HRS Detector Status

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Outline

- Beam commissioning and detector checkout during March and December 2014

- Optics calibration of LHRS

- Use of straw chambers in HRS tracking

- Future plans/Improvements

Hall A Experimental Equipment

High resolution spectrometers

Detector package

Compton polarimeter

Moller polarimeter

Target
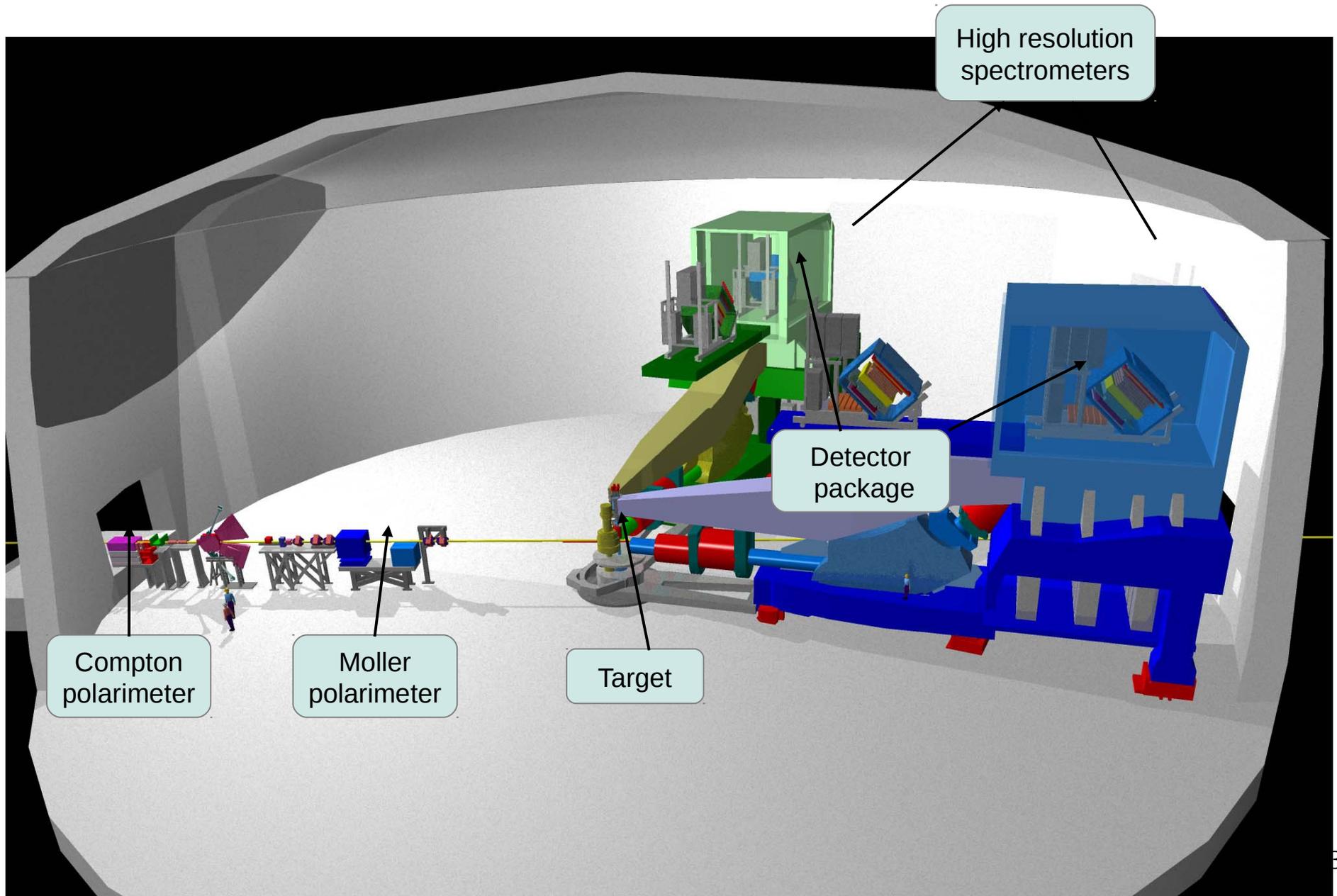
HRS Detector Stack

Central ray

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HRS Detector Configuration
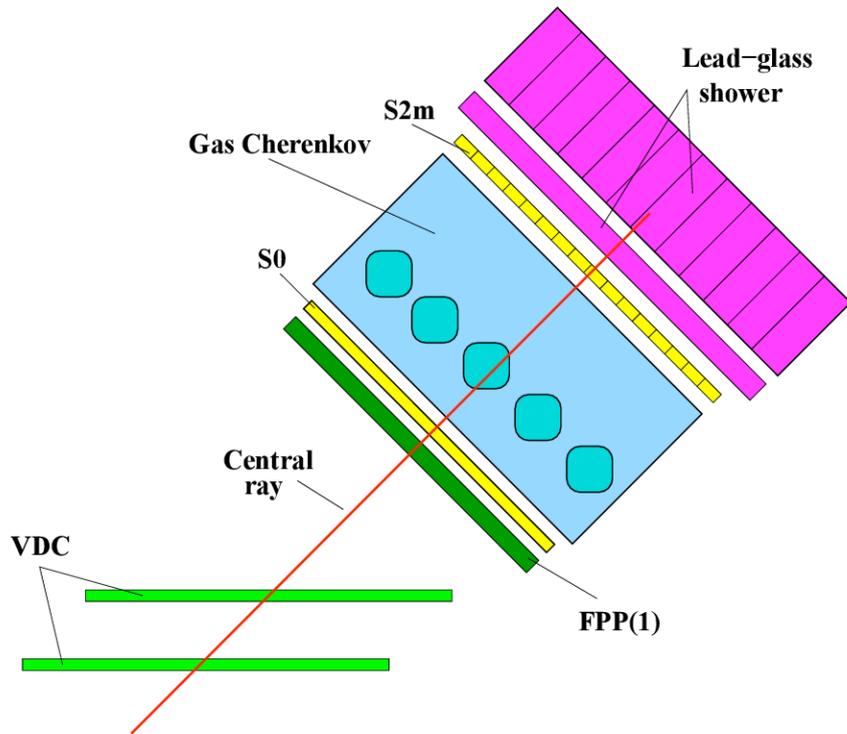
- Two VDCs at focal plane to determine particle direction

- Straw chamber as an auxiliary tracking detector

- Scintillator paddles S0 and S2m as primary trigger detectors

- Detectors for Particle ID: Cherenkov counters and lead-glass shower detectors

Detector Checkout with Beam

- Detectors on both spectrometers were checked out in last March (E_{beam}=4.89 GeV)

  – Beam taken on solid targets and LH2 target

  – Elastic and deep inelastic scattering data was collected

  – Data was used to calibrate optics matrix, study trigger efficiency, calculate *ep* cross section...

