E12-06-114:
Deeply Virtual Compton Scattering in Hall A

Hall A collaboration meeting

18 January 2017

Fall 2016 DVCS run: summary & outlook

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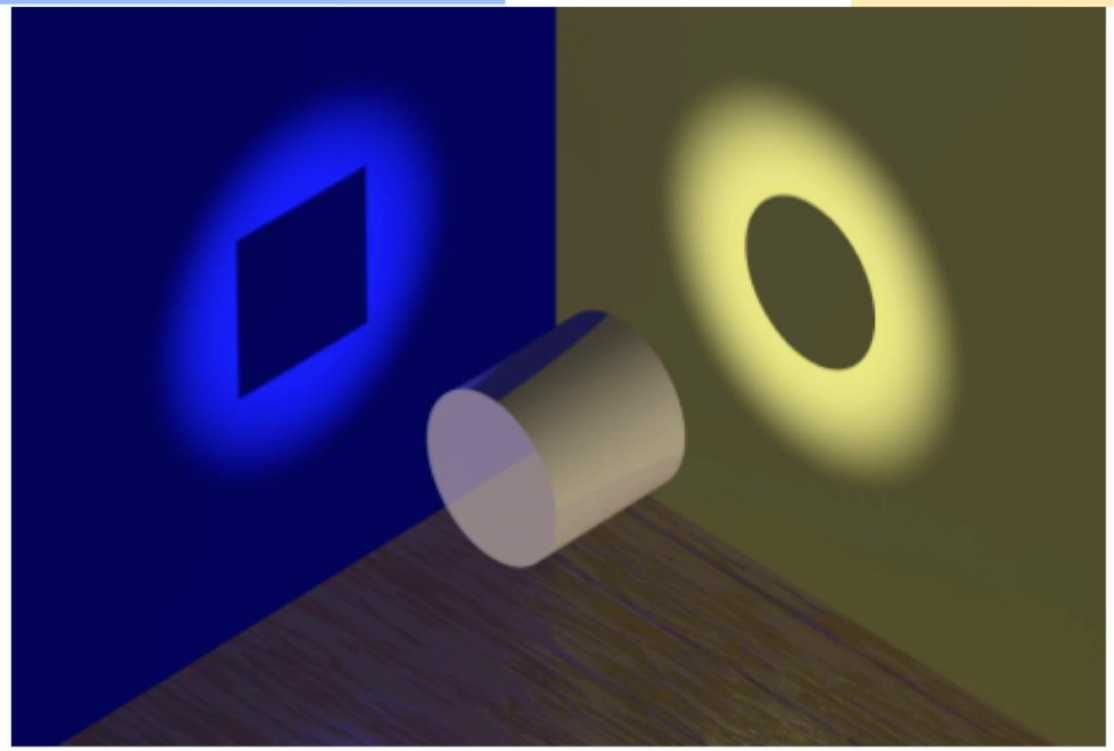
Outline

- GPDs, 3D picture of the nucleon - DVCS
- DVCS in Hall A
- Overview of DVCS Fall 2016 run
- Update from DVCS Spring 2016 run
- Status summary and Outlook

Generalized Parton Distributions and 3D picture of the nucleon

DIS Parton Distribution Functions

Elastic Form Factors



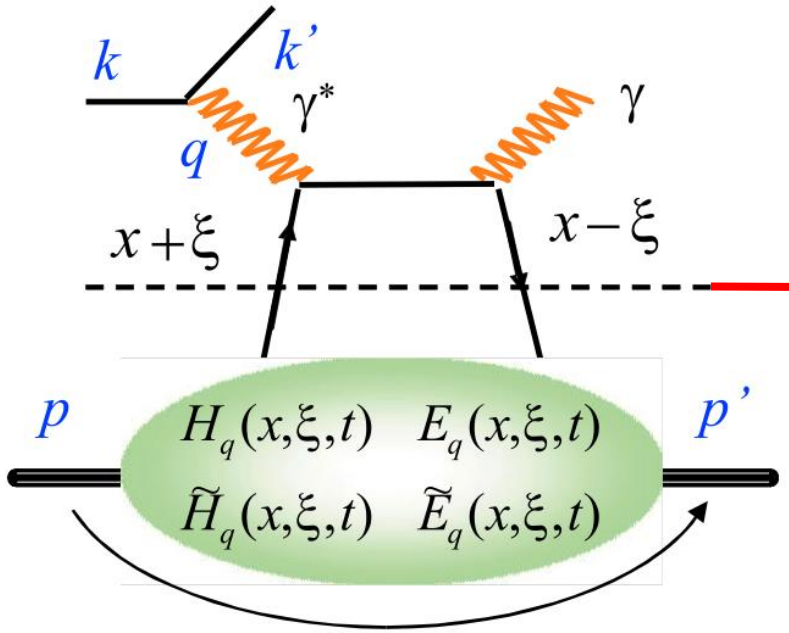
No information on the spatial location of the constituents

No information about the underlying dynamics of the system

GPDs: access to correlations between transverse spatial distributions and longitudinal momentum distributions

DVCS and GPDs

- DVCS is the cleanest way to access GPDs
- In the Bjorken Limit $Q^2 = \left.\begin{matrix} -q^2 \\ \nu \end{matrix}\right\} \begin{matrix} \to \\ \to \end{matrix} \left.\begin{matrix} \infty \\ \infty \end{matrix}\right\}$ $x_B = \frac{Q^2}{2M\nu}$ fixed



Hard Part

Factorization

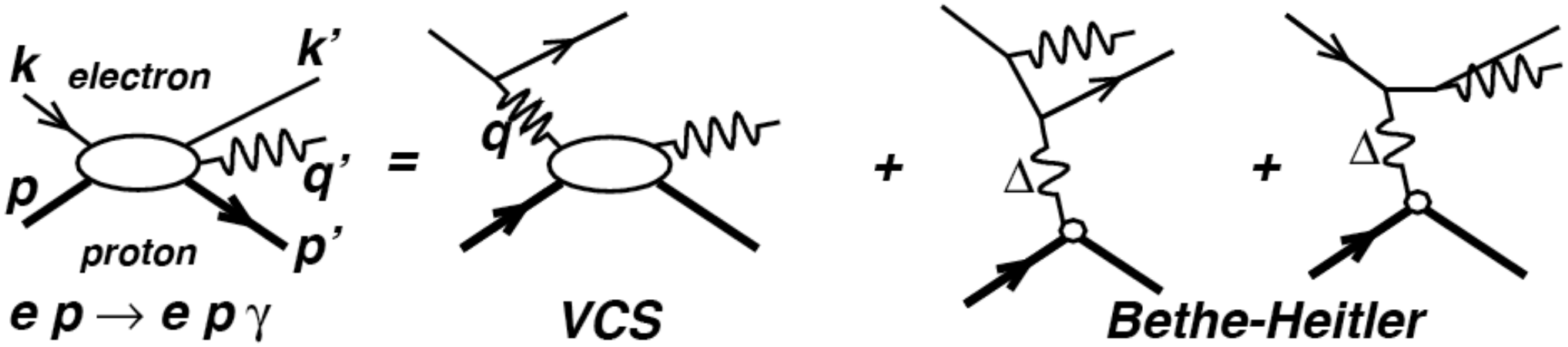
Soft Part
Parametrized by GPDs

$t = (p'-p)^2$

$\xi \approx \frac{x_B}{2 - xB}$

Nucleon Structure Described by 4 quark GPDs:
H, E (no helicity flip), $\tilde{H}$ $\tilde{E}$ (helicity flip)

DVCS and Bethe-Heitler



At leading twist:

$$d^5\overrightarrow{\sigma} - d^5\overleftarrow{\sigma} = \Im m\left(T^{BH}\cdot T^{DVCS}\right)$$

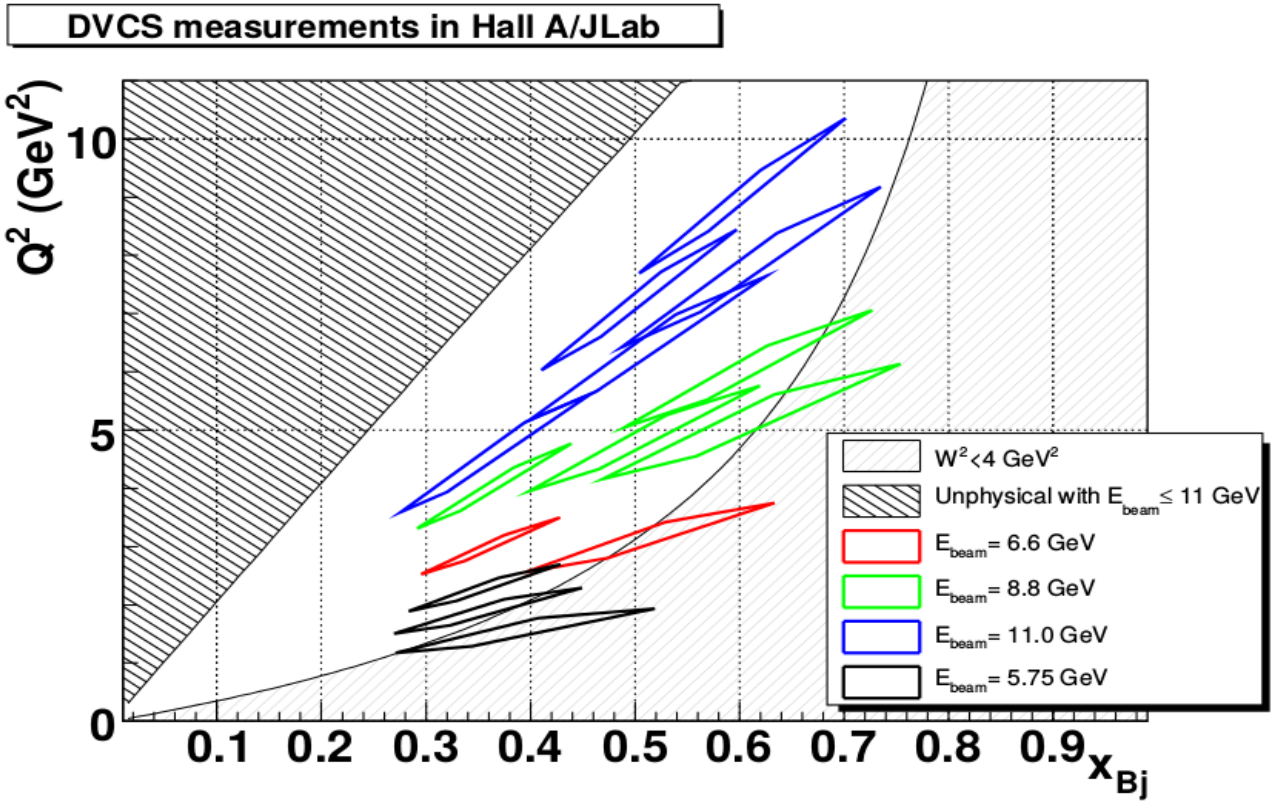
$$d^5\overrightarrow{\sigma} + d^5\overleftarrow{\sigma} = |BH|^2 + \Re e\left(T^{BH}\cdot T^{DVCS}\right) + |DVCS|^2$$

↓

Known to 1%

DVCS in Hall A - Goal

- Timeline:
  - E00-110/E03-106 (2004) : first round of dedicated experiments (Q^2 dependence study)
  - E07-007/E08-025 (2010) : second round of dedicated experiments (Q^2 dependence study + beam energy dependence)
  - E12-06-114 (2014 - 2016) : ~50% PAC days completed

