Instrumentation and analysis progress for g2p experiment

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On behalf of the E08-027(g2p) collaboration

Jefferson Lab

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g2p collaboration

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  - Don Crabb(UVA)
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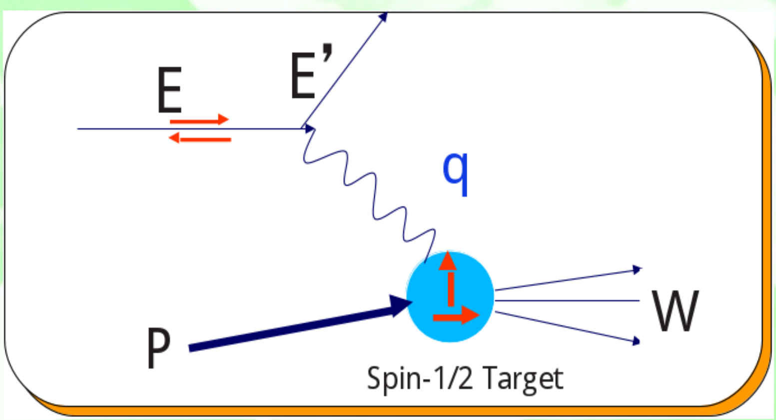
  - Melissa Cummings(W&M)
  - Min Huang(Duke)
  - Pengjia Zhu(USTC)
  - Toby Badman(UNH)
  - Ryan Zielinski(UNH)
- Institutions

  20 institutions

  72 collabrators

Introduction

- The g2p experiment measured the proton structure function g2 in the low Q2 region (0.02–0.2 GeV2) last spring for the first time
- Goal: 5% for cross section and 5% for asymmetries
- Standard Hall A High Resolution Spectrometer (HRS) with detectors
- Polarized NH3 target used with strong target field,beam depolarization effect limited beam current to 50nA
- Septum magnet added for 6 deg scattered electron angle detection
- New beamline instrumentations installed for low current, such as slow raster, tungsten calorimeter used for calibrating beam current monitor, superharp for calibrating beam position monitor
- Any points Jie mentioned in last presentation



$Q^2 \;\; 0.02-0.20\,GeV^2$

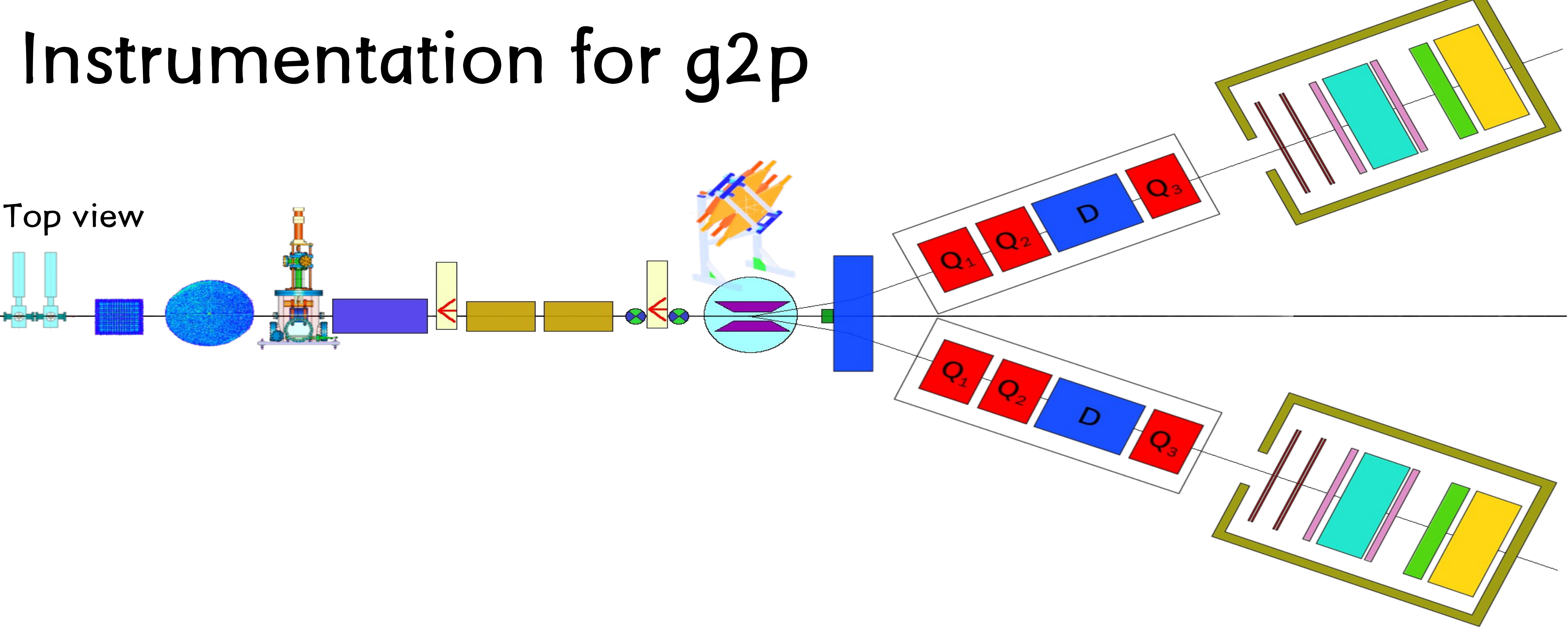
6^o *forward angle detection*

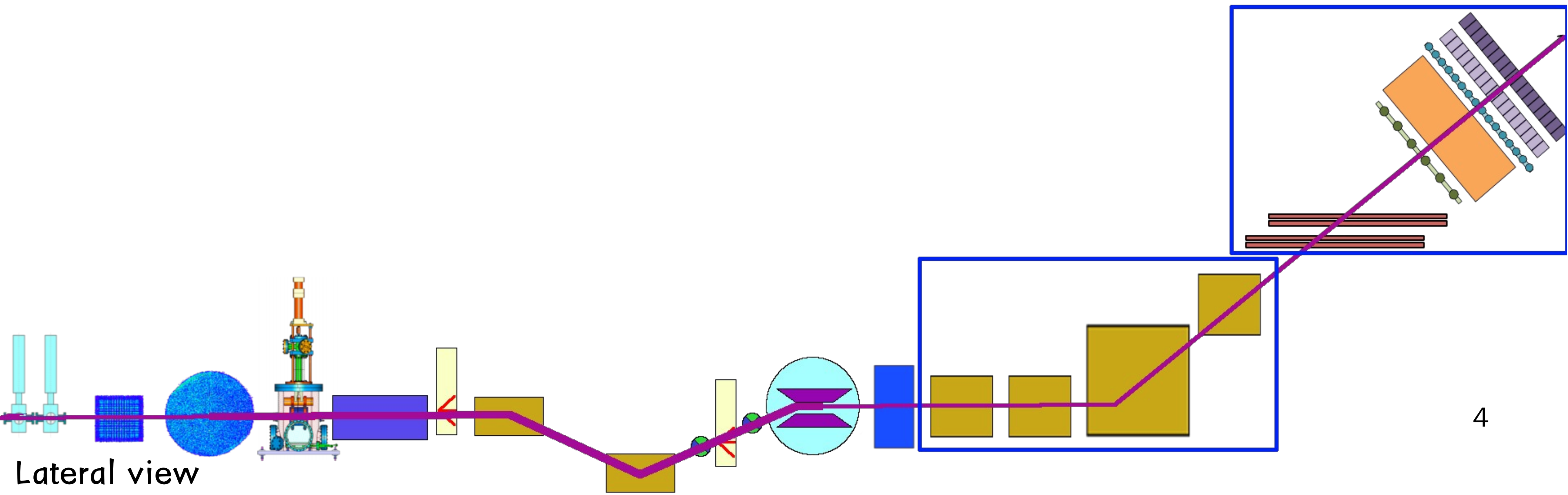
$Luminorsity: 10^{34}-10^{35}\,cm^{-2}s^{-1}$