- Last December optics and elastic data was taken on LHRS (E_{beam}=7.29 GeV)

Detector Performance (S0)

- S0 consists of a scintillator paddle with a PMT at each end

- One of main trigger detectors for GMp experiment

S0 time resolution

σ=0.75 ns

hs0Tres	
Entries	150863
Mean	243.7
RMS	2.015
χ² / ndf	81.37 / 10
Constant	1.927e+04 ± 6.719e+01
Mean	243.7 ± 0.0
Sigma	1.507 ± 0.004

Track projection on S0

All events

No TDC hit on at least one PMT

No TDC hit on both PMTs
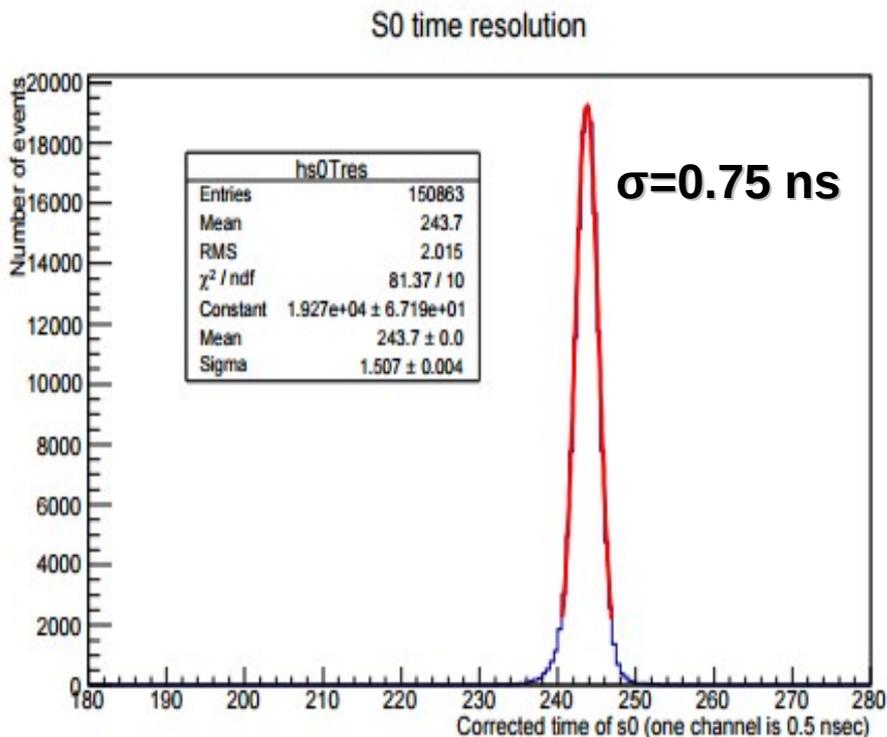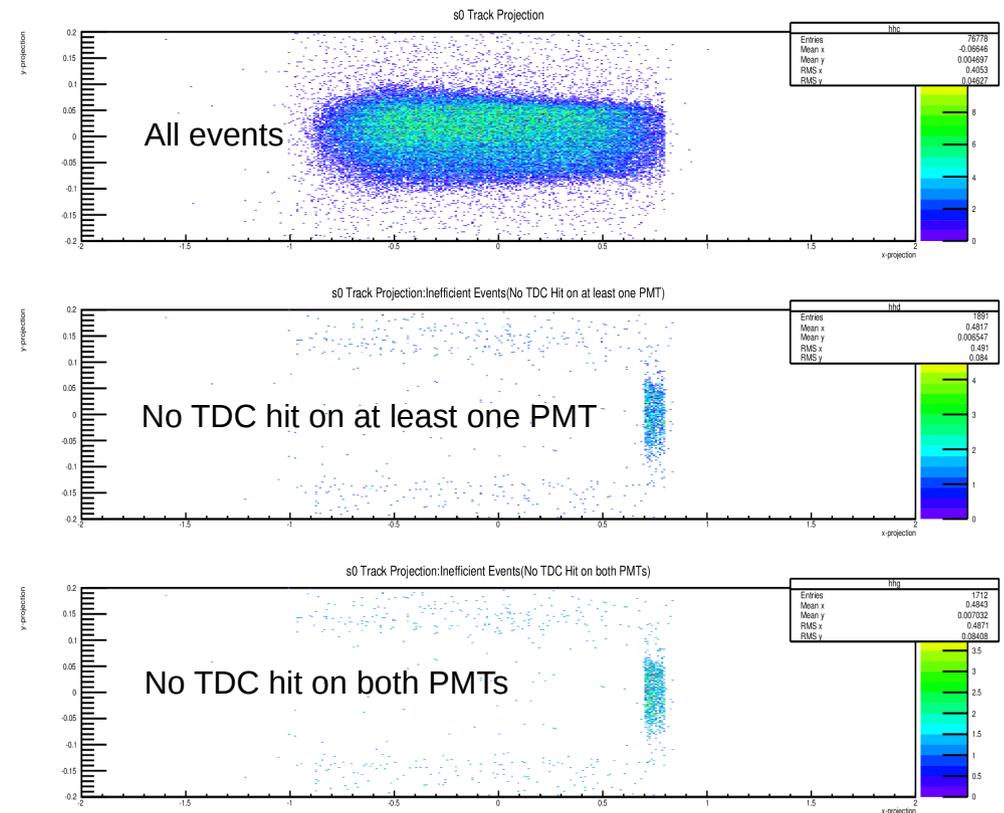
About 2.5% of total events are lost due to finite geometrical acceptance

Detector Performance (S2m)

- S2m consists of 16 scintillator paddles in a plane

- One of main trigger detectors for GMp experiment

σ=0.89 ns
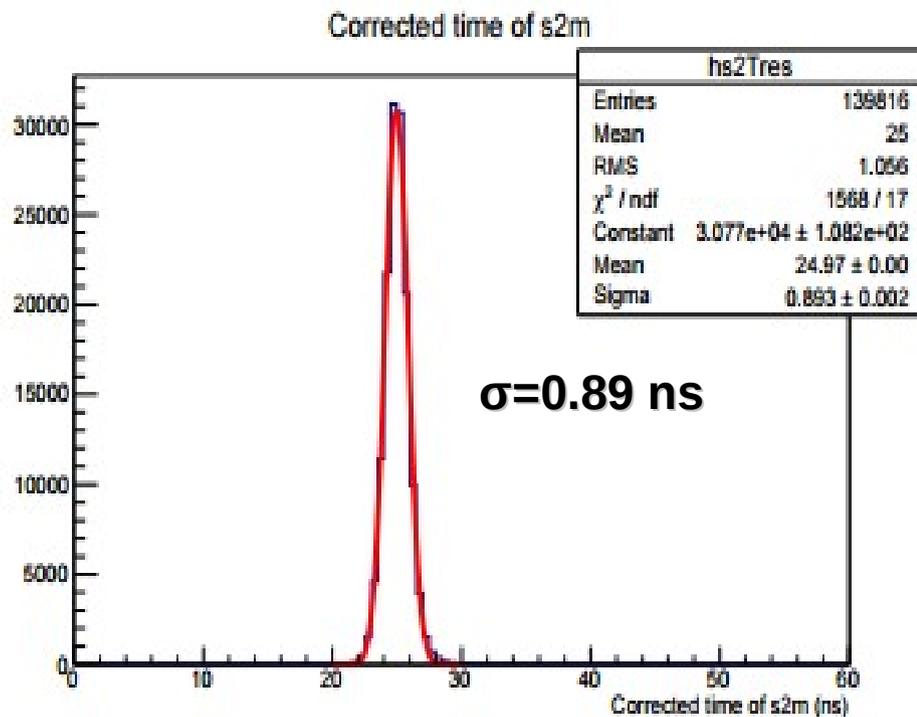
- One p.e. peak for each ADC channcel is aligned

- Geometrical acceptance of S2m is found to be 99.4%

- Current issue is pedestals are about three times wider than expected in some ADC channels

