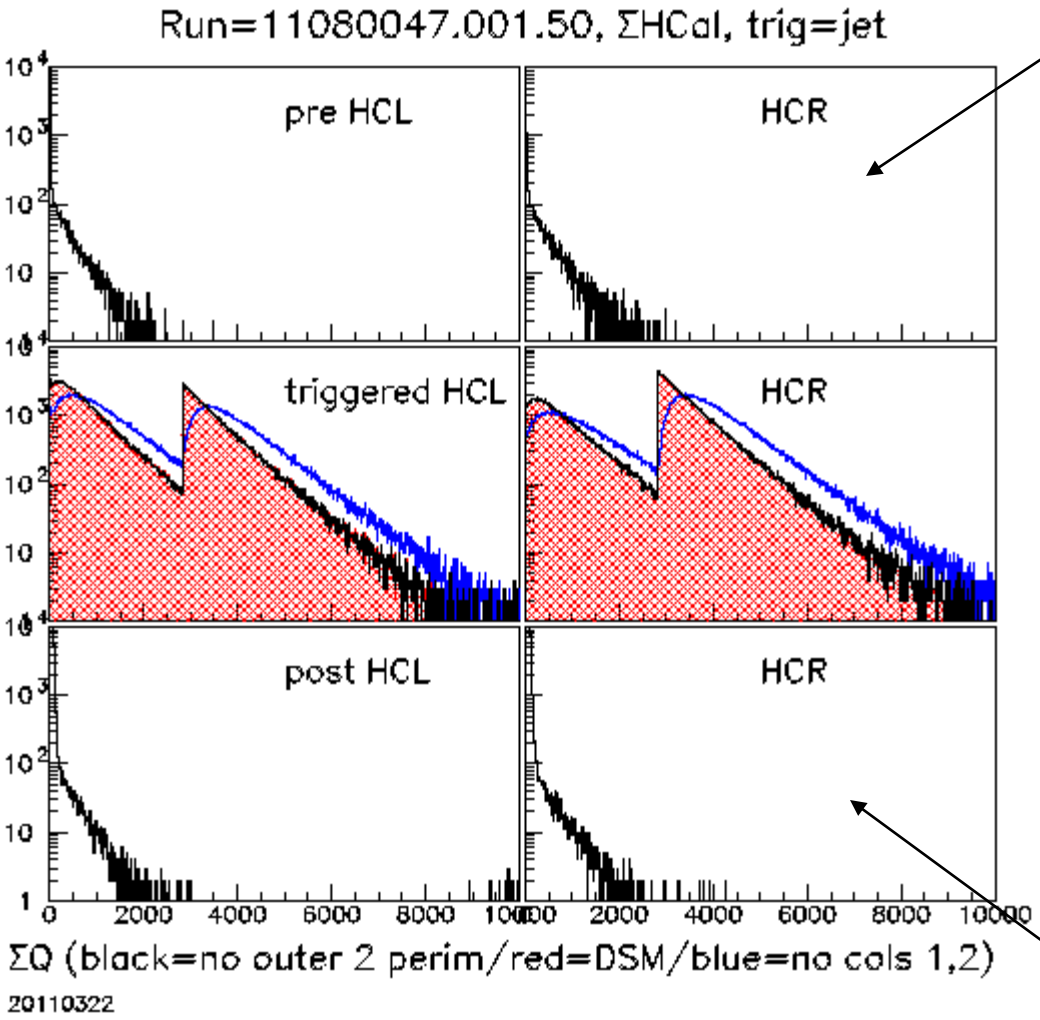


Slope matching of energy distributions in the cells

Minimum-bias data and PYTHIA+GEANT simulations (~4M events)

Reasonable agreement between data and simulations (except for a few cells)