$Energy: 1.1-3.3GeV$

Instrumentation for g2p

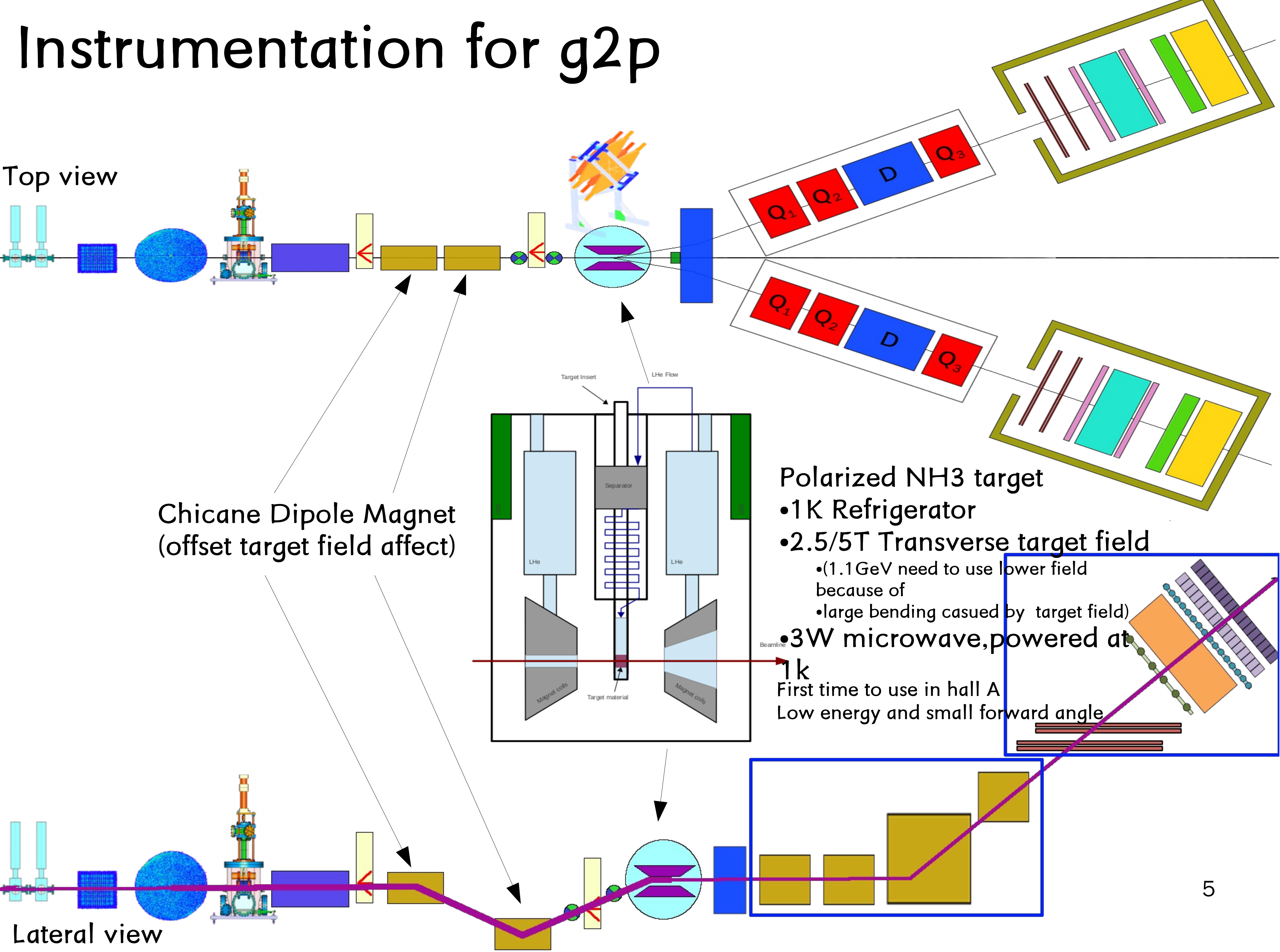
Top view





Lateral view

Instrumentation for g2p

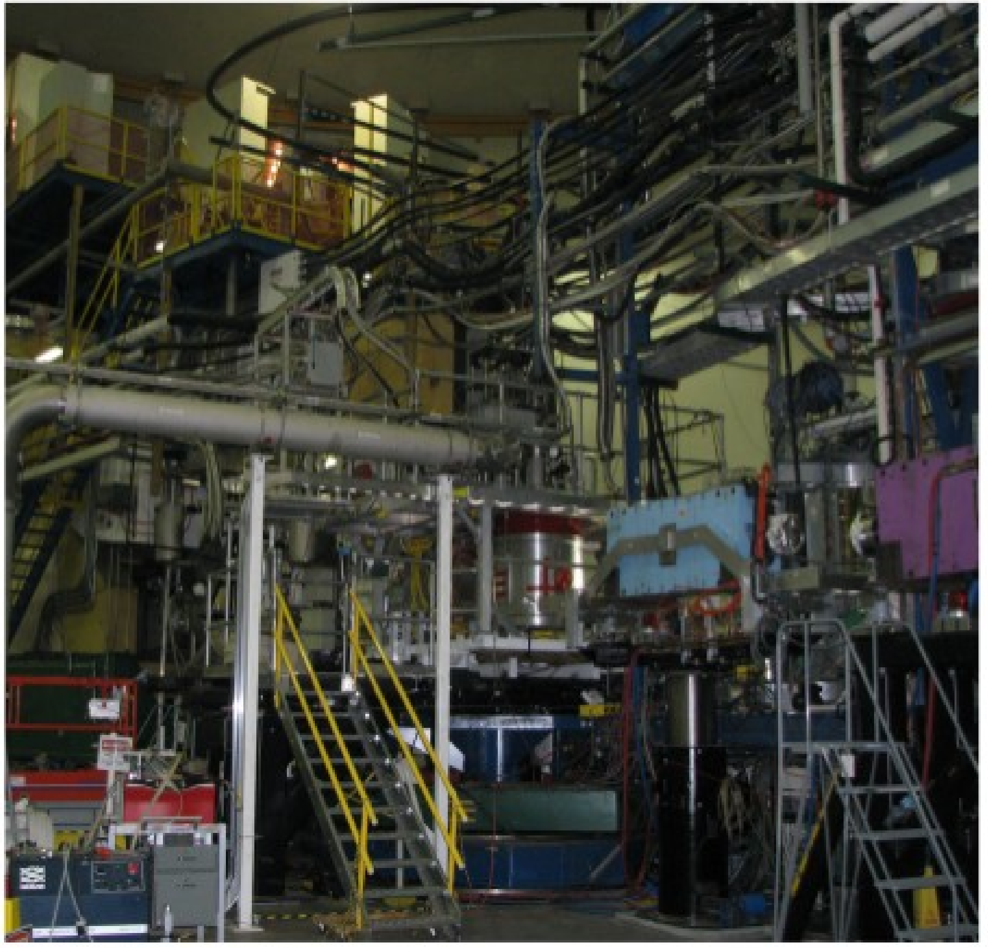


Polarized NH3 target
- 1K Refrigerator
- 2.5/5T Transverse target field
  - (1.1GeV need to use lower field because of
  - large bending casued by target field)
- 3W microwave,powered at 1k

First time to use in hall A
Low energy and small forward angle

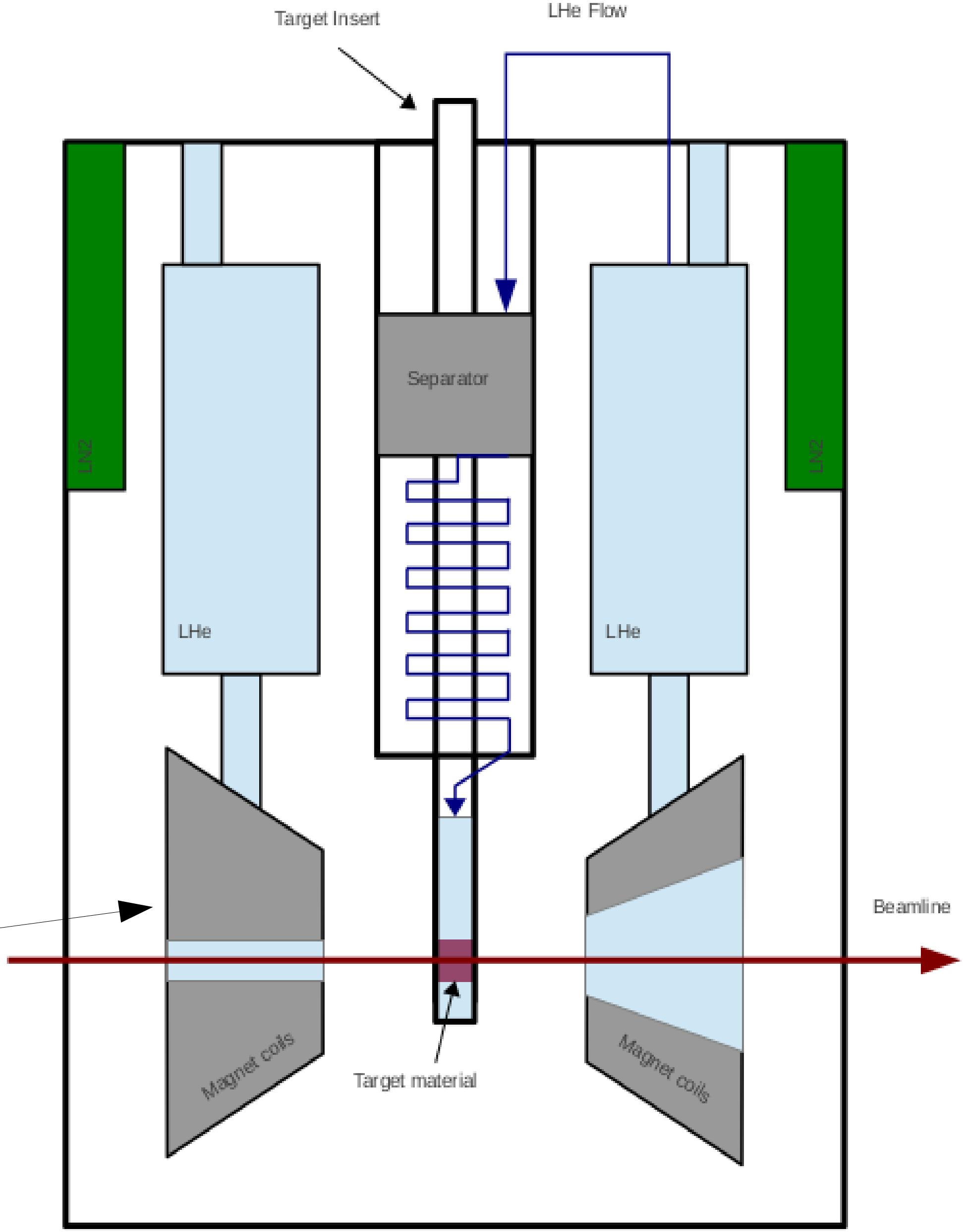
Target setup improvements