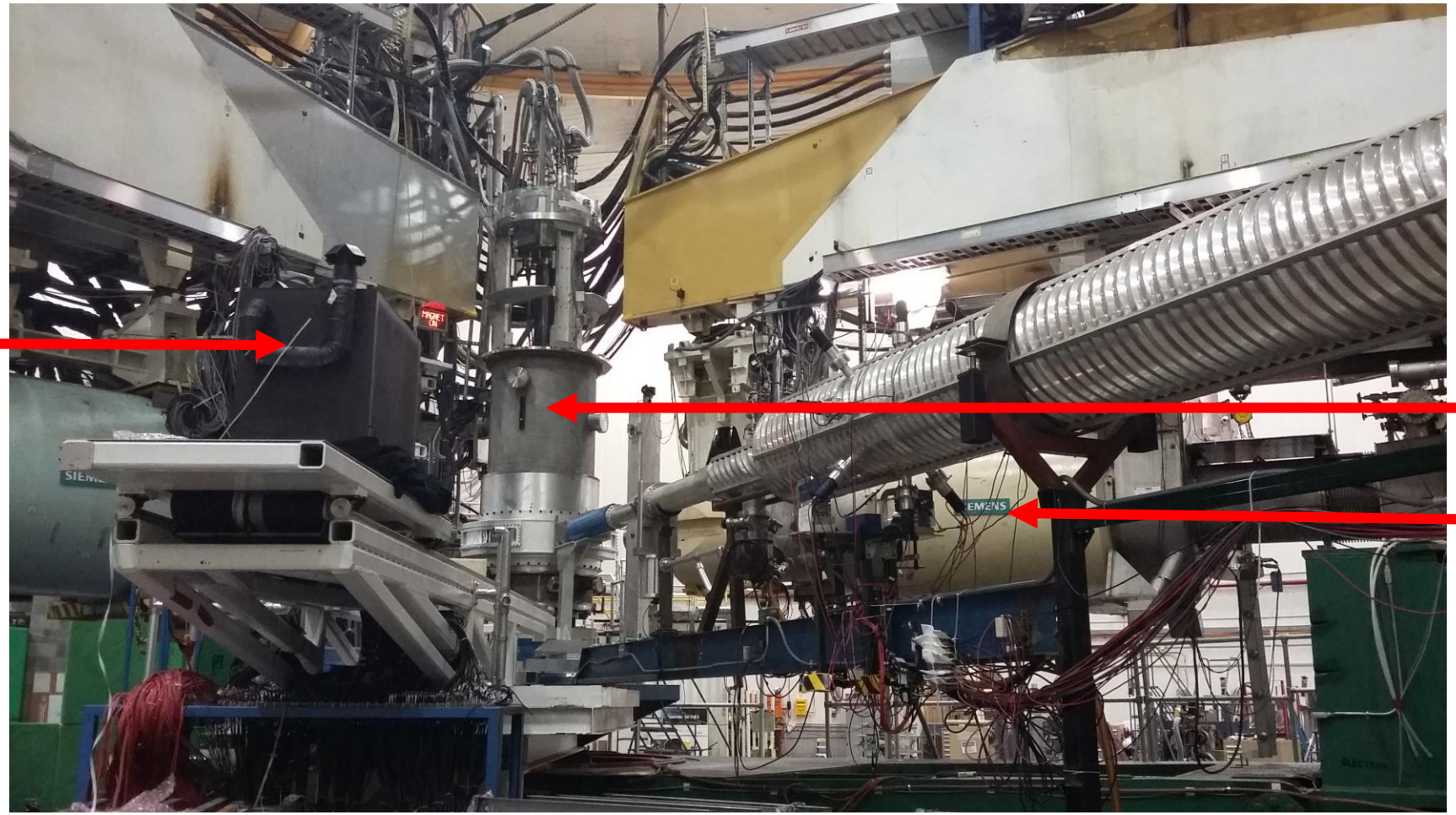


- E12-06-114 goals :
  - Scaling test : Wider Q^2 scans at fixed x_B (larger Q^2 lever arm than in 2010 & several values of x_B)
  - Separation of Re and Im parts of DVCS cross-section amplitude

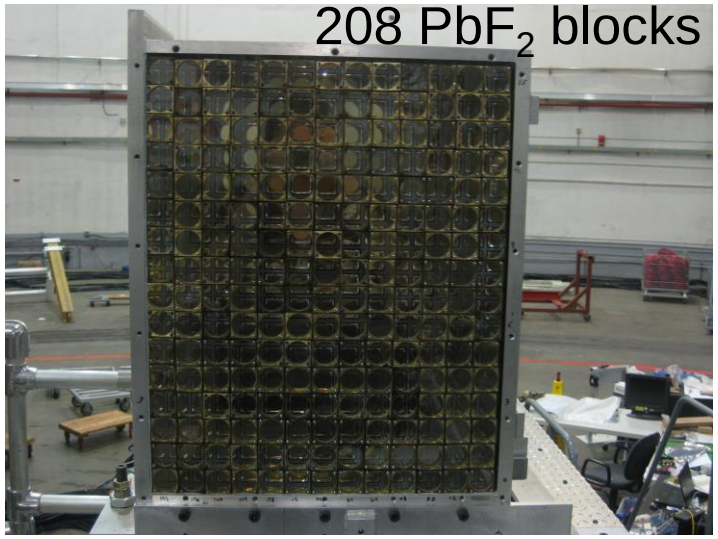
100 PAC days (88 + 12 calibration)

DVCS in Hall A - Apparatus

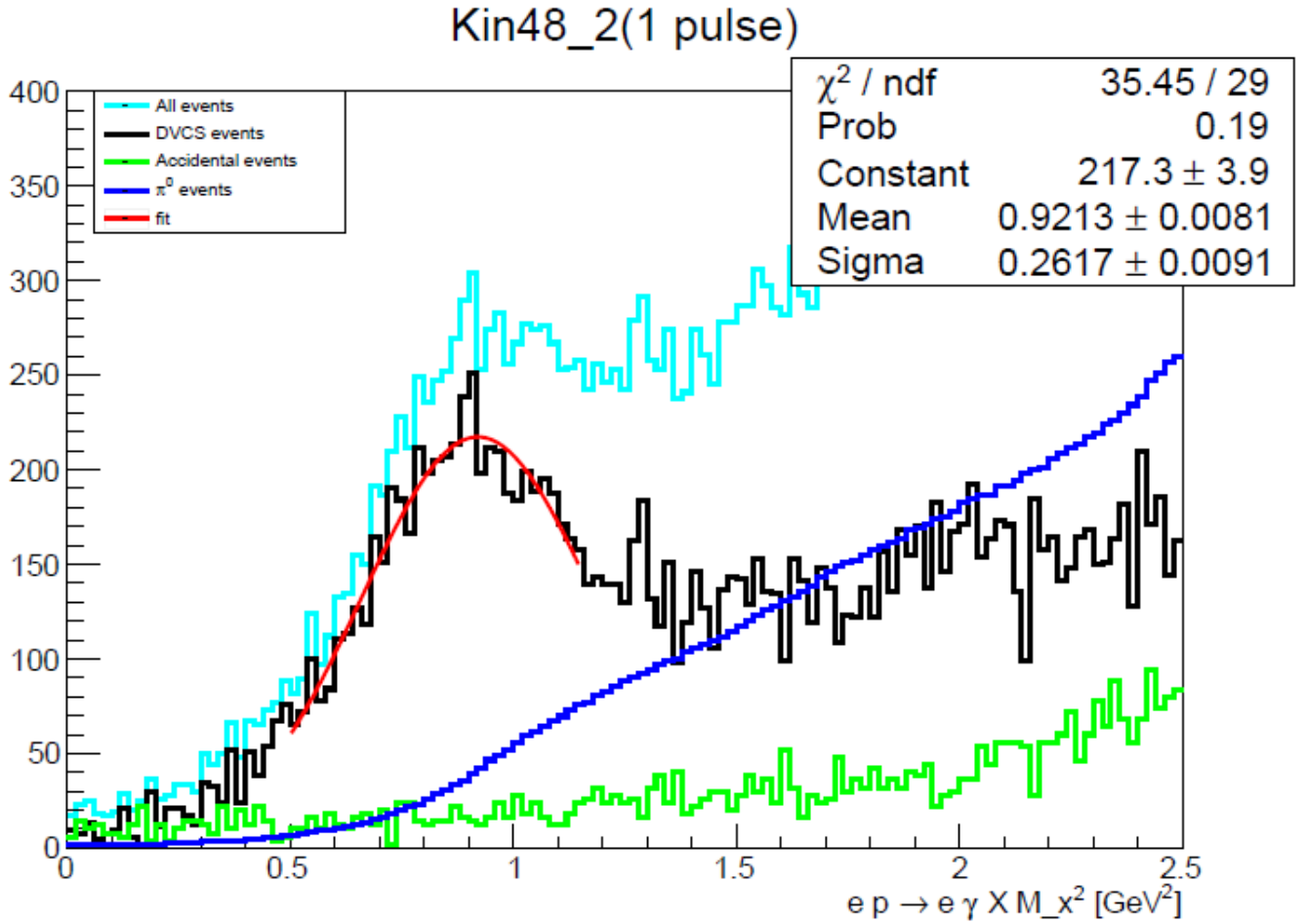
ep → e'p'γ



DVCS in Hall A - Apparatus



Calorimeter energy resolution ~3.6% at 4.2 GeV
→ Limiting factor



DVCS Missing mass:
e p → e' X γ

Missing mass = $(e + p - e' - \gamma)^2$

Exclusivity is ensured by missing mass cut

Overview of DVCS Fall 2016 Run Period

Overview

- Fall 2014
  - New EDTM system in LHRS
  - Beam dump certification
  - DVCS electronic commissioning
  - Moller polarimeter commissioning
  - DVCS calorimeter calibration
  - DVCS production : 1 kinematic point (3 PAC days)

- Spring 2015
  - New raster system
  - BPM & BCM calibration
  - Beam energy measurement
  - Compton polarimeter commissioning
  - Target Boiling studies
  - LHRS optics calibration (detuned Q1)
  - No production data taken

- Spring 2016
  - Beam polarization measurement (Moller &Compton)
  - Beam energy measurement
  - BPM & BCM calibration (up to 30 μA)
  - DVCS calorimeter calibration at 4.4GeV (x2)
  - LHRS optics calibration (Q1 : max current too low, detuned against {Q2, D, Q3} → need 4 calibrations)
  - DVCS production : 4 new kinematic points

- Fall 2016
  - Beam polarization measurement (Moller, x4)
  - Beam energy measurement (x6)
  - BPM (x1) & BCM (x3) calibration
  - Trigger efficiency measurement (x12)
  - DVCS calorimeter calibration at 6.4 GeV (x2)
  - DVCS production : 4 new kinematic points

Many thanks to the collaboration, the accelerator, the techs, RCs, and shift workers for making this run possible!

Special Thanks for all the people who made it possible to run through Thanksgiving!

Fall 2016 - Running

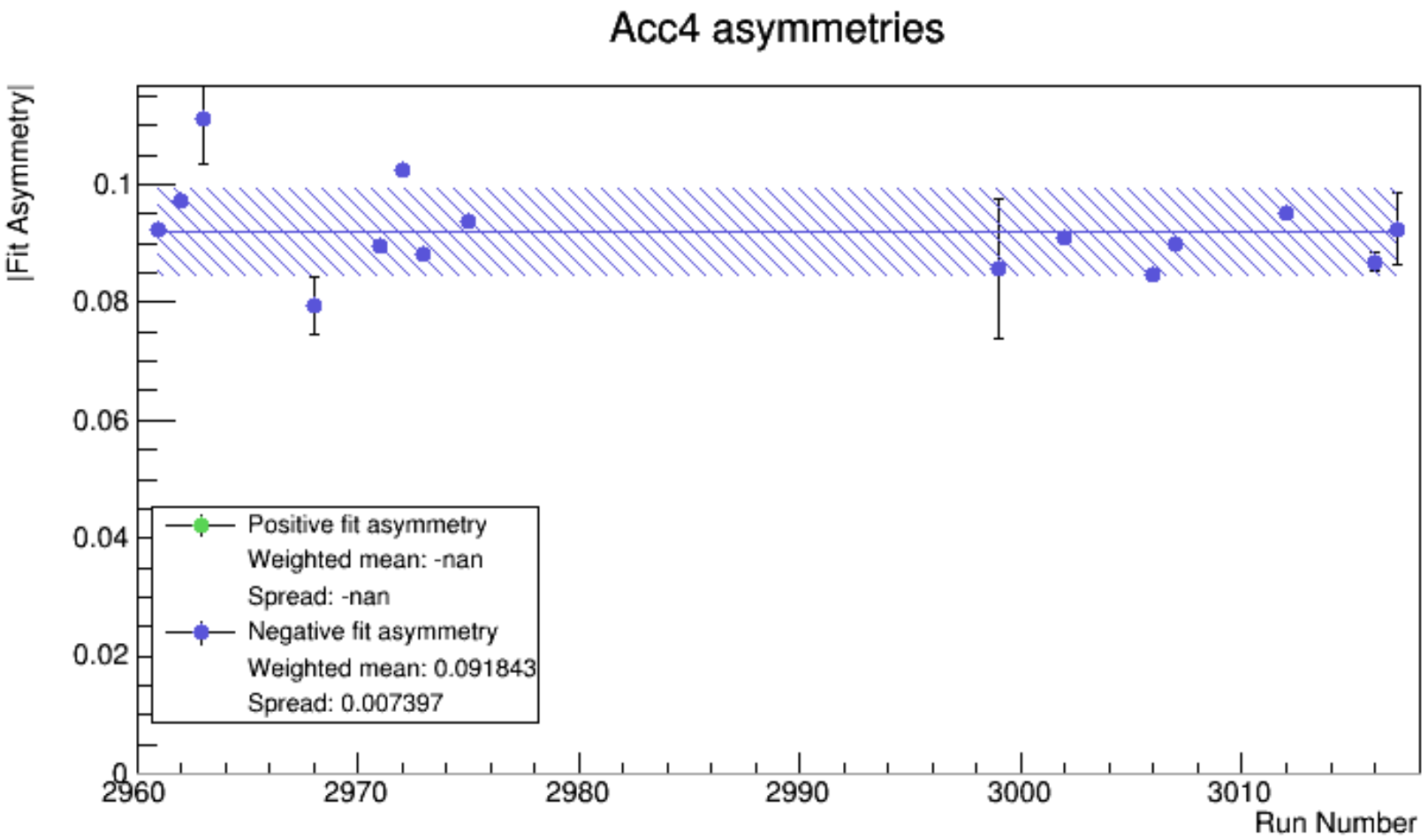
Moller polarization measurement (Kharkov Institute & Temple University)

- Operational during whole duration of Fall 2016.
- Fast measurements.
- 4 measurements with GEANT corrections (±statistics error ±systematics error):
  - October 31: E_{beam} = 8.495 GeV ; polarization = 86.75(±0.10 ±1.0)%
  - November 28: E_{beam} = 10.590 GeV ; polarization = 85.39(±0.11 ±1.0)%
  - December 07: E_{beam} = 10.591 GeV ; polarization = 84.18(±0.10 ±1.0)%
  - December 19: E_{beam} = 8.498 GeV ; polarization = 86.20(±0.10 ±1.0)%

→ Polarization rather stable

Fall 2016 - Running

Compton polarization measurement (Larisa Thorne)



- (preliminary results)
- Raw asymmetries between November 3 and November 7.
- Confirms that polarization is stable.
- Analysis in progress (more information in Compton Status update).