Gas Cherenkov Counter

- All 20 PMTs are covered with wavelength-shifting paint
- The effect of WLS paint was tested last spring
  - 50% increase in #p.e. was observed
  - Typically 15-20 p.e. were detected in GC after application of WLS paint
- #p.e. was measured again in last December and found to be the same as that in spring

LHRS Gas Cherenkov PMT #5:Full Light Cone

With WLS: N = 20.3

Without WLS: N = 12.5

LHRS Gas Cherenkov PMT #3

With WLS: Spring 2014
With WLS: Spring 2014
With WLS: Fall 2014

No time dependence observed
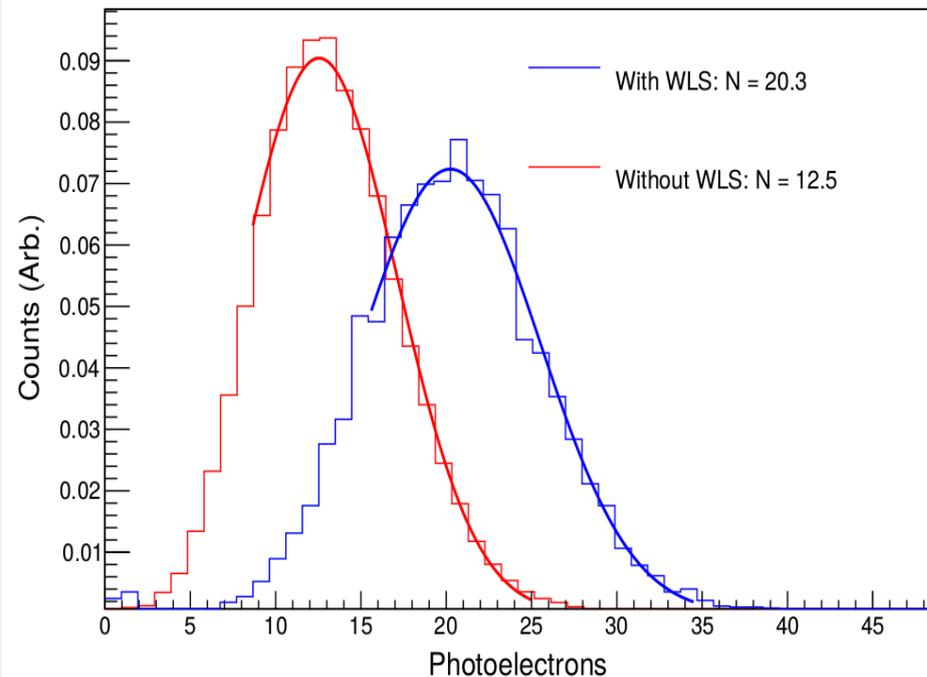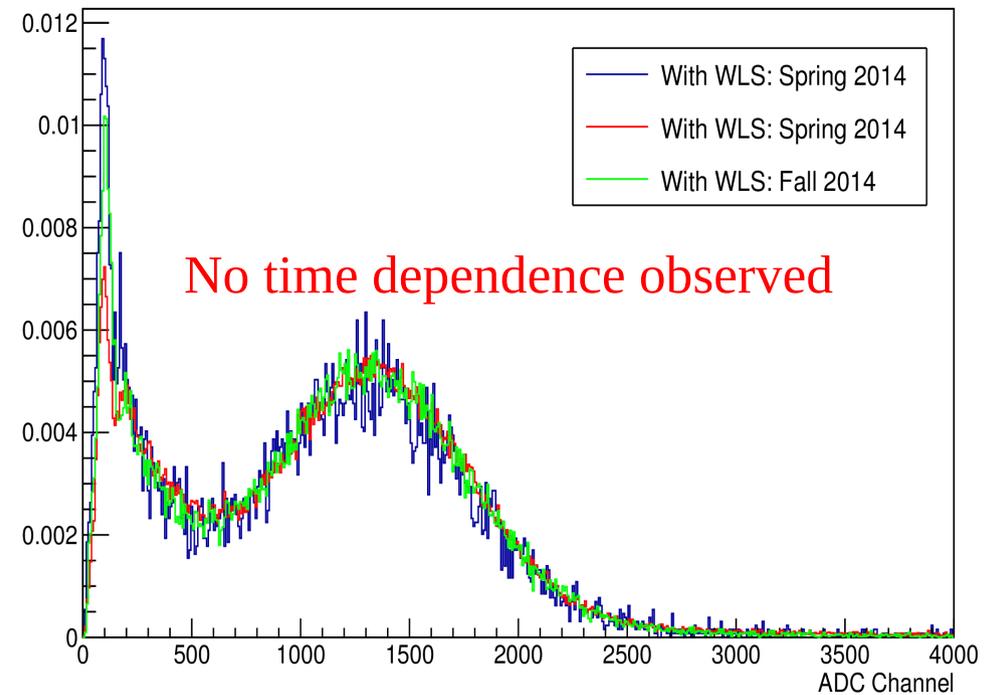
Lead Glass Calorimeter

- Two layers of lead glass blocks
- Gain matching of all ADC channels
- Particle ID (with GC counter)

Energy resolution:

LHRS: 6% @ 3GeV

RHRS: 6% @ 1GeV

E/p for electron events (LHRS)

h	
Entries	137031
Mean	0.9765
RMS	0.1244
χ^2 / ndf	100 / 18
Constant	8768 ± 34.1
Mean	0.9862 ± 0.0002
Sigma	0.05866 ± 0.00022