- Refrigerator was constructed using improved techniques
  - Improved performance:1.1k with 3W microwave power
- Last minute failure of original(UVa/JLab) magnet
  - Hall B magnet was able to be modified as a replacement
  - Redesigned target insert
  - Less cumbersome
- More reliable



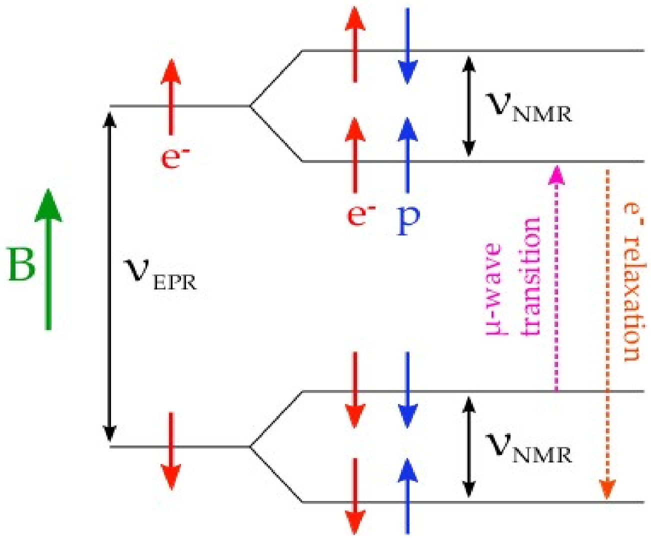
Target Magnetic Field

- Superconducting NbTi split-pair
- Capable of 10−4 uniformity over cylindrical volume 2cm in diameter and 2cm long
- Open geometry allows for beam to pass through longitudinal or transverse