Fall 2016 - Running

Beam energy measurement (Doug Higinbotham)

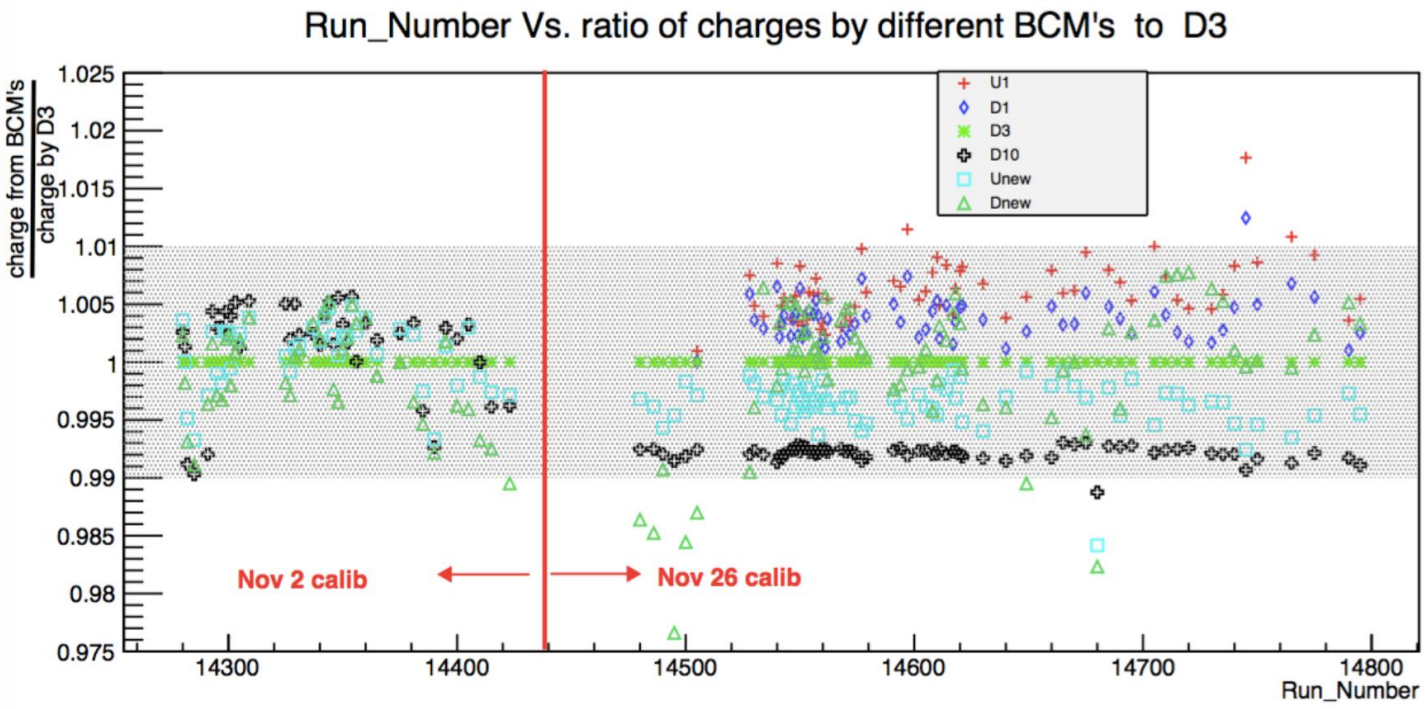
6 measurements (4 dispersive, 2 acromatic):

- 1 pass measurement (dispersive): 2.222 GeV (2.218 GeV from epics) ; 1.002 scale factor
- 3 pass measurement (acromatic & dispersive): 6.427 GeV (6.407 GeV from epics) ; 1.003 scale factor
- 4 pass measurement (dispersive): 8.520 GeV (8.497 GeV from epics) ; 1.003 scale factor
- 5 pass measurement (acromatic & dispersive): 10.587 GeV (10.589 GeV from epics) ; agreement

- Beam energy does shift against time
- Conclusion: use “epics value * scale factor”, run by run

Fall 2016 - Preliminary Studies

BCM calibration (Bishnu Karki & Julie Roche)



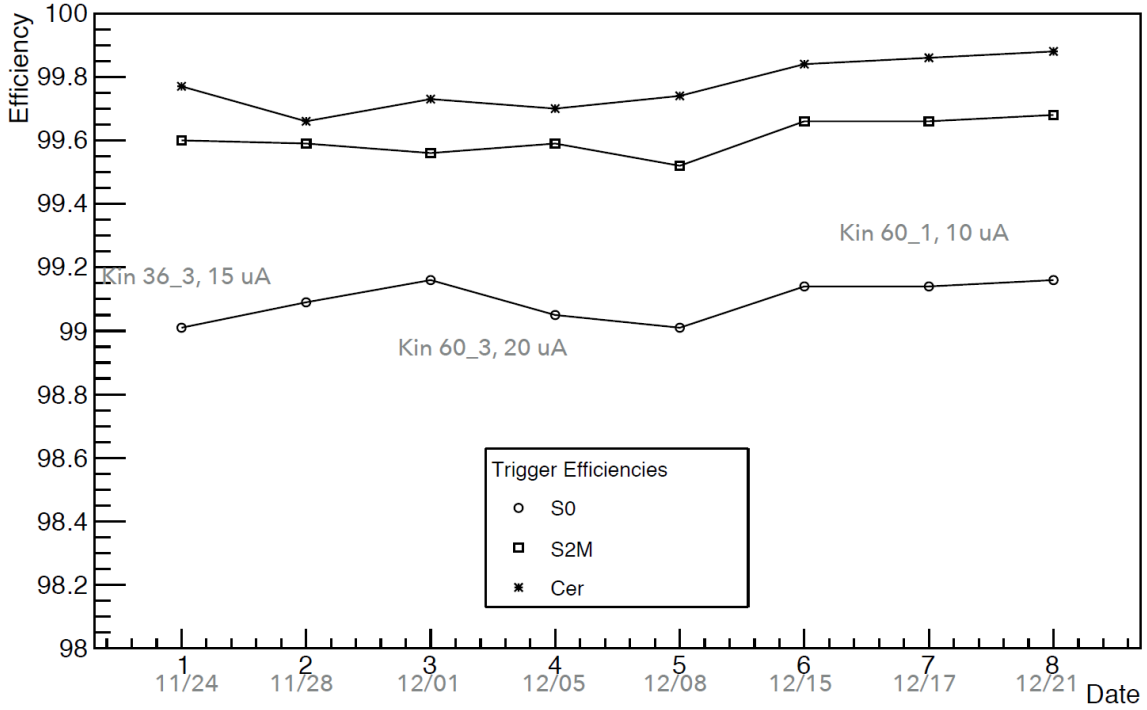
- 3 BCM calibrations against the Unser
  - October 15: up to 80 μA at 1 pass
  - November 2: up to 30 μA at 4 pass
  - November 26: up to 40 μA at 5 pass
- Coefficients fairly stable

- D3 & D10 agree within 1%
- D3 & D10 linear for 5 μA ≤ I ≤ 25 μA
- Unew & Dnew are noisier (electronics)
- U1 & D1 are not linear ≤ 10 μA
- Beam current used: 10 μA ≤ I ≤ 20 μA
- Conclusion: rely on D3 & D10, or average of them

Fall 2016 - Preliminary Studies

Trigger efficiency measurement (Hashir Rashad)

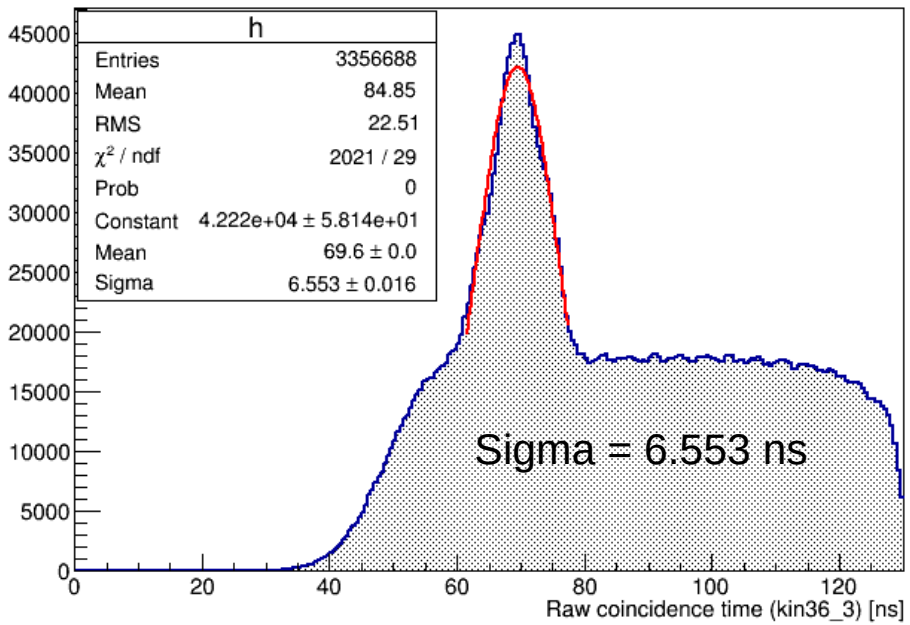
	11/24/16 (36_3, 15uA)	11/28/16 (60_3, 20uA)	12/01/16 (60_3, 20uA)	12/05/16 (60_3, 20uA)	12/08/16 (60_3, 20uA)	12/15/16 (60_1, 10uA)	12/17/16 (60_1, 10uA)	12/21/16 (60_1, 10uA)
S0	99.01	99.09	99.16	99.05	99.01	99.14	99.14	99.16
S2M	99.60	99.59	99.56	99.59	99.52	99.66	99.66	99.68
Cer	99.77	99.66	99.73	99.70	99.74	99.84	99.86	99.88

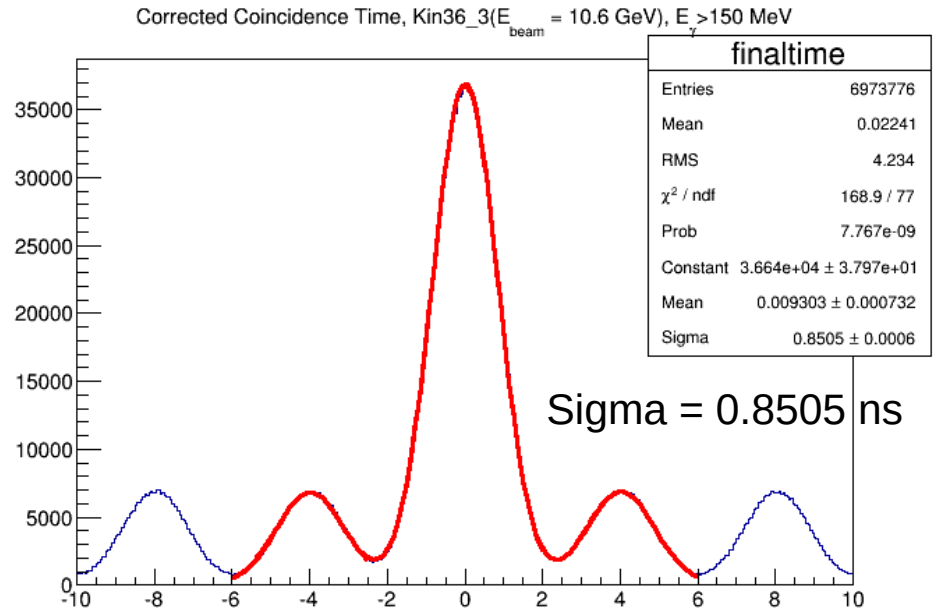


- S0, S2 and Cerenkov efficiency > 99%

Fall 2016 - Preliminary Studies

Coincidence time correction (Mongi Dlamini)