σ=6%@3GeV

L.prl2.e:L.prl1.e

e⁻

π⁻
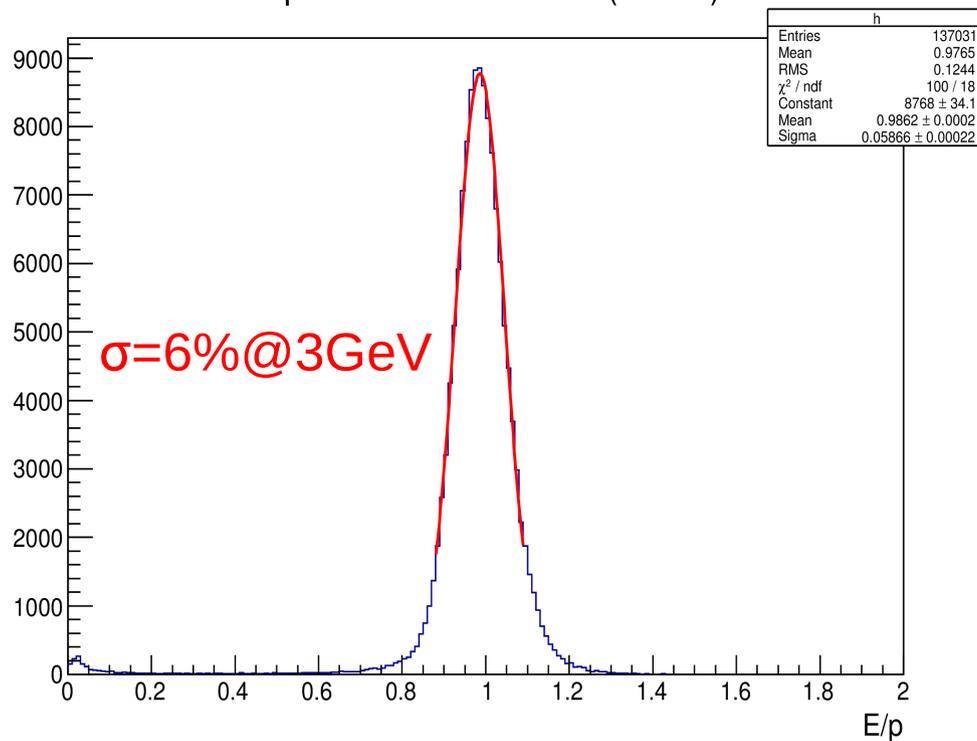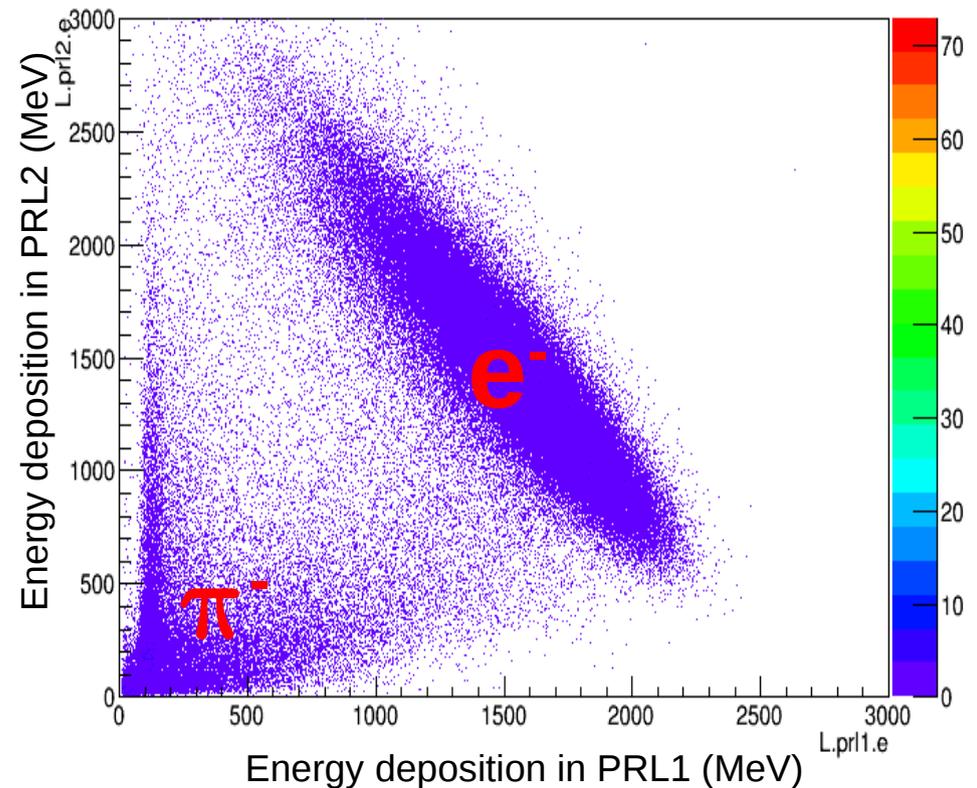
Electronic Dead-Time Monitor (EDTM)

- New electronics for EDTM (electronic dead-time measurement) was implemented on the LHRS last summer

  - Attenuated logical EDTM pulses are mixed with signals from the Gas Cherenkov, S0 and S2m detectors

  - The number of 'tagged' EDTM pulses that are recorded in scalers is monitored

Detector outputs

Mixer

To ADC

To DISC

Attenuated

EDTM pulses
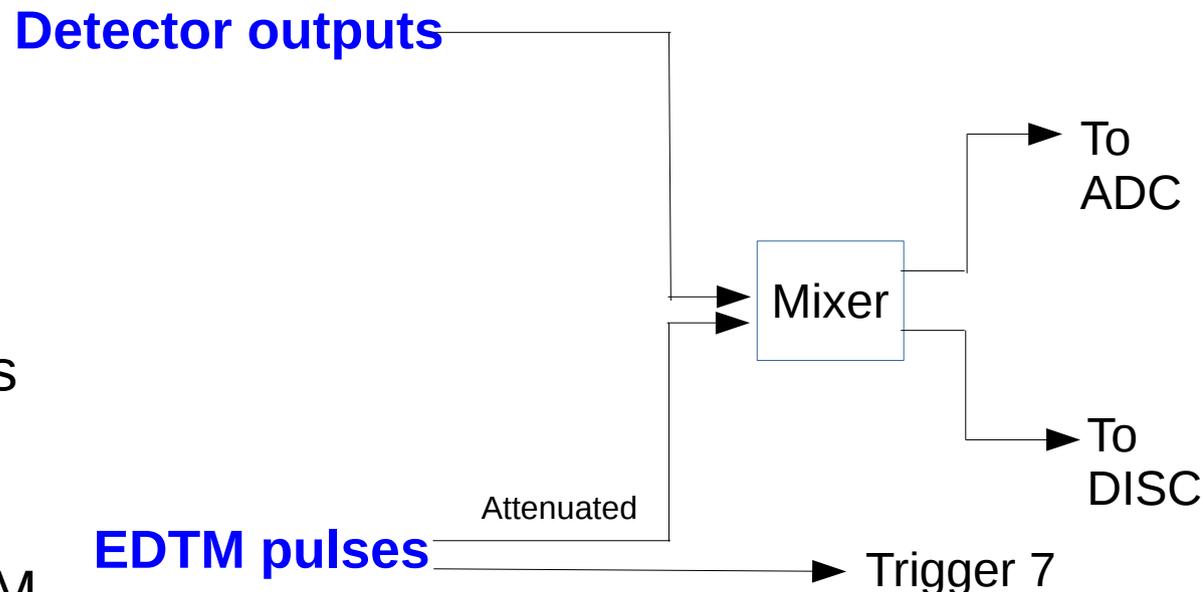
Trigger 7

Electronic dead-time was measured and found to be negligible, but more test is needed in high-rate situation

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HRS Data Acquisition Status

- Triggers are prepared by programmable module (MLU)
  - T1 = S0 && S2
  - T2 = S0 && GC
  - T3 = S2 && GC
  - T4 = S0 && SH
  - T5 = S2 && SH
  - T6 = GC && SH

- Single detector mode can also be selected from software

- EDTM pulse and clock are also sent to MLU

Schematic for Trigger System

NIM output

CLK
EDTM
GS — Trigger MLU — CLK
S0 — EDTM
S2 — GC&SH
SH — S2&SH
S0&SH
S2&GC
S0&GC
S0&S2

NIM_ECL

TS

S0&SH
S2&GC — OR Logic — Retiming signal
S0&GC
S0&S2

Generates Level 1 Trigger (LIA)

Comes first and wait For Retiming Signal

Retiming Module (Delayed the output)