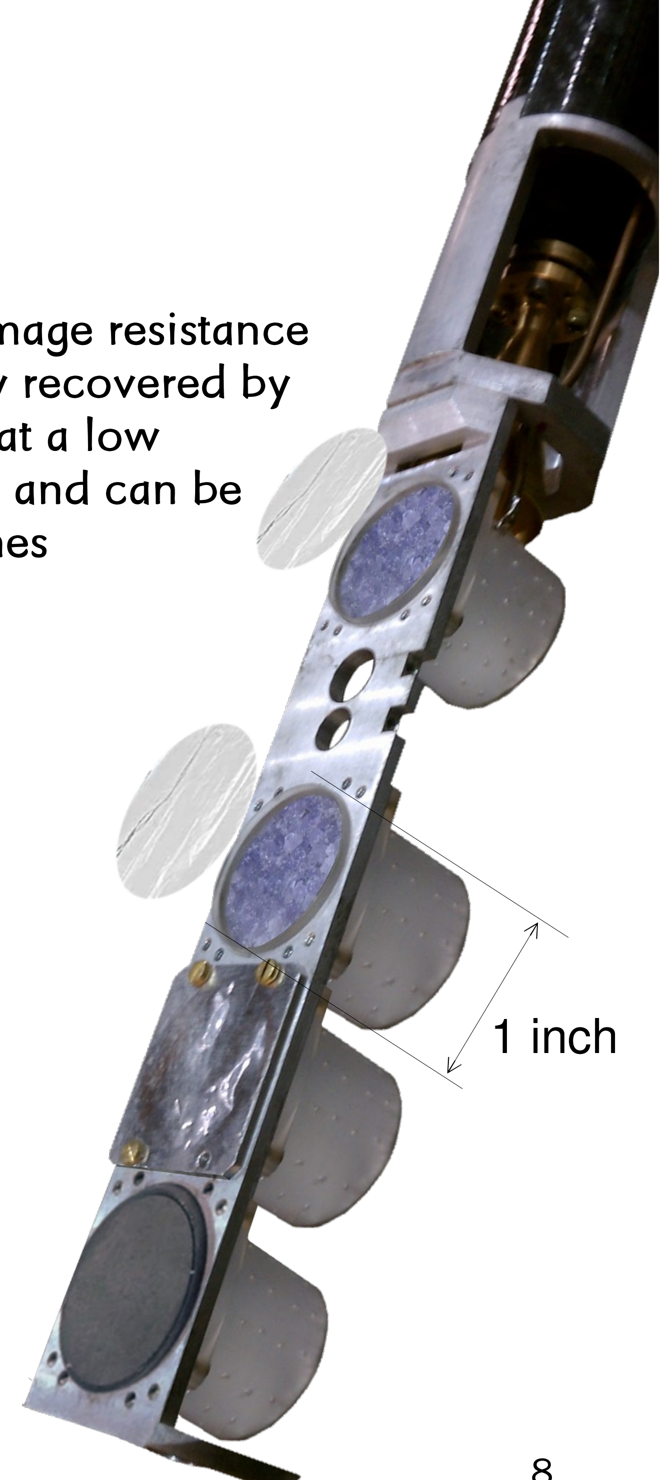
Target material

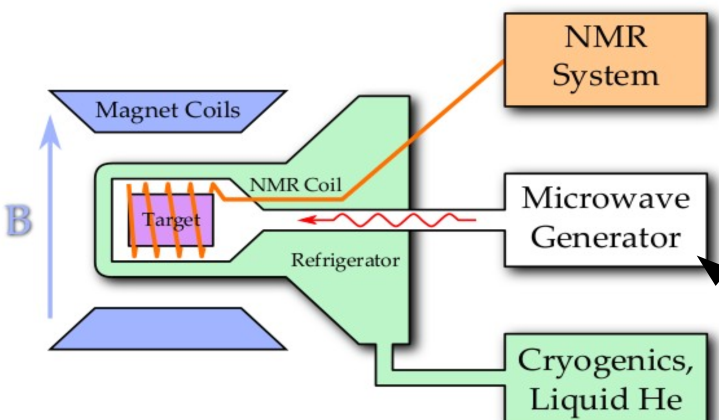
Dynamic Nuclear Polarization



Why NH3?

- High radiation damage resistance
- Can be completely recovered by annealing sample at a low temperature(~77k) and can be repeated many times



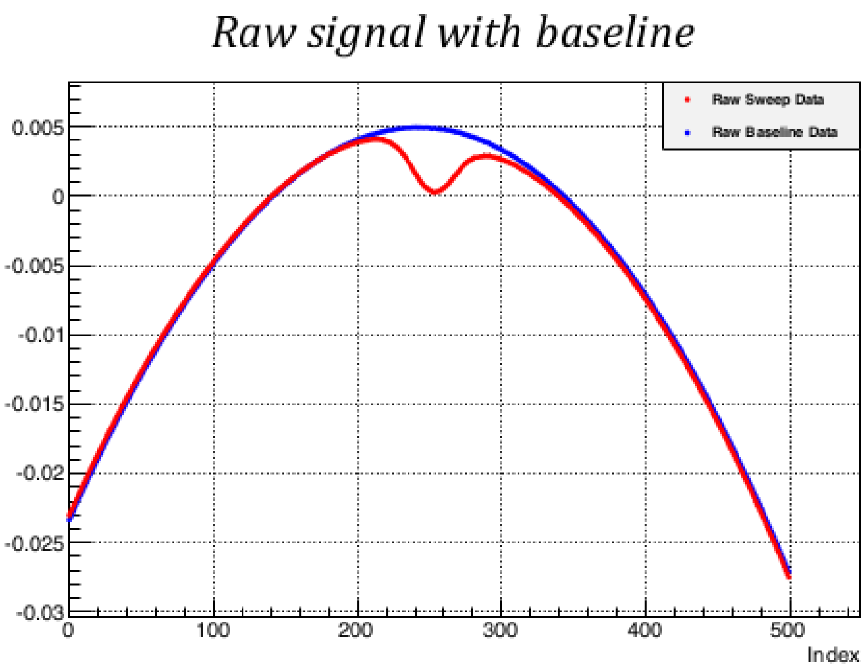


Calibrate NMR:
Thermal equilibrium(TE)