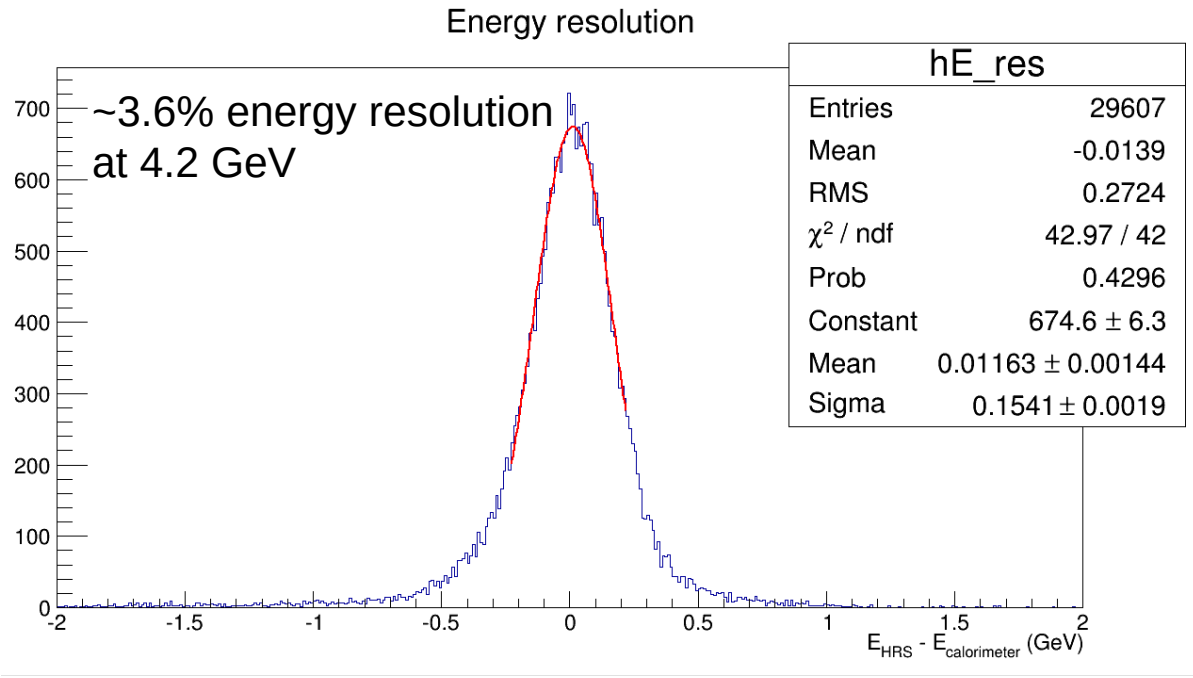
Corrected for:

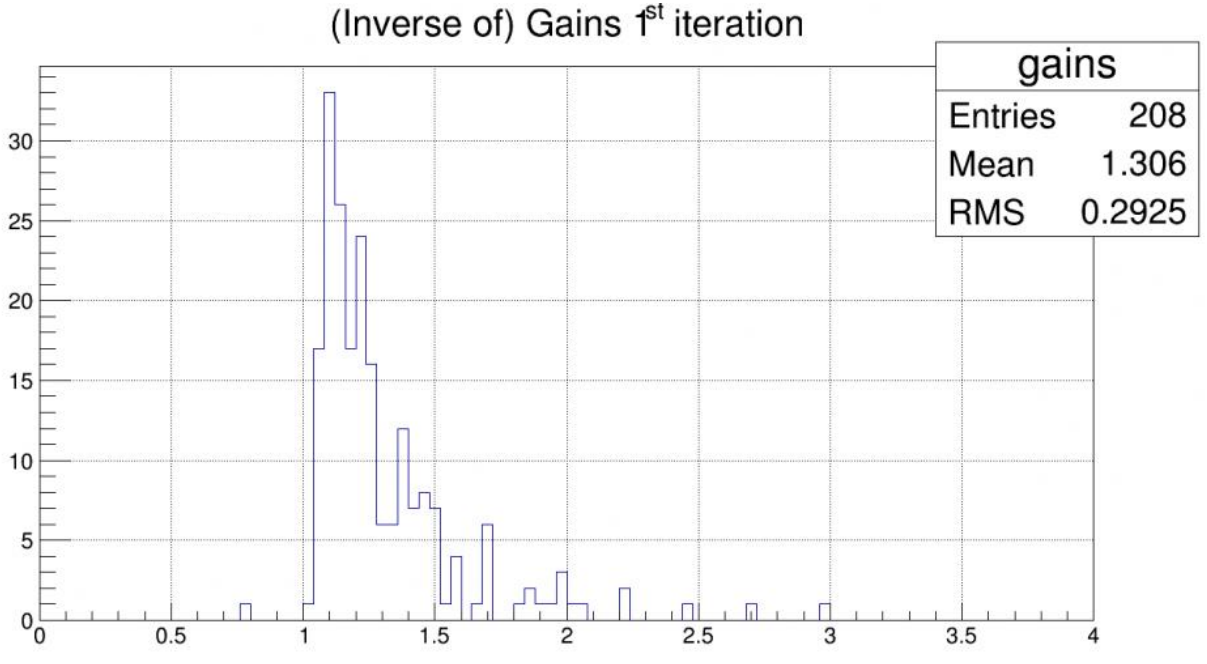
- Trigger jitter
- Calorimeter blocks relative time (cabling)
- S2m paddles relative time
- Photons travel time in S2m
- Electron travel time

Good identification of calorimeter - LHRS coincidence allows to remove accidentals.

Fall 2016 - Preliminary Studies

Calorimeter elastic calibration (Mongi Dlamini)





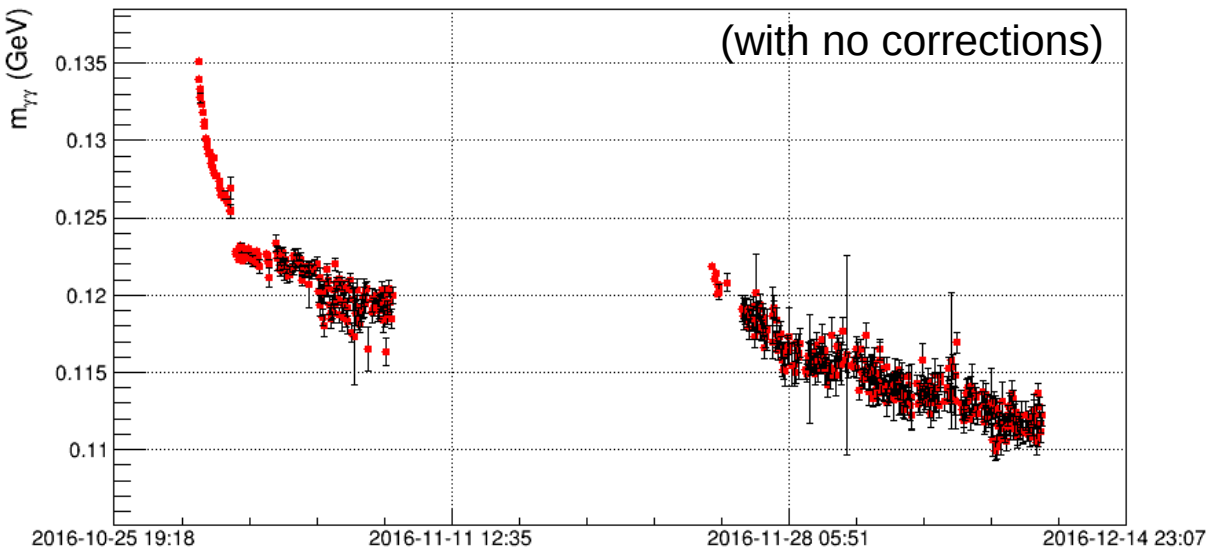
- Proton detected in LHRS, electron detected in calorimeter.
- Compute expected electron energy using detected proton (elastic)
- Reconstruct electron energy in calorimeter
- Adjust calorimeter blocks gains

- 2 elastic calibrations at 3 pass:
  - October 29
  - December 13 (see plots above)
- ~30% increase of the gain (increased calorimeter HV) to compensate for blocks loss of gain (radiation damage).

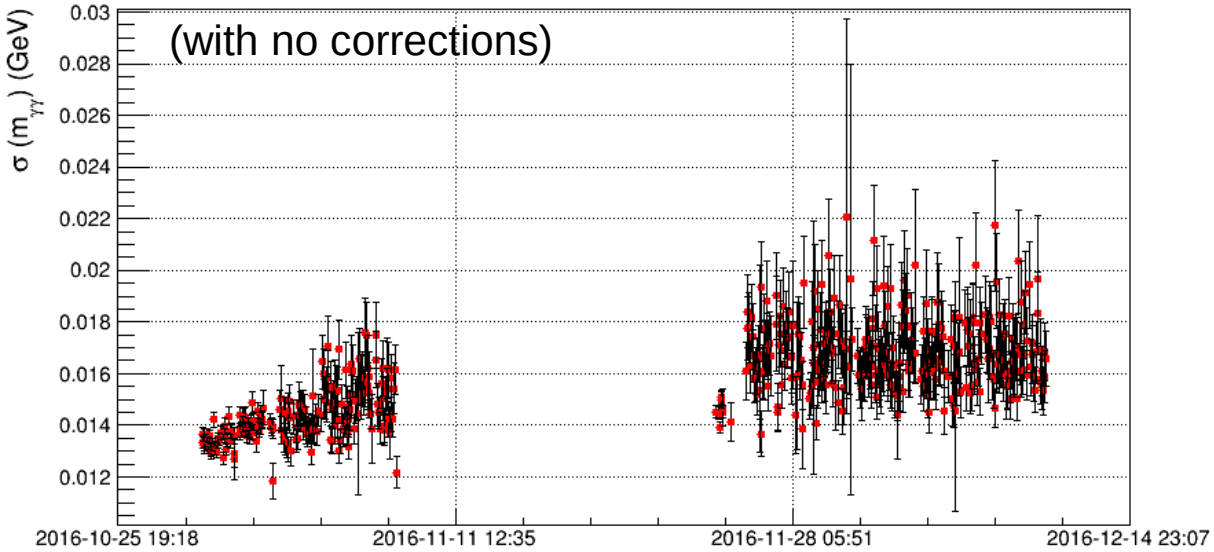
Fall 2016 - Preliminary Studies

Calorimeter loss of gain (Carlos Munoz Camacho)

π^0 invariant mass



π^0 invariant mass resolution

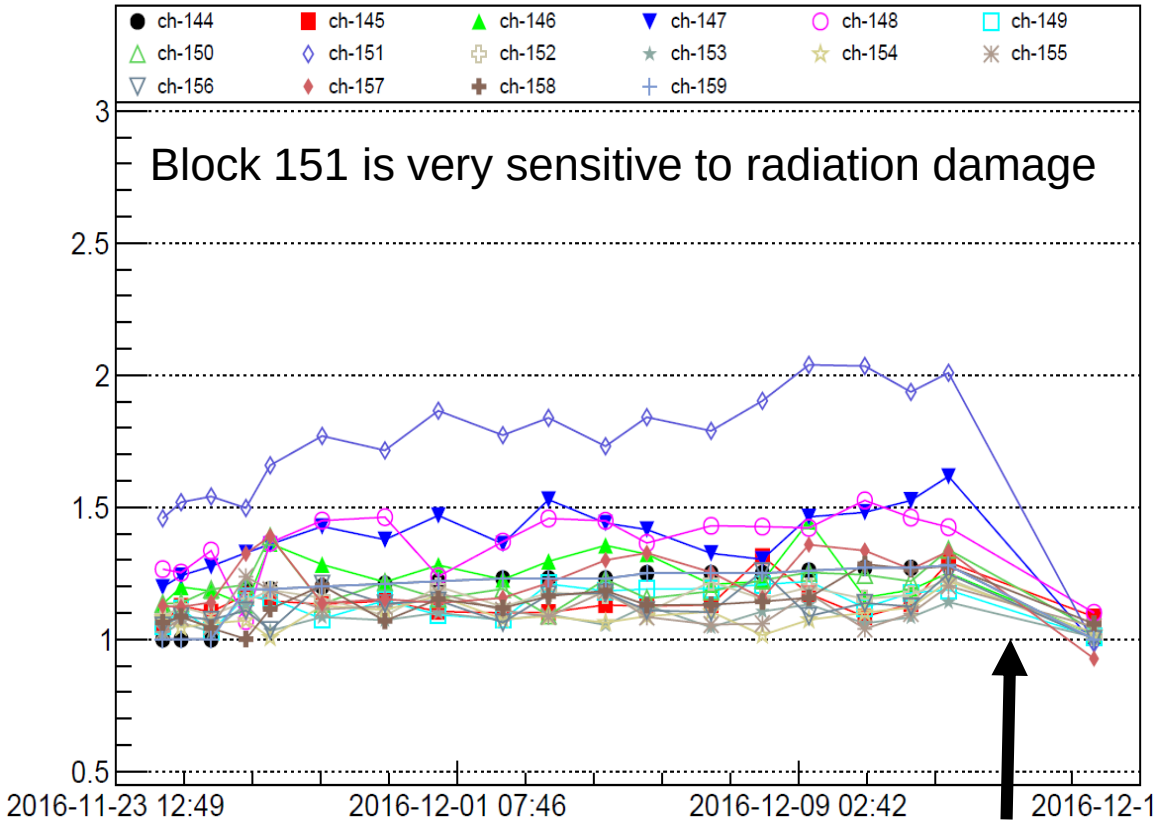


- Extremely fast initial loss of gain of the calorimeter blocks (radiation damage)
- Slower but continuous loss of gain afterward
- Small recovery after long down time