Trigger Module → Gates for ADC And common stop for TDC
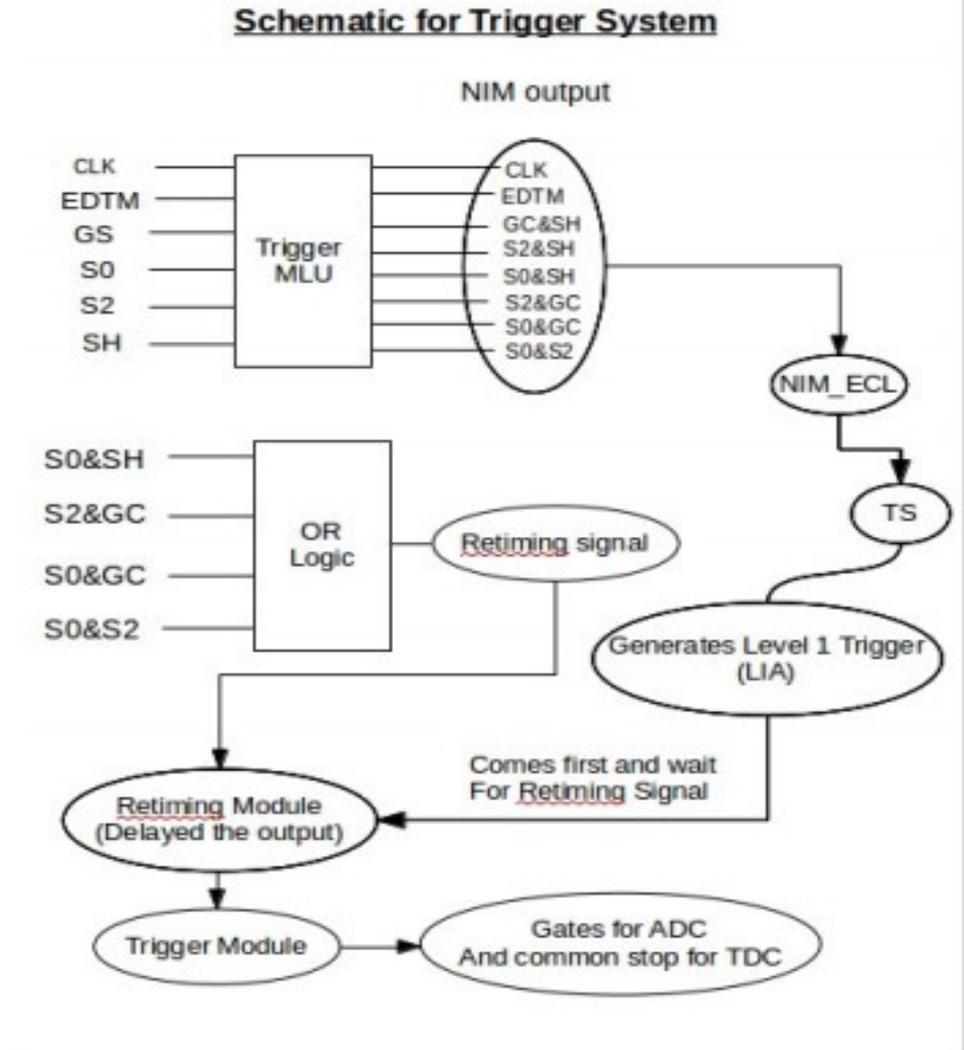
GMp Optics

DIS data was taken last March and December for optics calibration:

E_{beam}=4.89 GeV, E'=3.00 GeV, θ_{HRS}=15.0°, Q^2=1.00 GeV^2, W=1.85 GeV

Out-of-plane angle vs. in-plane angle
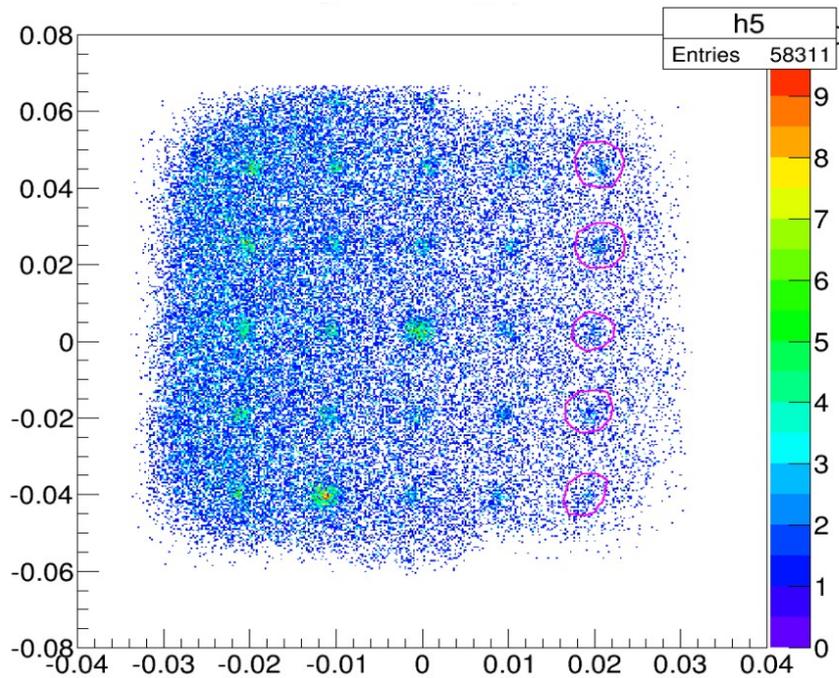
5 mm stainless steel sieve slit
7 holes by 7 holes
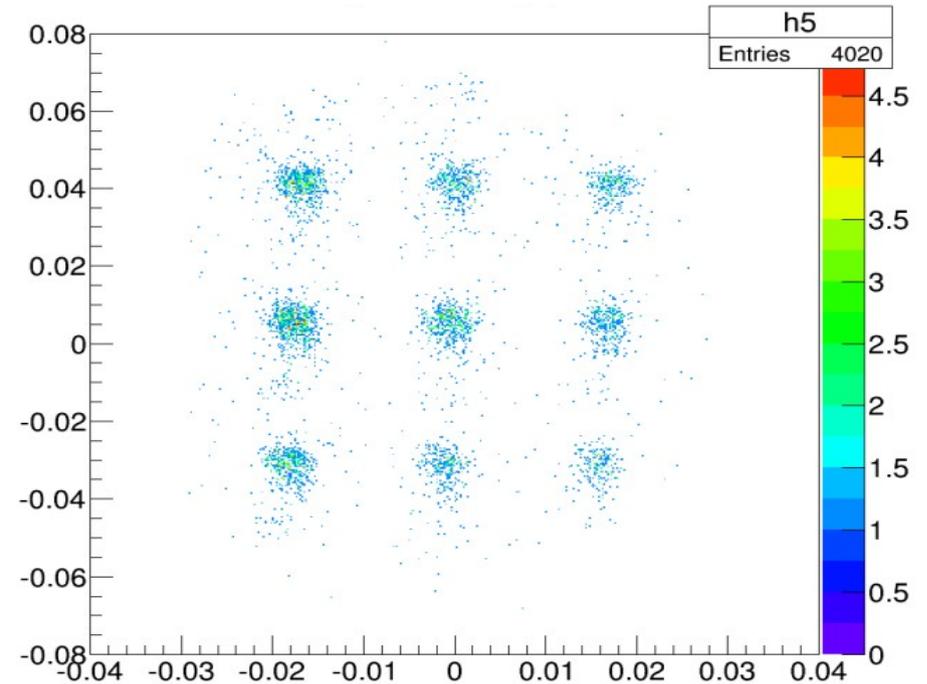
2 inch lead sieve slit
5 holes by 5 holes

GMp Optics

New tungsten sieve in the December run:

E_{beam}=7.29 GeV, E'=2.92 GeV, θ_{HRS}=22.8°, Q^2=3.33 GeV^2, W=2.40 GeV

Out-of-plane angle vs. in-plane angle
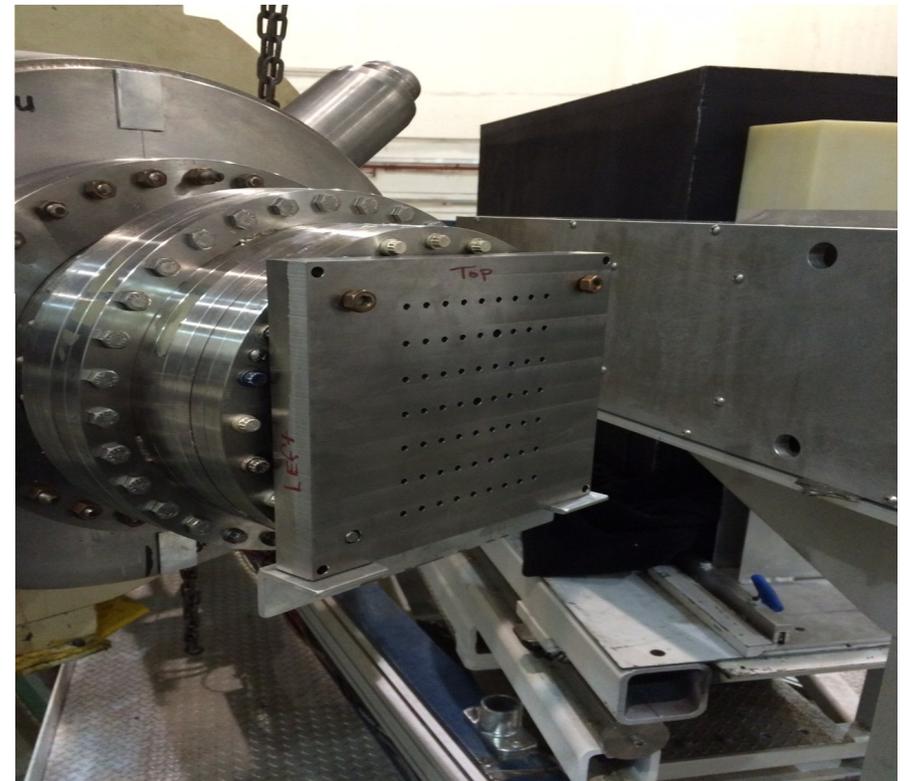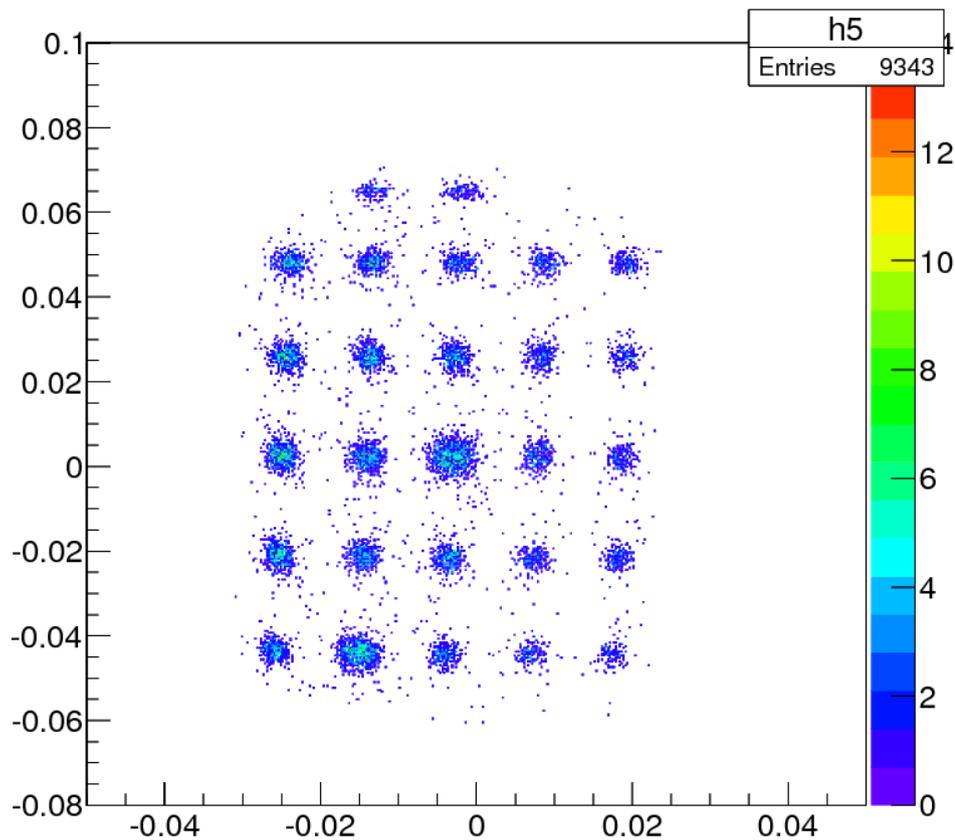
GMp Optics

Angle calibration

Before calibration
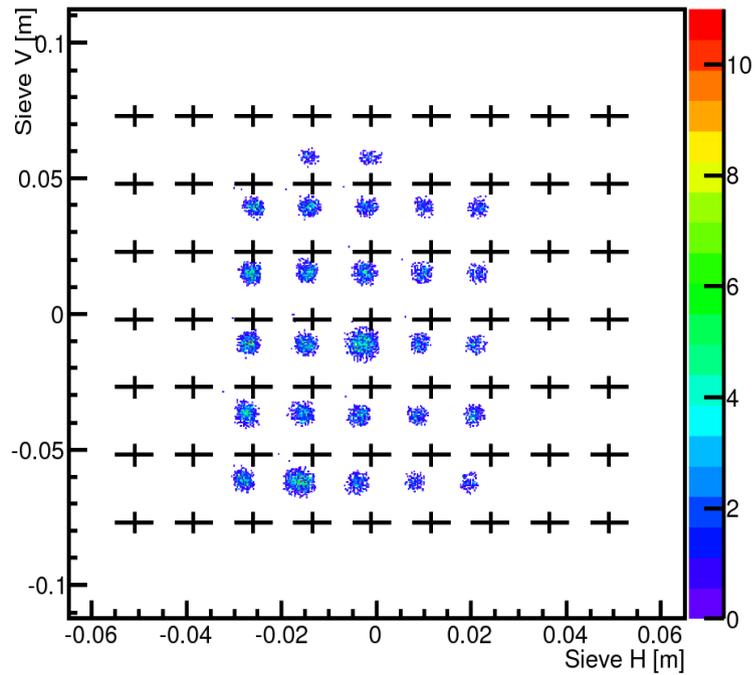
After calibration
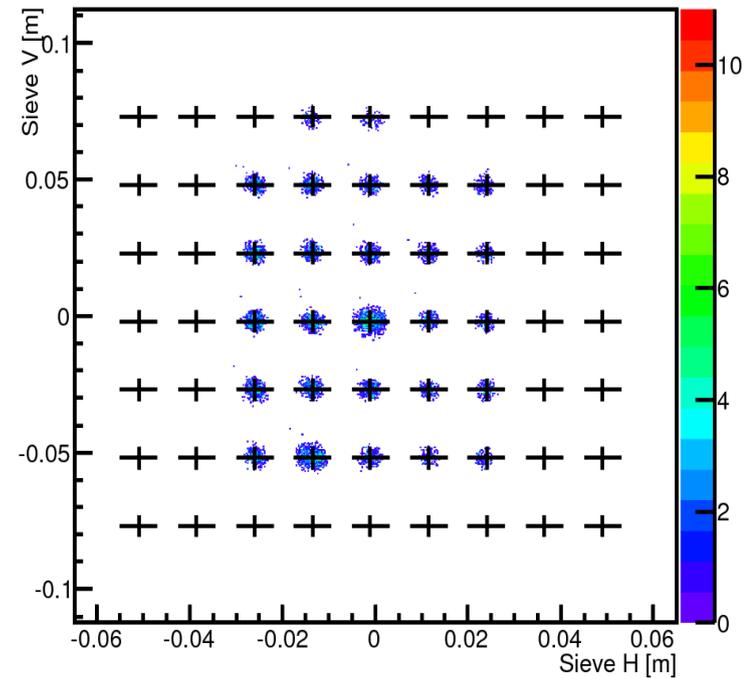
Event Reconstruction from December Run