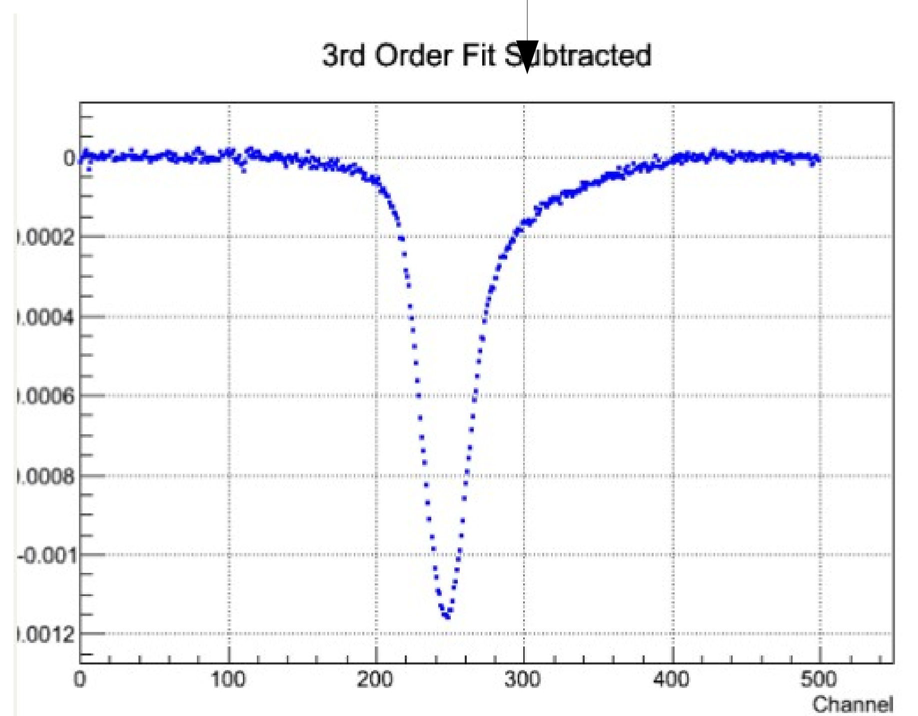
$$Polarization = \tanh\left[\frac{\mu_B H}{kt}\right]$$

5T ~140GHz
2.5T ~ 70GHz

NMR signal



3[rd] order polynomilal fit for raw signal to subtract background



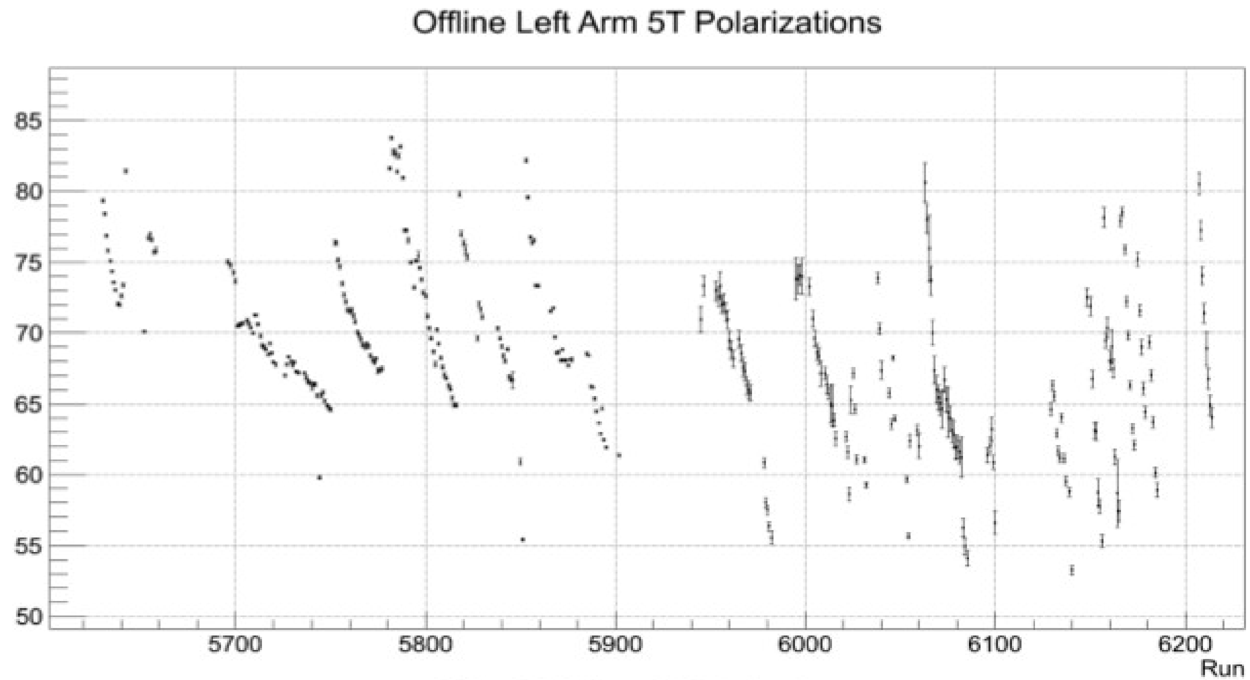
Courtesy by Toby Badman

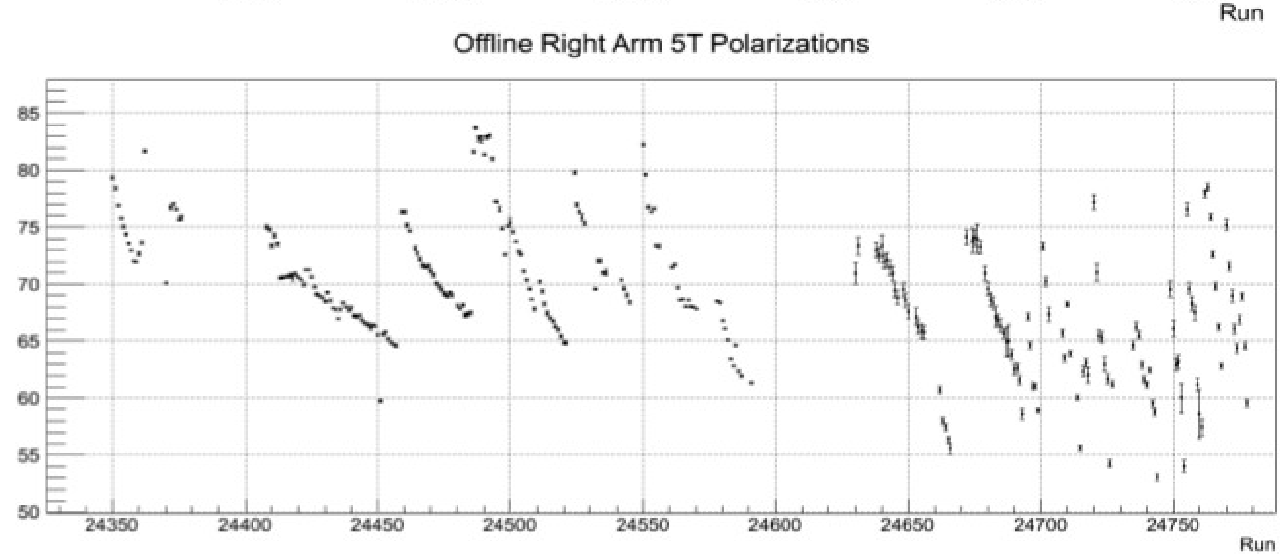
Final offline polarization results

P=C*A
A = integration area
P = polarization
C calibrated from Thermal equilibrium