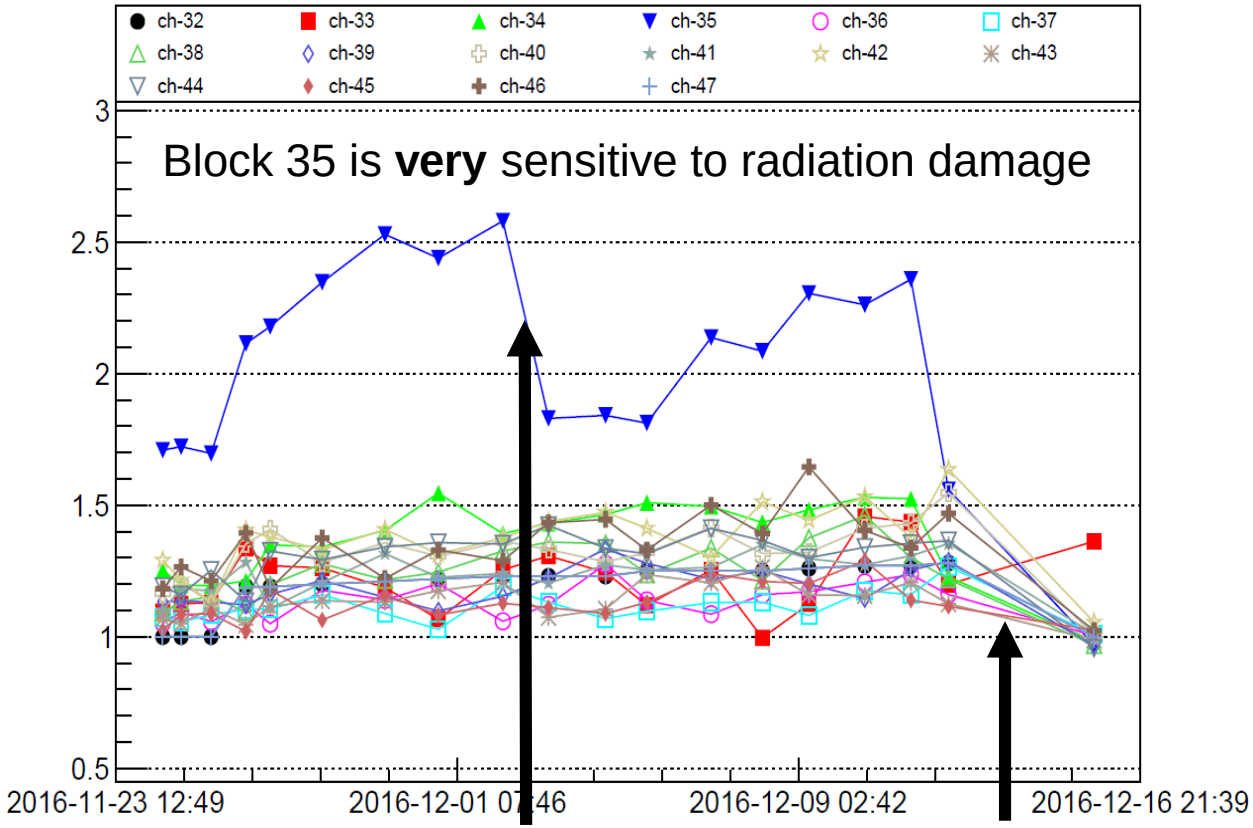
Fall 2016 - Preliminary Studies

Calorimeter loss of gain and π^0 calibration (F. G. & Mongi Dlamini)

- Compute correction coefficients by reconstructing π^0 invariant mass.
- Optimize π^0 invariant mass mean value and resolution



elastic calibration



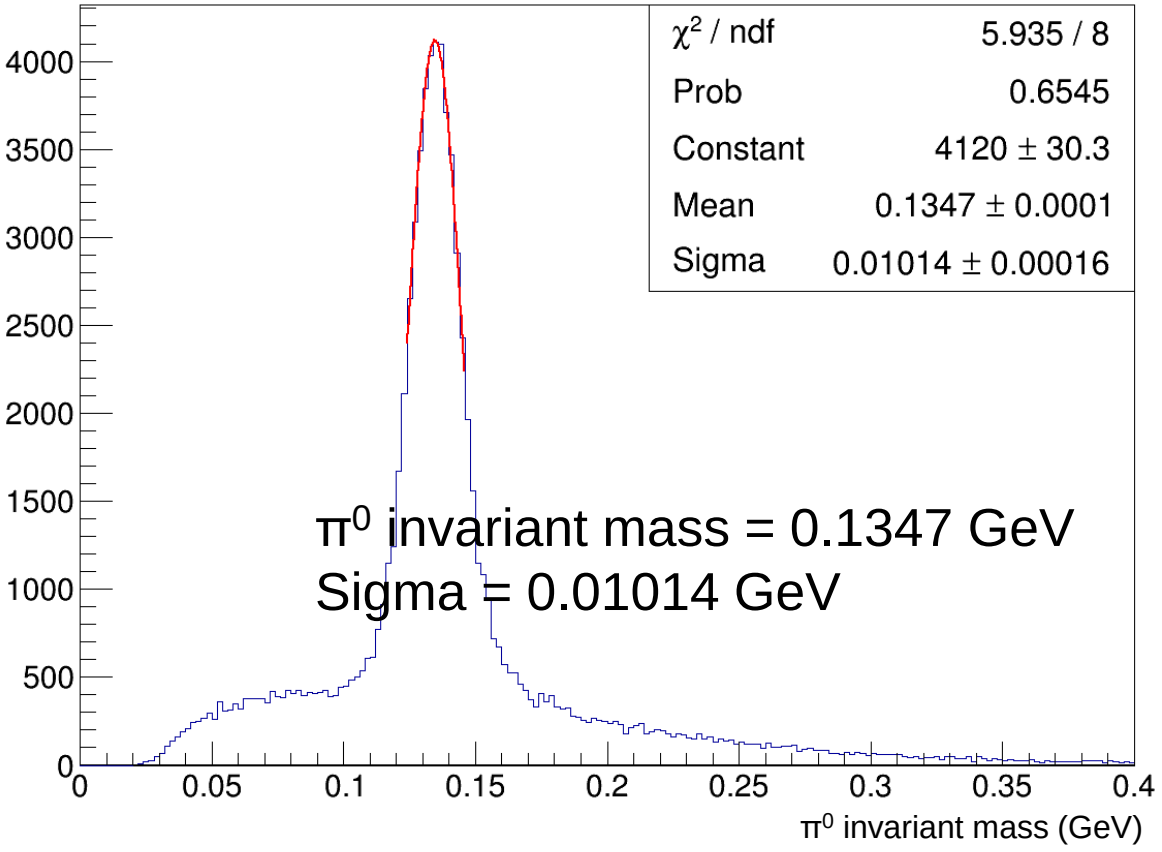
Increased HV of block 35

elastic calibration

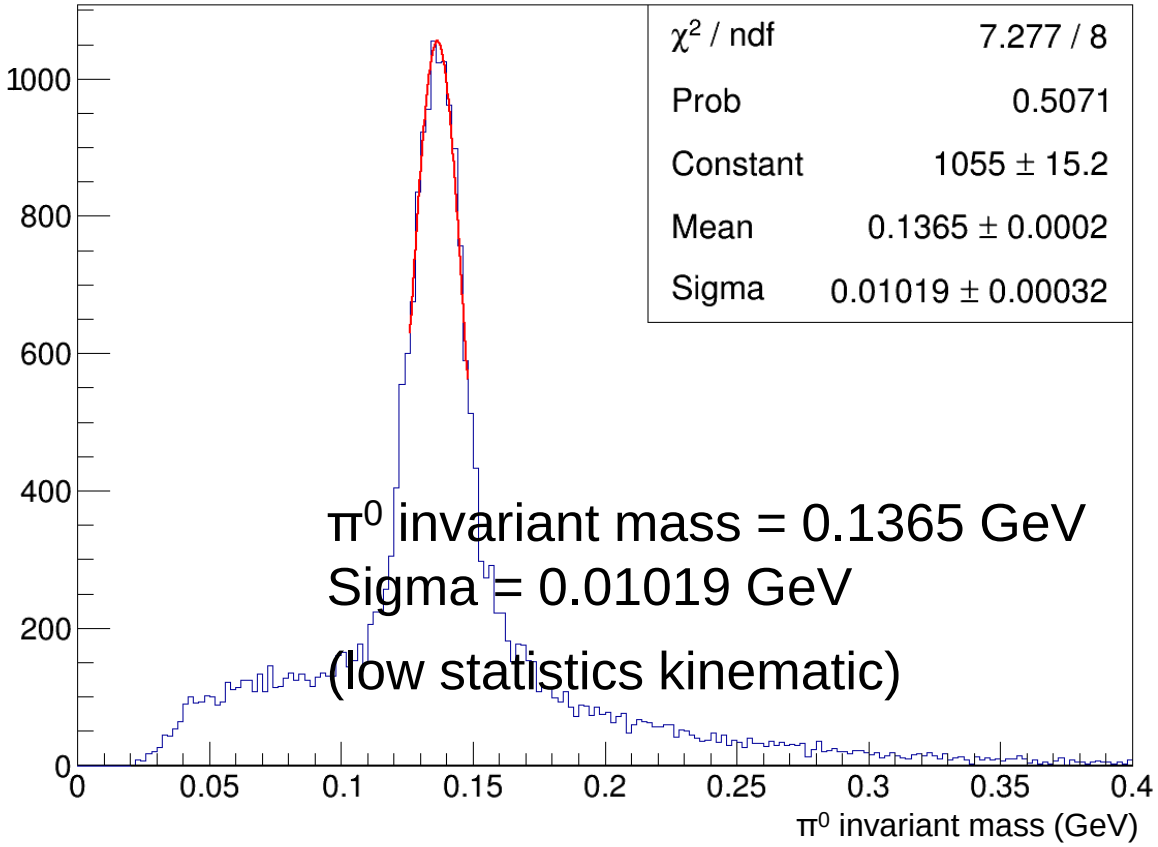
Fall 2016 - Preliminary Studies

Calorimeter π^0 calibration

November 24-25



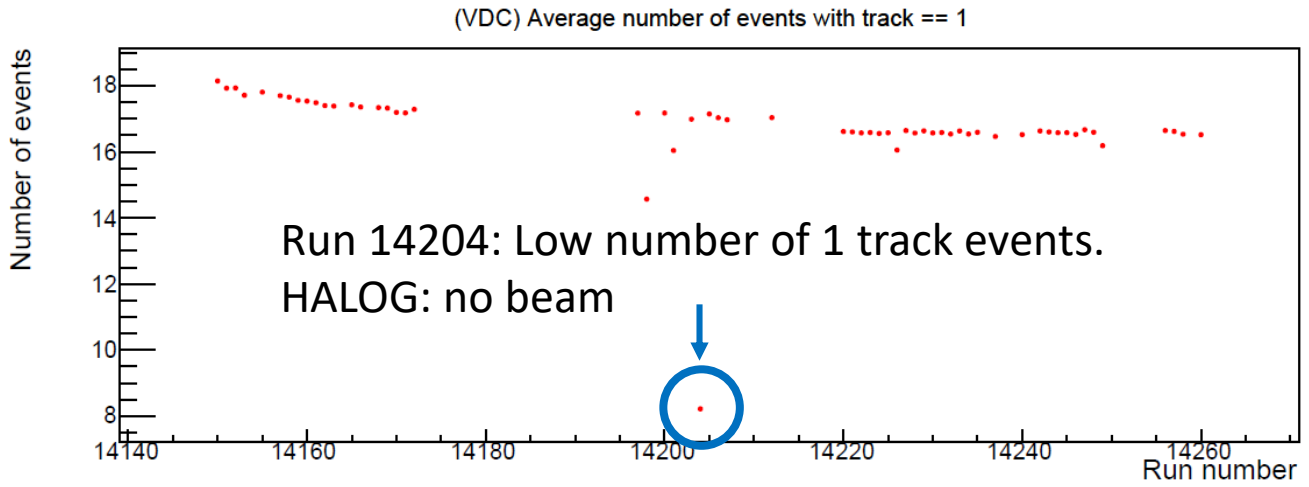
December 10-12

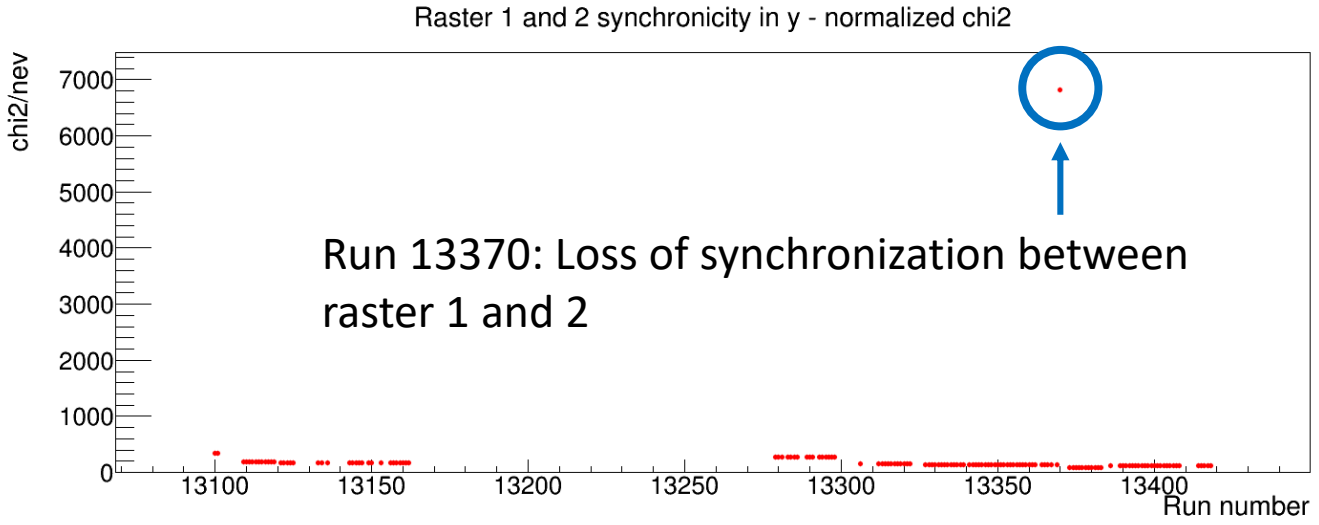


- π^0 calibration allows to correct calorimeter gains between elastic calibrations