Jet Trigger

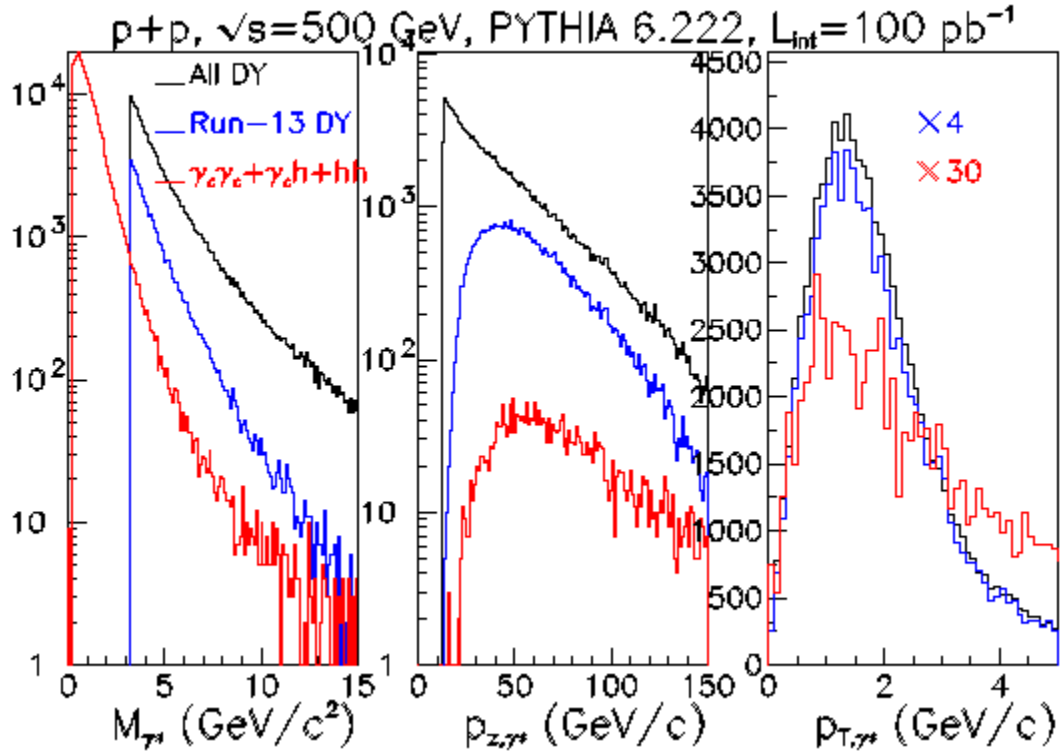


Hadron calorimeter is quiet ~107ns before jet event

- 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 run11

Hadron calorimeter is quiet again ~107ns after jet event

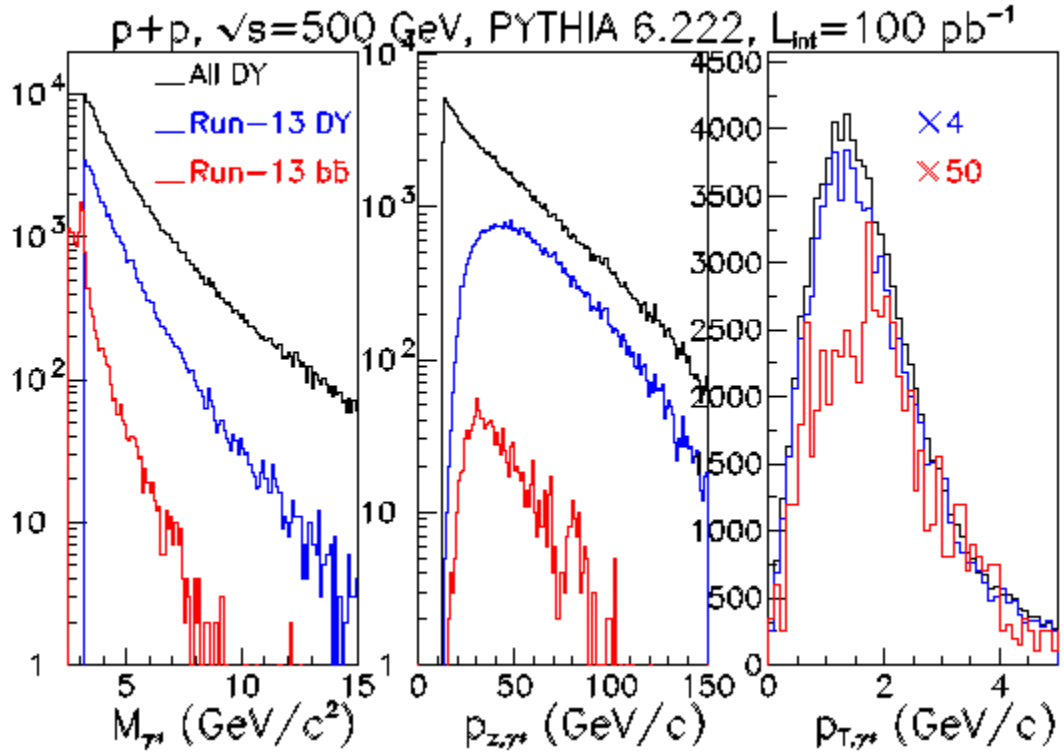
Reducible Backgrounds



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



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).