Main uncertainty:
- From fit for integration area <3%
- TE measurement
  - Target field reading ~2%
  - Temperature comverted from pressure measurement in target nose

Final uncertainty 3.5%~4%





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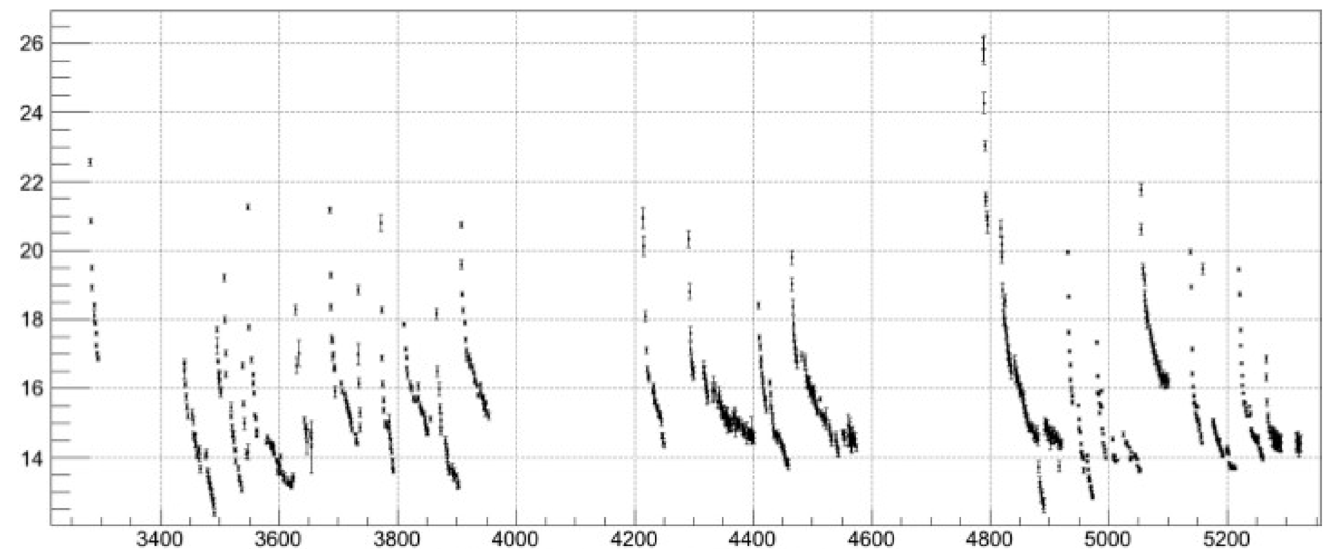
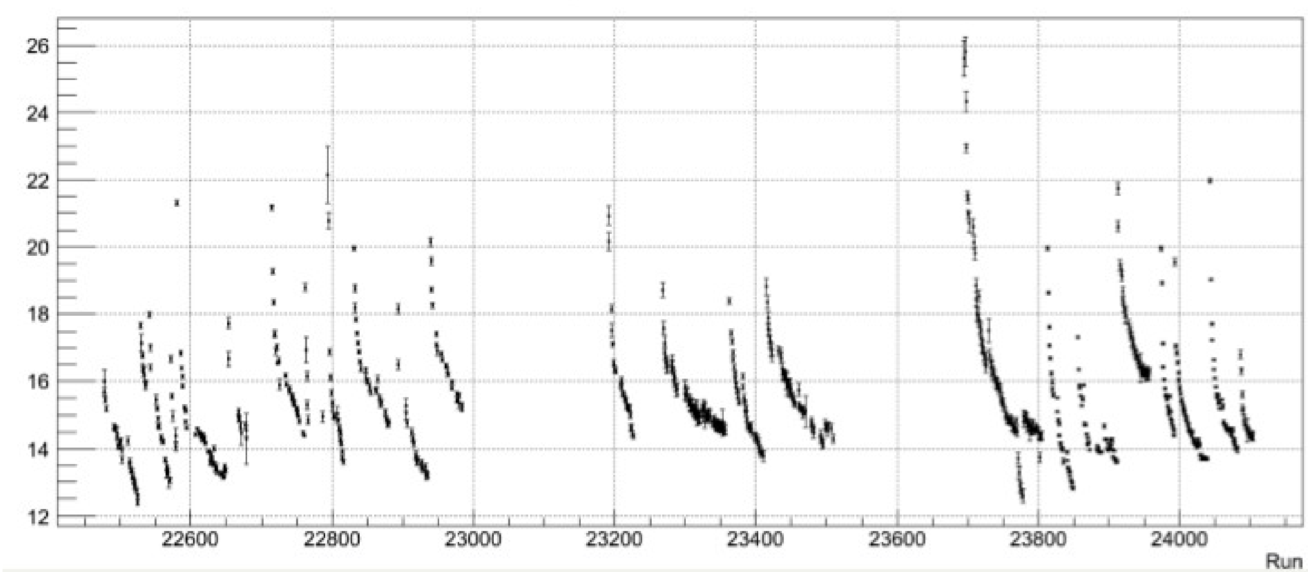
Offline Left Arm 2.5T Polarizations