Fall 2016 - Preliminary Studies

Quality analysis (F. G. & Mongi Dlamini)





Fall 2016:

- Kin36_2: 7 / 65 runs removed (~3.8% of total charge)
- Kin36_3: 8 / 39 runs removed (~5.3% of total charge)
- Kin60_1 and kin60_3 still need to be done

Spring 2016:

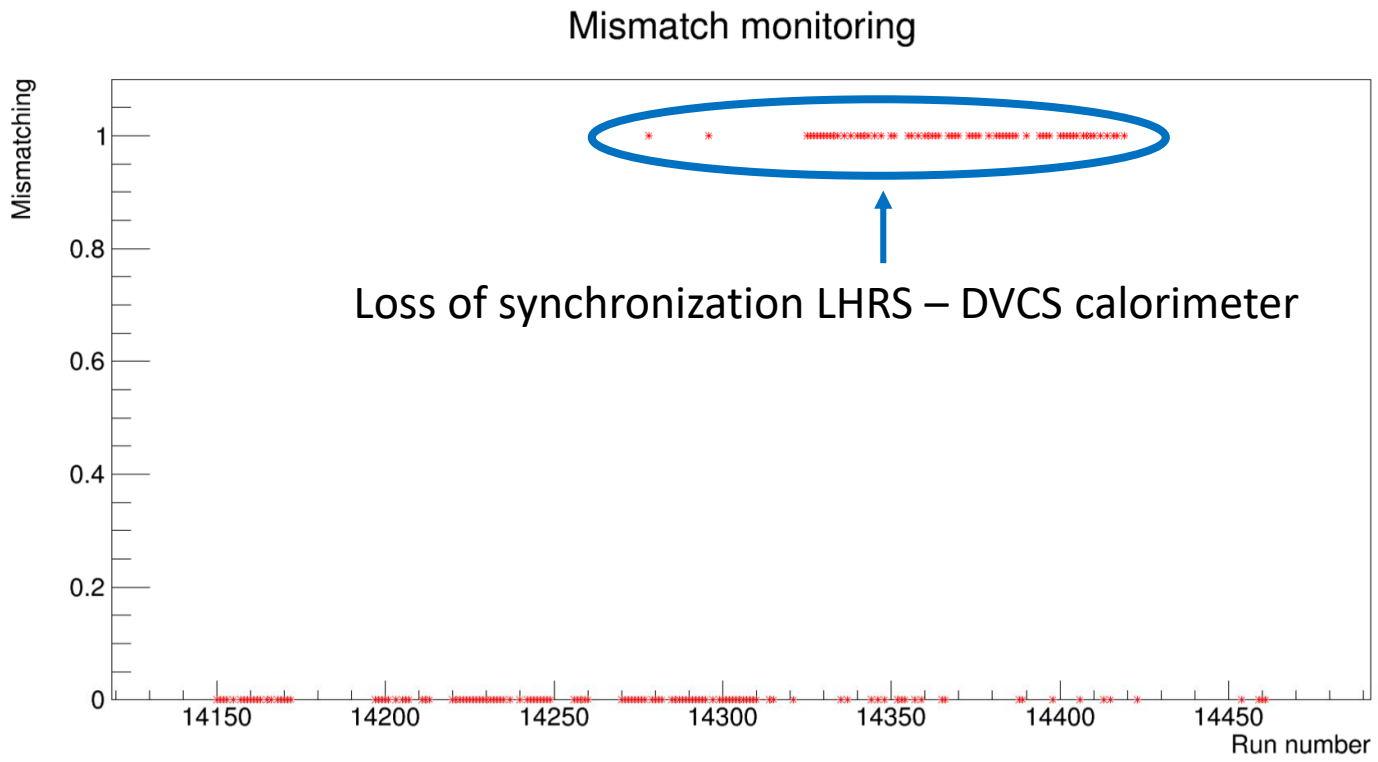
- Kin48_1: 8 / 74 runs removed (~1.3% of total charge)
- Kin48_2: 1 / 58 runs removed (~0.5% of total charge)
- Kin48_3: 14 / 122 runs removed (~1% of total charge)
- Kin48_4: 13 / 153 runs removed (~3.9% of total charge)

Main rejection reasons:

- Very short runs / Very few events recorded (beam trips)
- Raster issue
- Abnormal trigger rates

Fall 2016 - Difficulties

Loss of synchronization LHRS - DVCS calorimeter

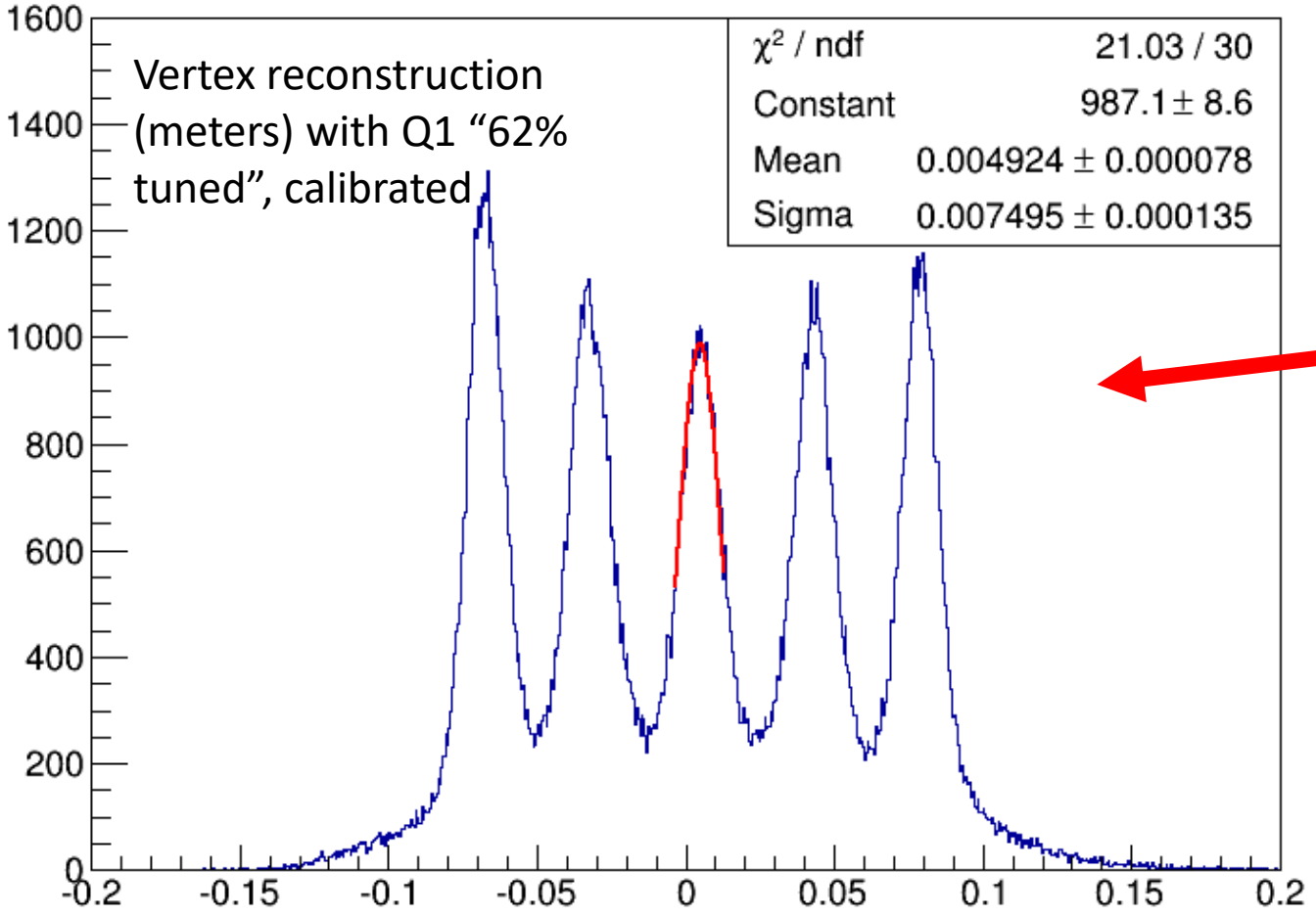


- A cable carrying a 100kHz clock signal was found plugged into the live input of the trigger supervisor.
- Reason and origin unknown.
- Consequences : loss of synchronization between LHRS and DVCS calorimeter.
- 63 runs compromised (3.5 full days of production ~ 30% of kin60_1 statistics)
- Recovering using EDTM trigger (6Hz clock signal sent to both LHRS and DVCS calorimeter)
- Very small loss of statistics.
- Work currently ongoing…

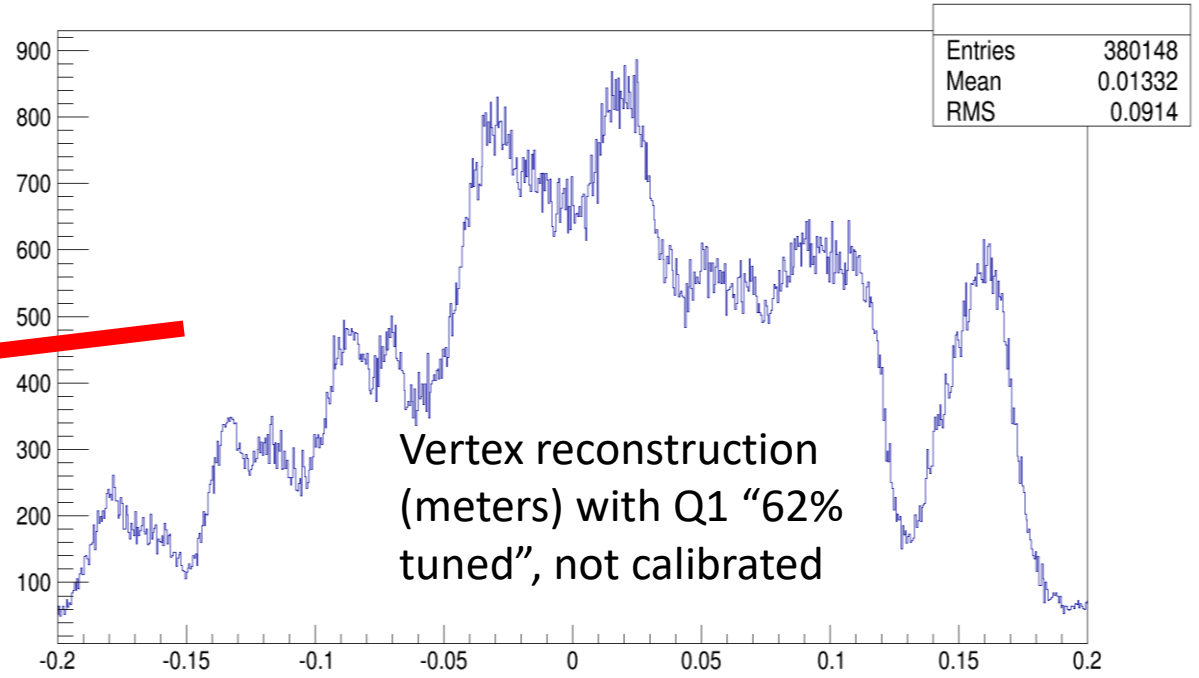
Update from Spring 2016 Run Period

Update from Spring 2016

LHRS Optics calibration



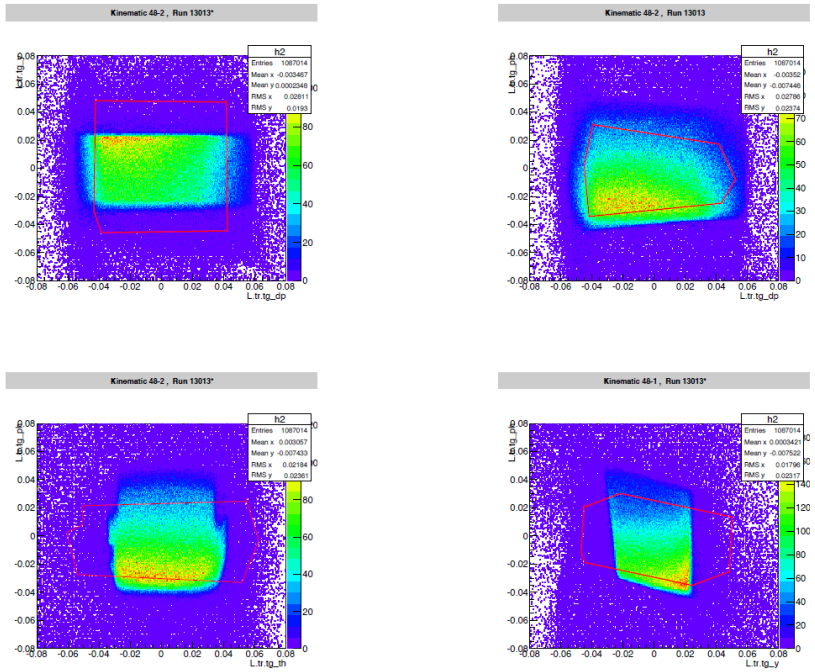
LHRS angle: 16.629 deg



- Optics calibration complete for all 4 settings of Q1
- Used the "Q1 100% tuned" calibration for this Fall
- 1 new calibration for Fall 2016 (Yang Wang)