Proton Magnetic Form Factor Measurement

Squared invariant mass of recoil system, $(GeV/c)^2$

Momentum transfer $Q^2 = 7.73 \ (GeV/c)^2$

$\in = 0.63$

$\sigma = 0.035 \ GeV^2$

No. of events

$W^2 \ (GeV^2)$
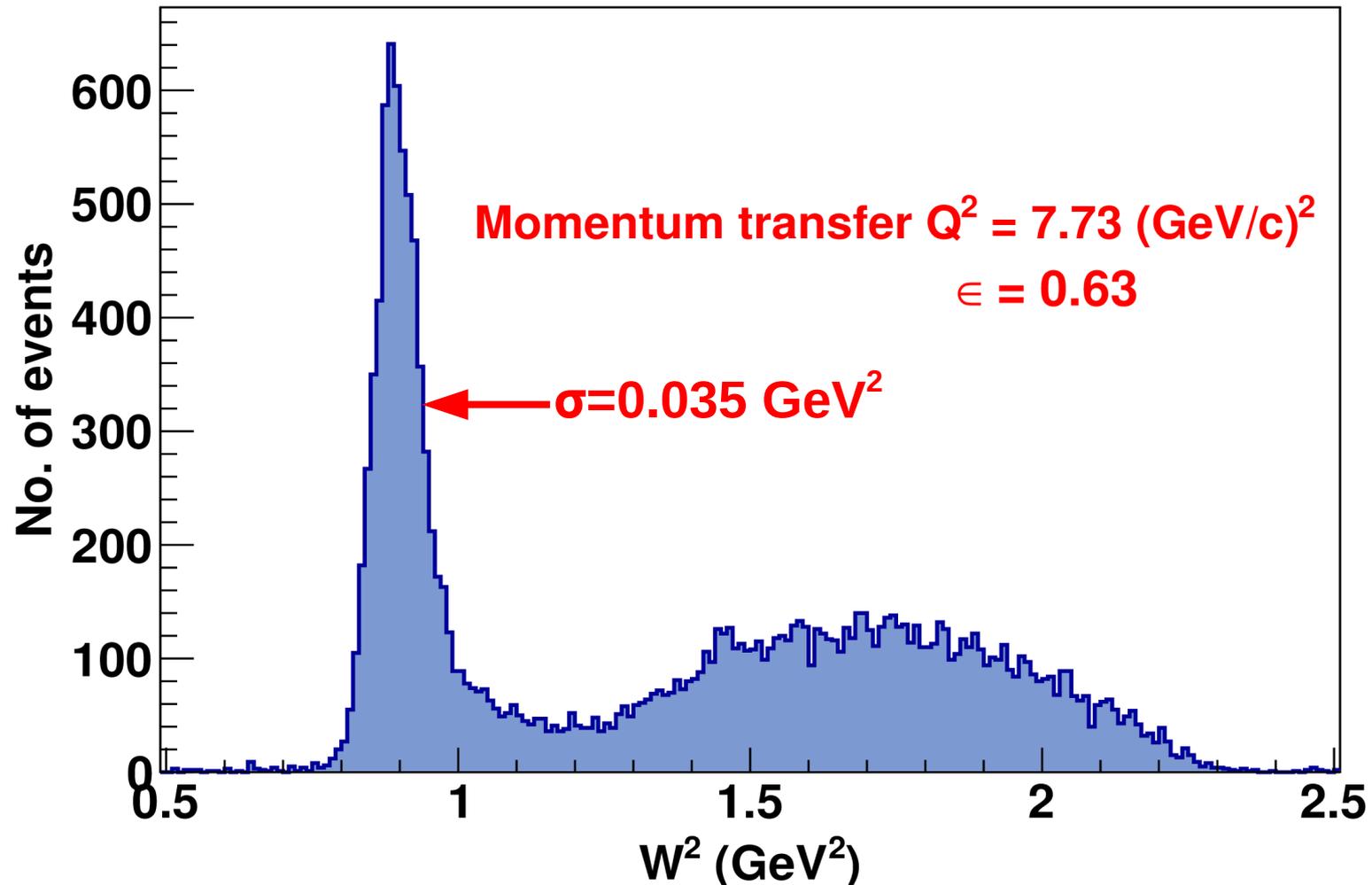
Straw Chambers

- One Straw Chamber installed in each HRS
- 3 U and 3 V planes
- U-V angle: 45° to horizontal
- 170 straws per plane
- Wire spacing: 1.095 cm

- Help resolve ambiguous tracks from VDC
- Improve tracking
- Useful for high rates experiments (APEX)