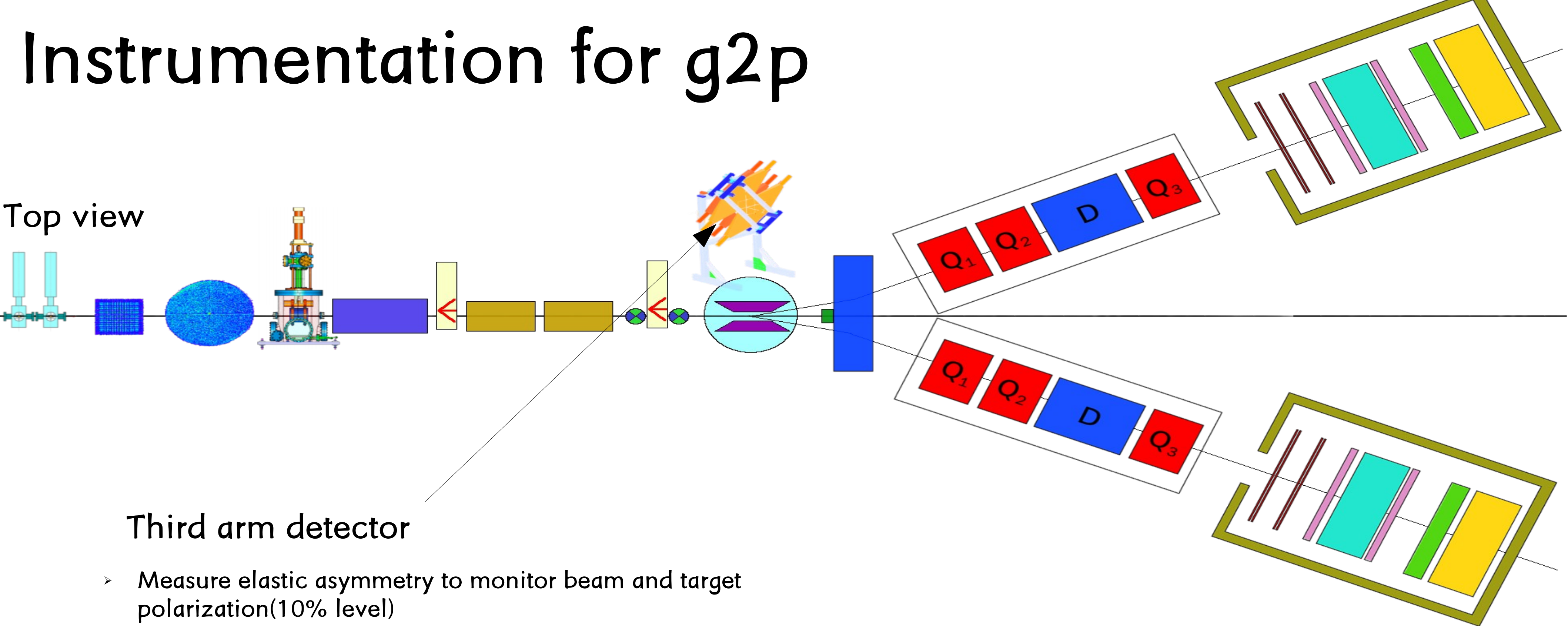


Offline Right Arm 2.5T Polarizations



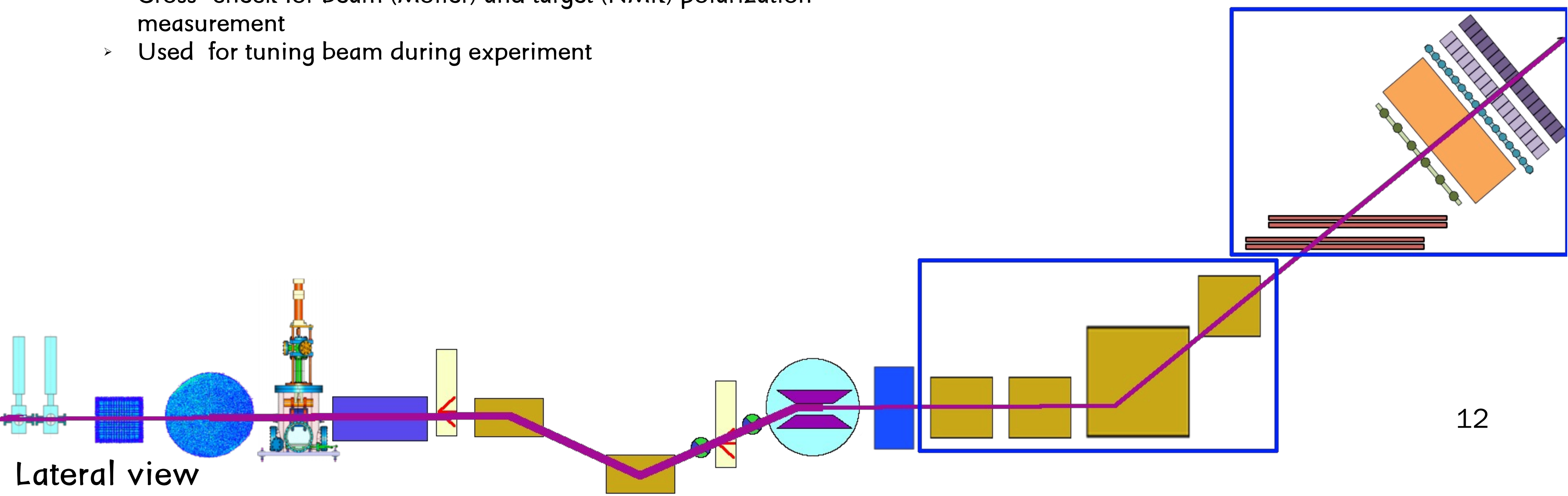
Courtesy by Toby Badman

Instrumentation for g2p

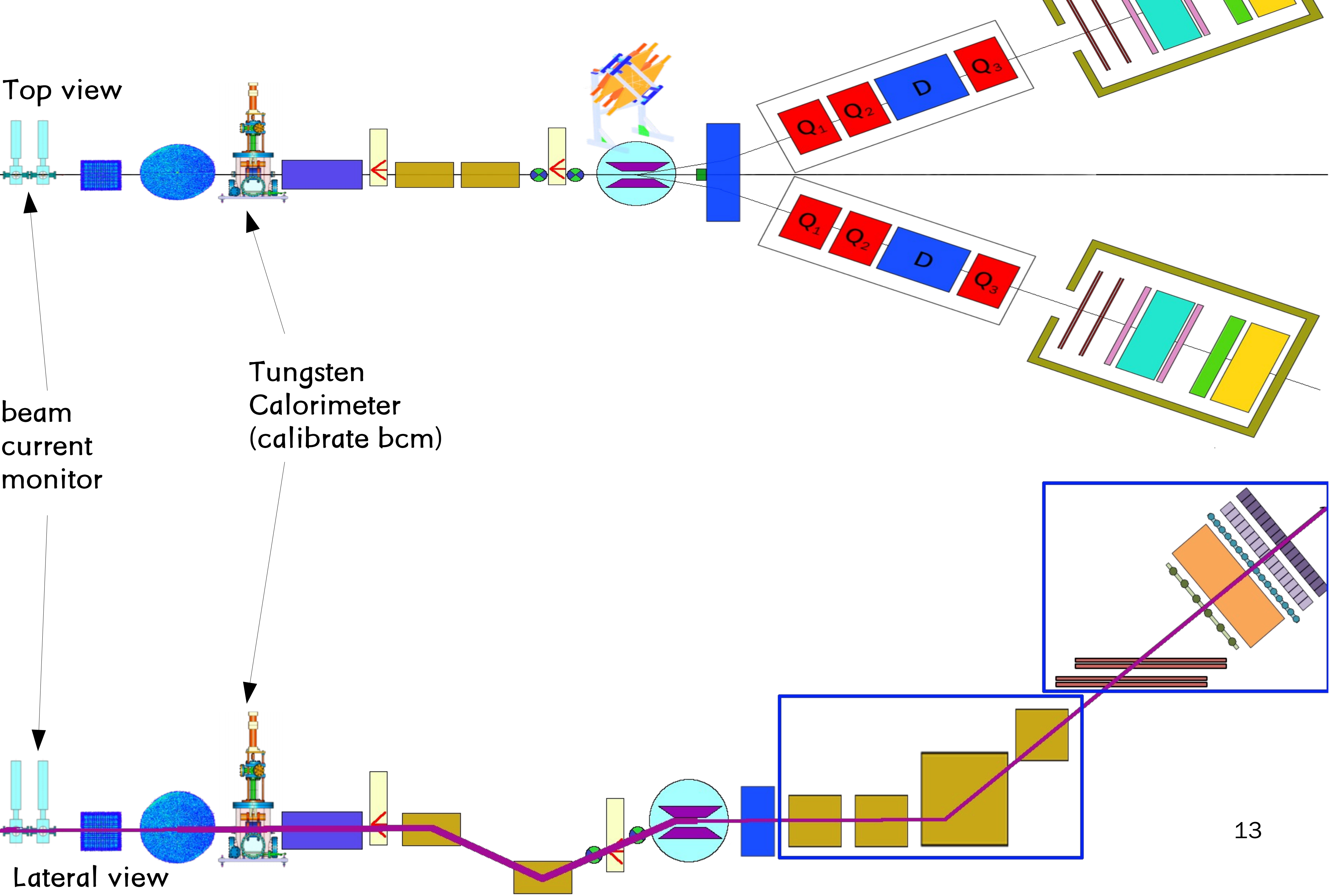


Third arm detector

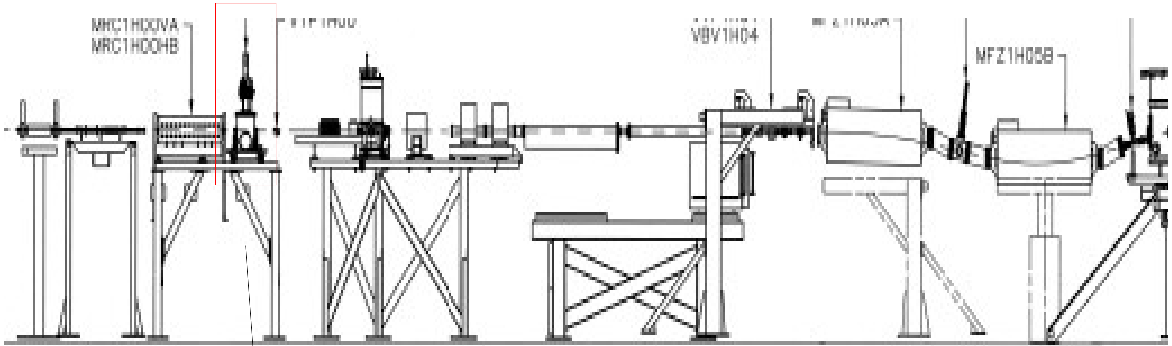
- Measure elastic asymmetry to monitor beam and target polarization(10% level)