Update from Spring 2016

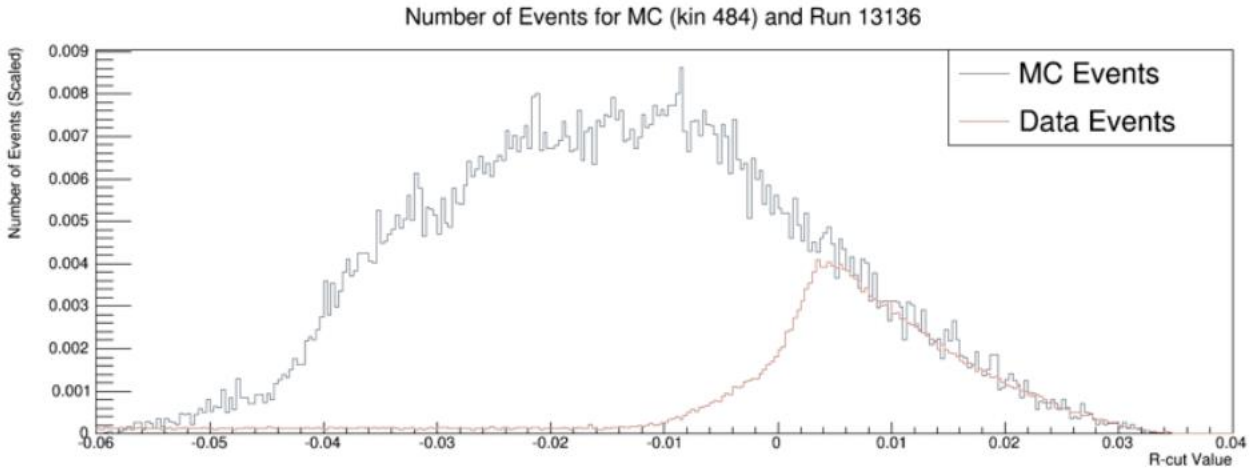
R-function (Alexa Johnson & Gulakhshan Hamad)

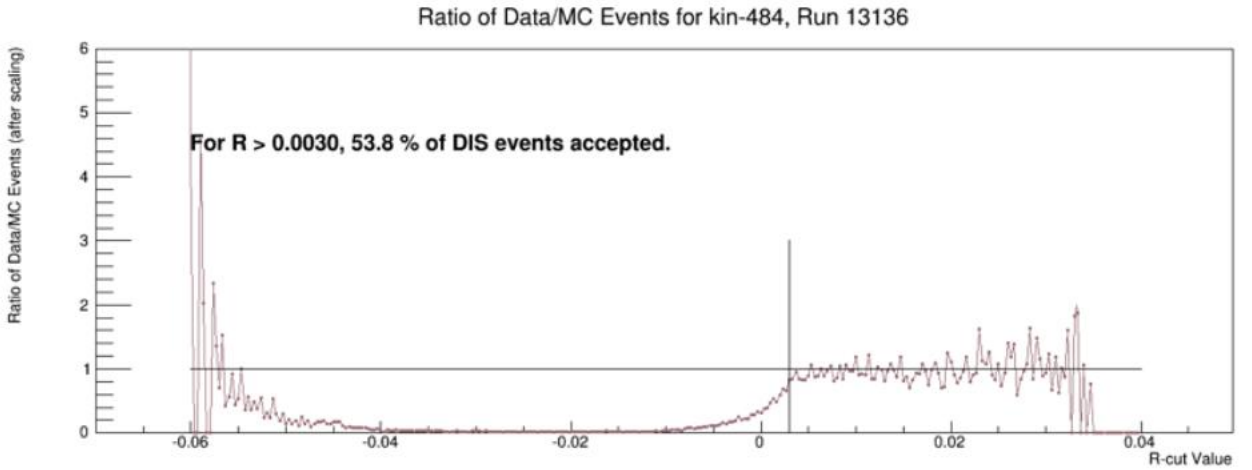


- Defined/computed 4 new R-functions
- Determined appropriate R-cut values

Still need to (mainly):

- Check R-cut values (DIS cross-section stable)
- Implement in DVCS libraries
- Repeat for Fall 2016





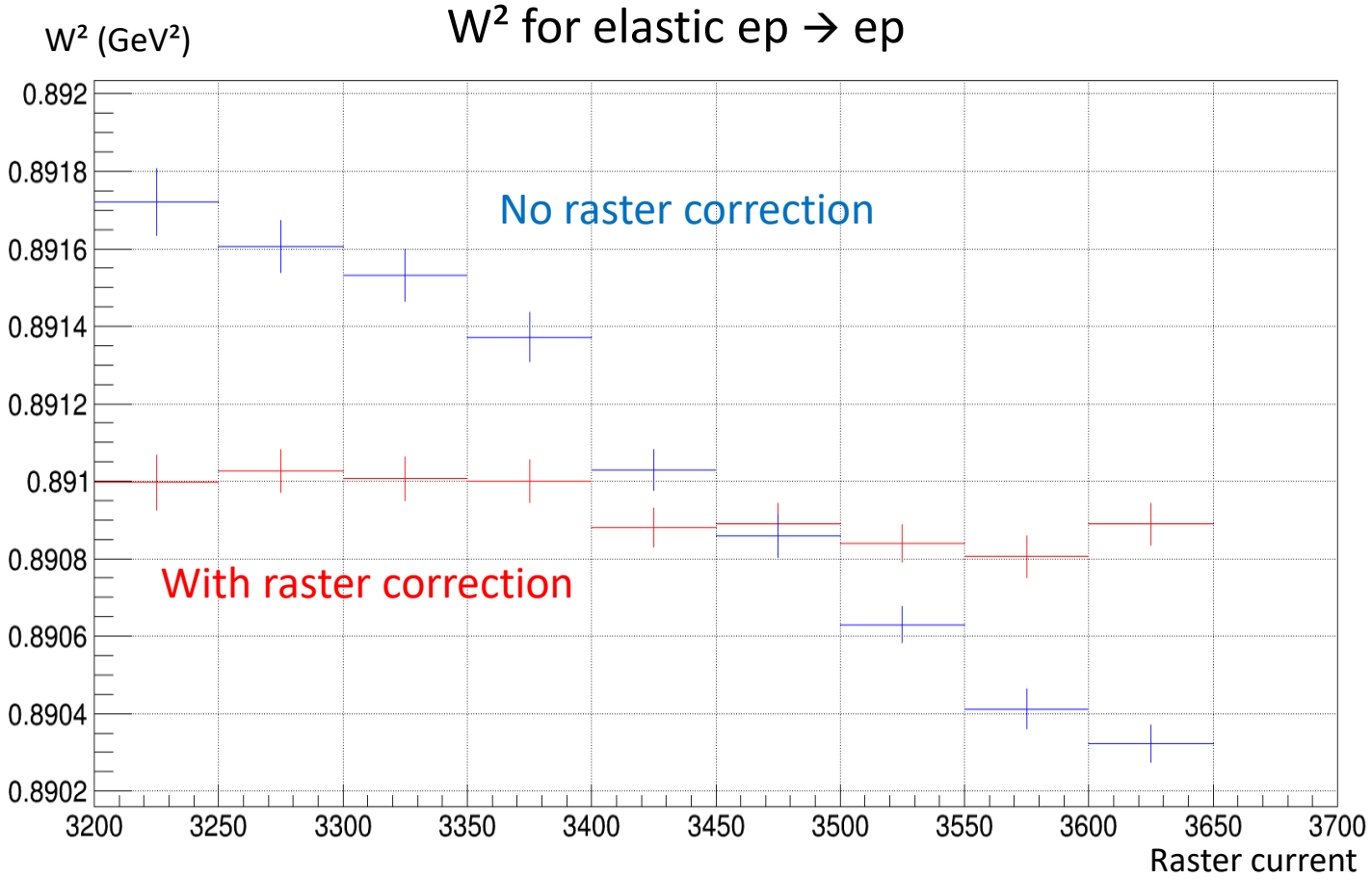
Needed for Q1-detuned settings

Update from Spring 2016

Raster calibration

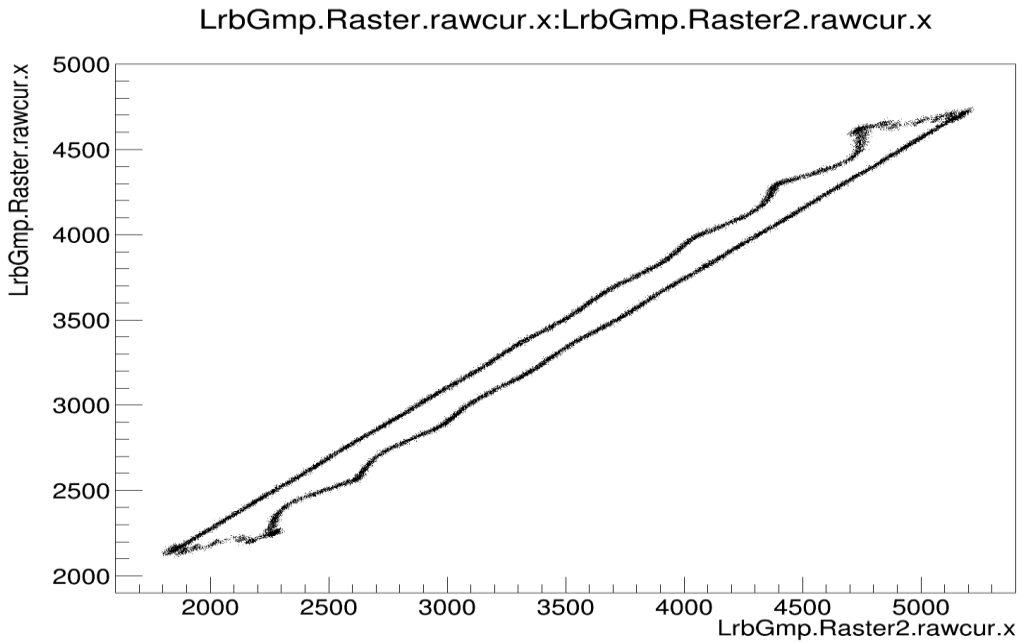
- Needed 7 calibrations for Spring 2016 (for each beam energy changes)
- Raster calibration complete
- Raster correction taken into account
- New calibrations required for Fall 2016

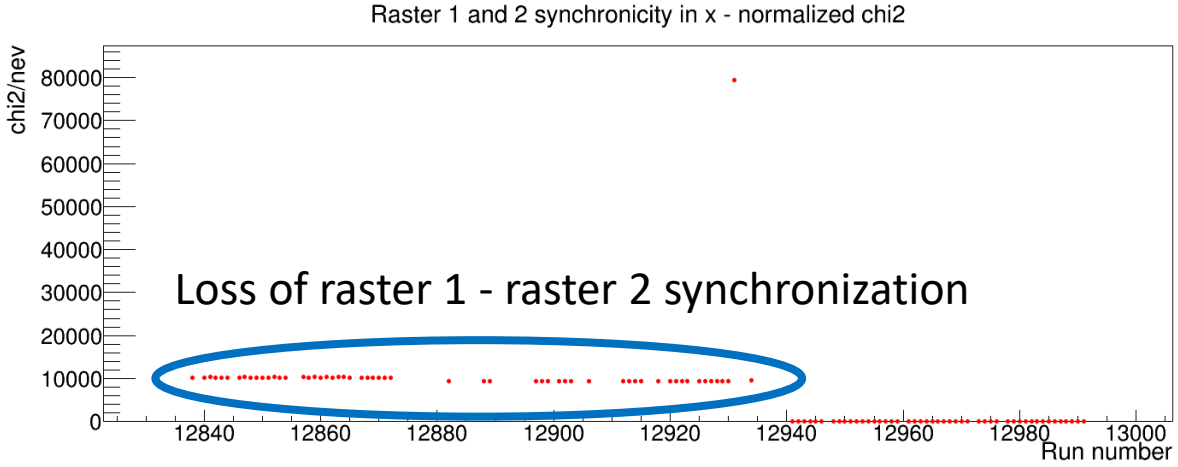
Raster size calibrated against BPM readings.