Straw

wire

Proton trajecory

Straw chamber

VDC
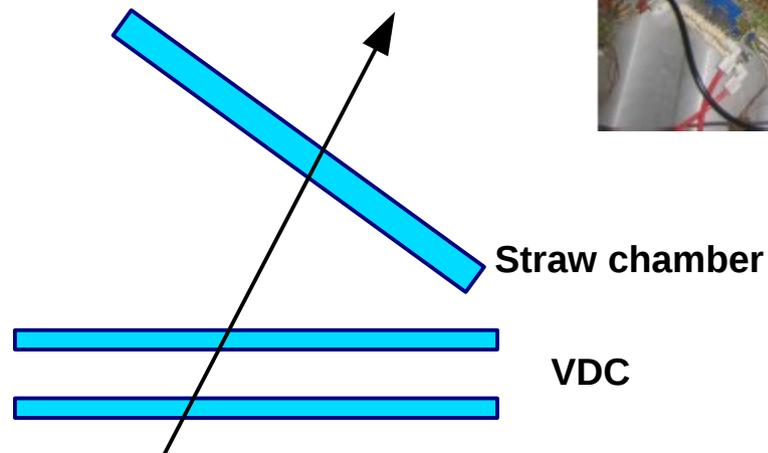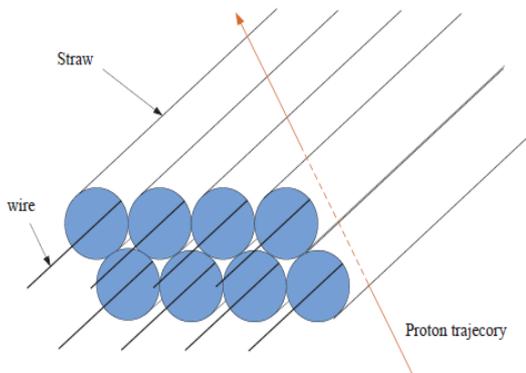
Tools for Event Display
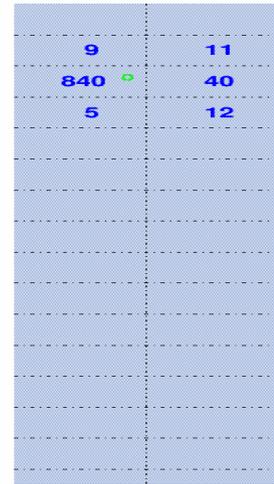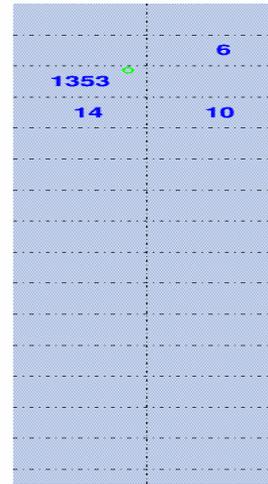
One-cluster event
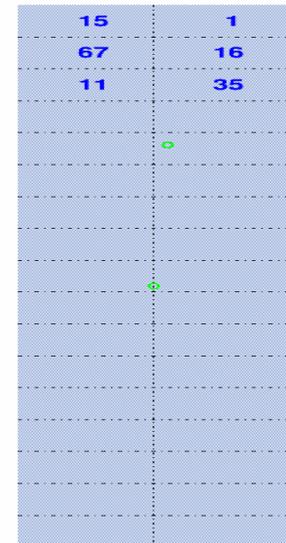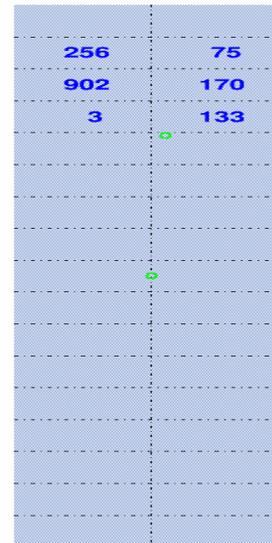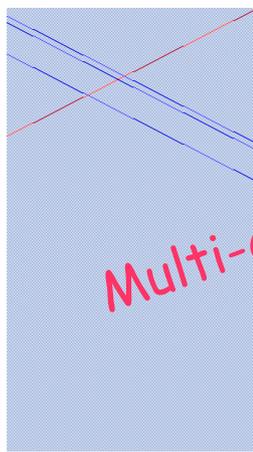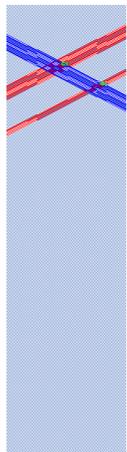
Multi-cluster event

VDC   VDC   FPP   S2m   PRL1   PRL2

Tracking with Straw Chambers

Analysis of multi-cluster events in VDC:

- Select events with one cluster in bottom VDC and straw chambers but more than one clusters in top VDC

- Reconstruct track using clusters in bottom VDC and straw chambers (disregarding clusters in top VDC)

- Reconstructed track is then used to calculate target and kinematic variables

Fraction of one cluster events in VDC:
$N_{single}/N_{total} = 21790/23831 = 0.914$

Squared invariant mass of recoil system (GeV^2)

Electron events
One cluster in all 4 vdc planes
$\sigma = 0.039 GeV^2$
$N_{elastic}/N_{total} = 8959/21790 = 0.411$

W^2 (GeV^2)

One cluster in bottom VDC and straw chamber more than one cluster in top VDC
$\sigma = 0.047 GeV^2$
$N_{elastic}/N_{total} = 218/543 = 0.401$
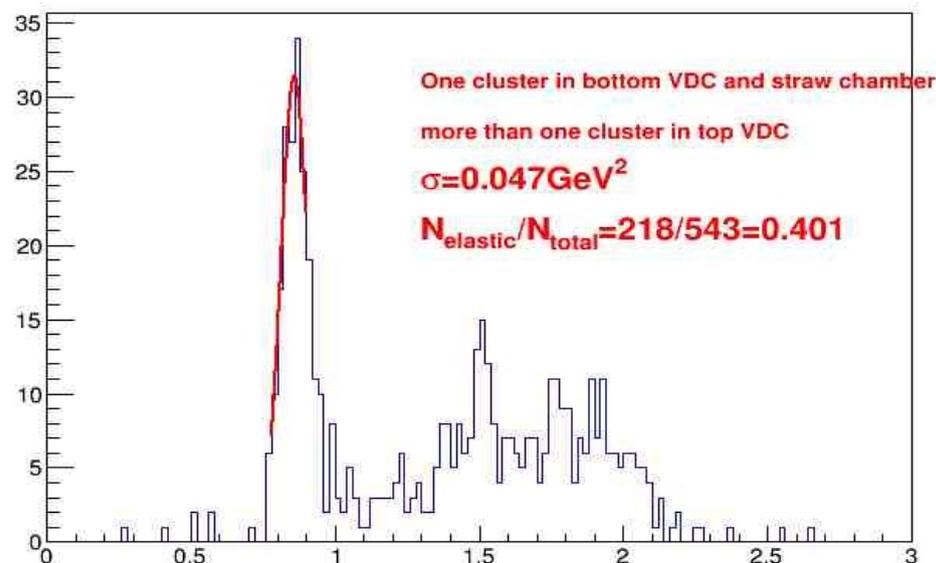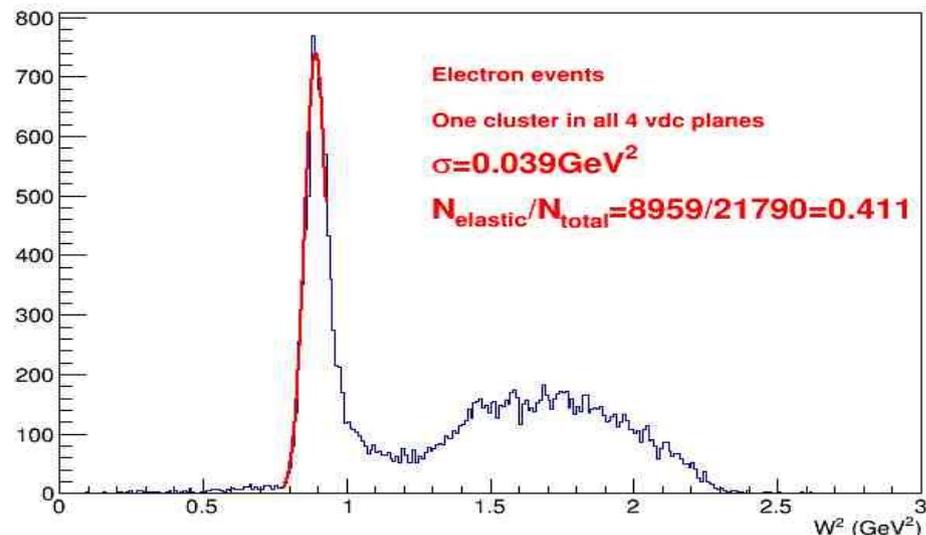
Multi-cluster events have elastic electrons and they need to be taken into account for calculation of cross section

Future Plans

- Continue the work of HRS tracking with straw chamber

- Tuning of SOS quad for right HRS and optics calibration

- Implement EDTM electronics on right HRS

- Study trigger efficiency, particle ID efficiency, etc.

- Possibility of using GEM detector as an active sieve slit

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Summary

- Detectors on both HRSs were checked out and proved to work reliably

- Optics calibration results for GMp experiment are shown

- Analysis of multi-cluster events with straw chamber is successful and can benefit other high rate experiments like APEX

- SOS quad was installed on right HRS and will be used for GMp experiment