Update from Spring 2016

Raster loss of synchronization

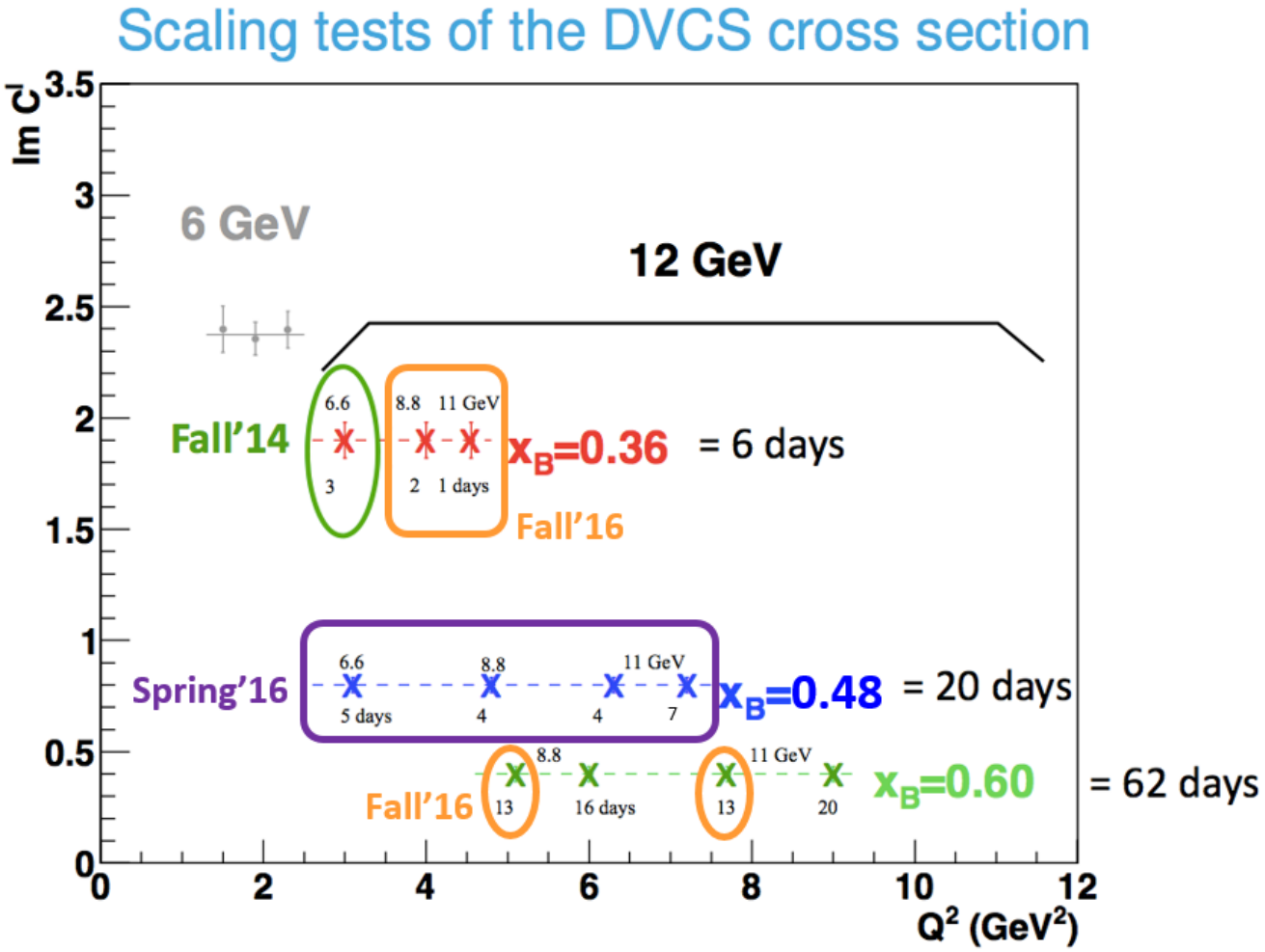




- Failing raster power supply → loss of synchronization between raster 1 and 2.
- Calibration not currently possible (assumes raster 1 and 2 synchronized).
- > 50% of kin48_3 affected.
- But simulation shows that error on variable reconstruction is smaller than experimental resolution.
- Online display monitoring was put into place during Fall 2016 for early warning.
- Did not happen during Fall 2016.

Summary

DVCS Cumulated Statistics - Summary



kinematic	% of target charge	PAC days
kin36_1	100.0	3
kin36_2	100.0	2
kin36_3	100.0	1
kin48_1	100.0	5
kin48_2	56.6	4
kin48_3	76.4	4
kin48_4	53.0	7
kin60_1	100.0	13
kin60_2	0.0	16
kin60_3	100.0	13
kin60_4	0.0	20

Could not go back and complete kin48_[234] because of beam energy change over the summer.

~50% of PAC allocation completed between 2014 and 2016

Summary and Outlook

- Fall 2014 : Successful Commissioning + 1 complete kinematic point
- Spring 2016 : 4 partial kinematic points (~70% overall statistics)
- Fall 2016 : 4 complete kinematic points.
- **2 kinematic points missing. ~50% PAC day missing**
- Data analysis already started and to be continued. Lot of work ahead of us.
- Very exciting results to come, stay tuned!

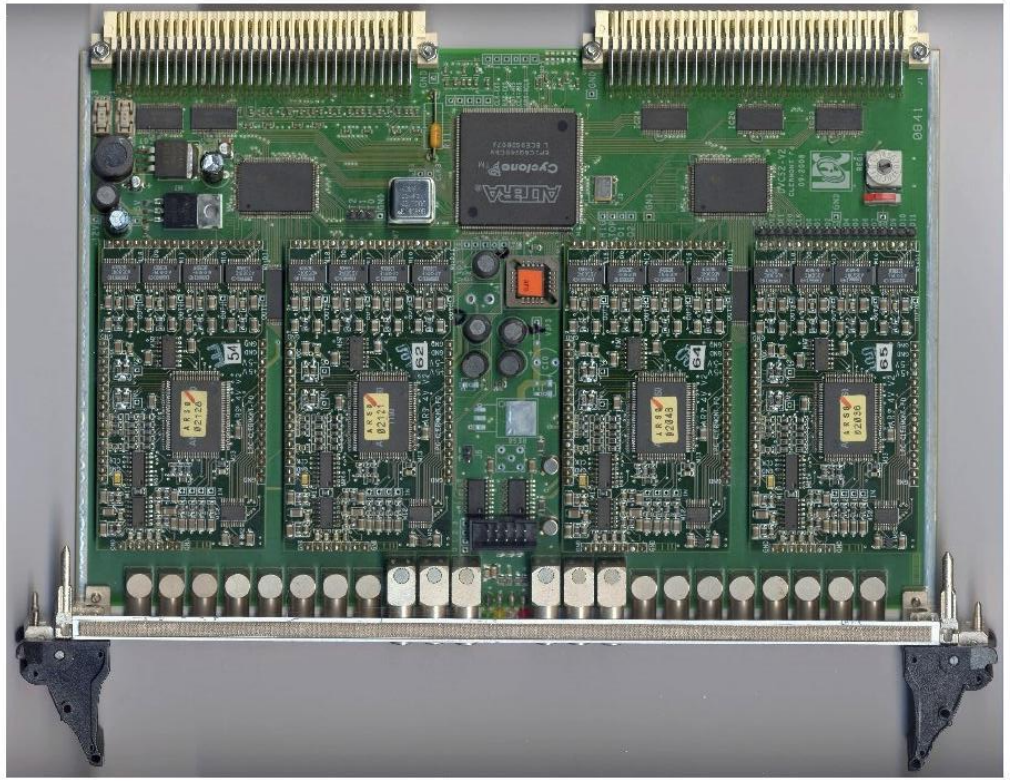
Acknowledgement :

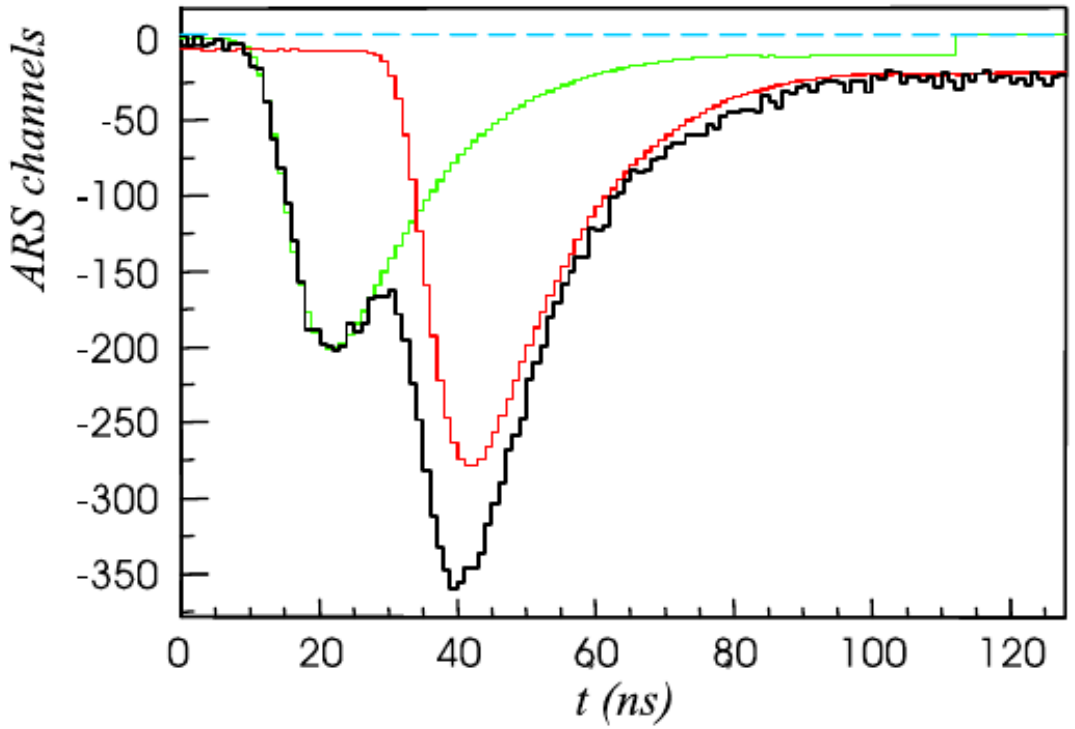
- Hall A collaboration
- Hall A technical staff
- Accelerator staff
- Shift Workers & RCs

For their ever so valuable work and help!

Thank You!

DVCS in Hall A - Instrumentation



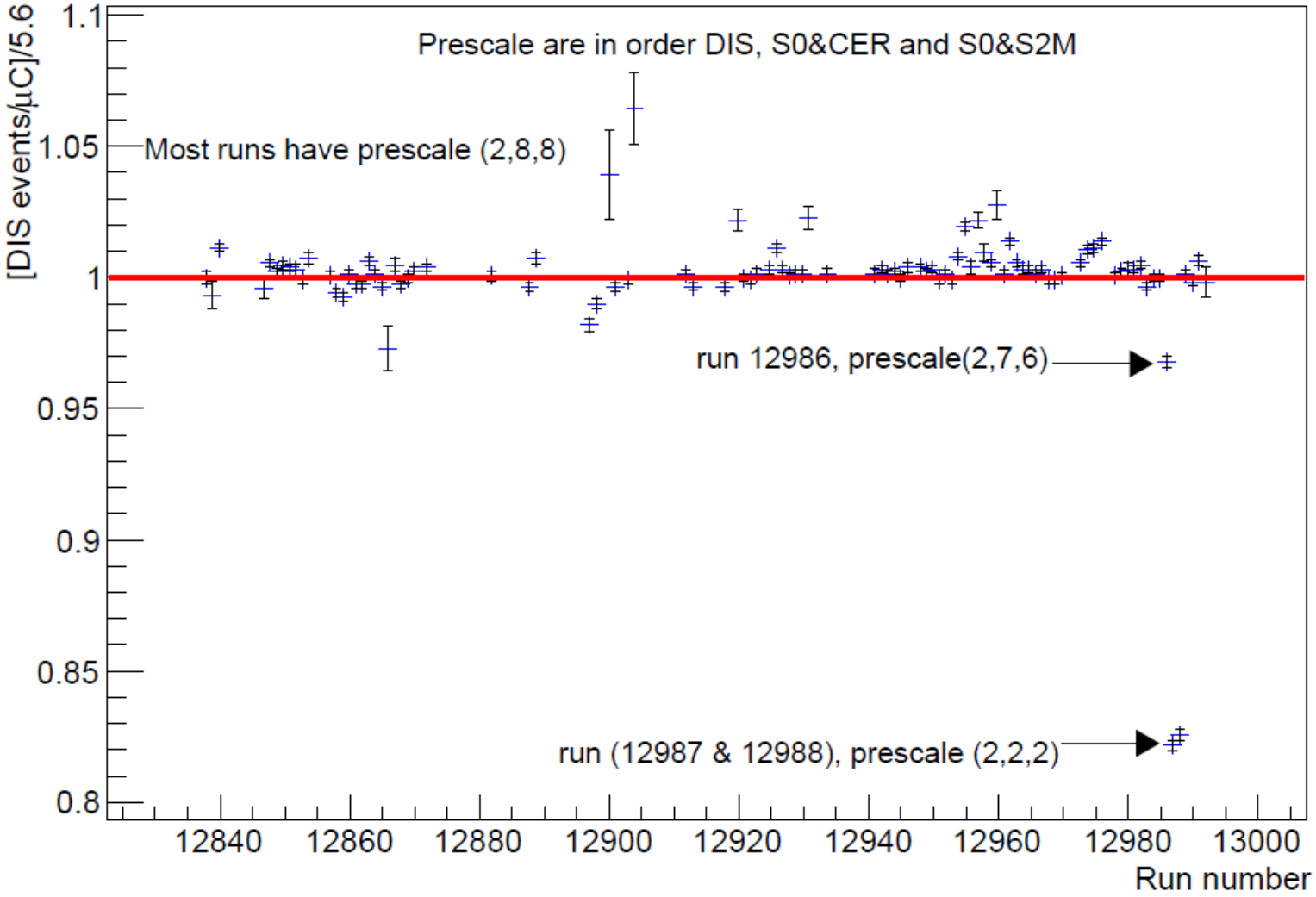


- ARS boards : 1GHz Digitizer electronics.

→ Allows clear identification of DVCS photons and pile-up resolution.

Update from Spring 2016

DIS rates studies (Bishnu Karki)



- DIS rates consistent within 2% if trigger prescales unchanged.
- DIS rates variations up to 18% when trigger prescales changed.
- Some DIS events seem to be missed by coincidence trigger.
- Work ongoing to understand these observations.