    - A_raw = P_b * P_t * D * A_phy
- Cross-check for beam (Moller) and target (NMR) polarization measurement
- Used for tuning beam during experiment



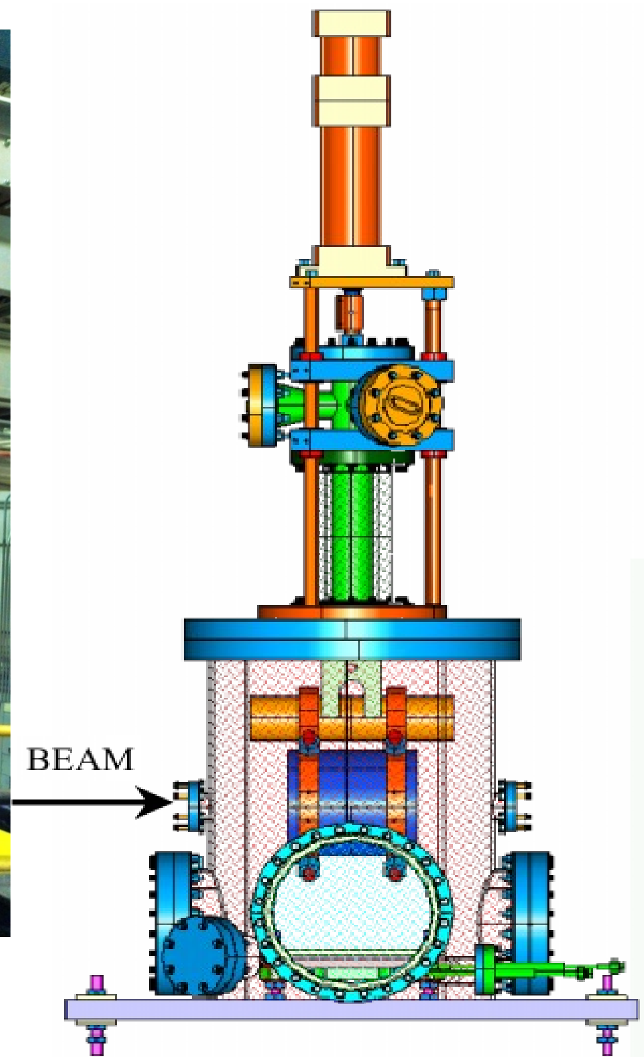
Instrumentation for g2p



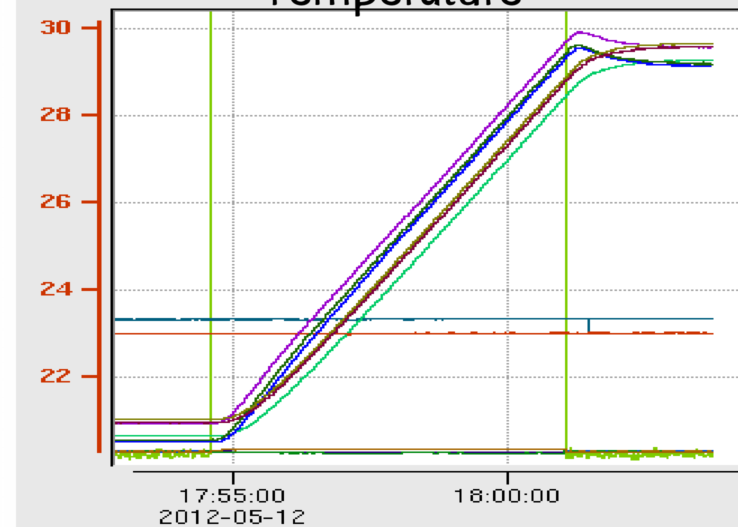
Tungsten Calorimeter --------> Calibrate Beam Current Monitor



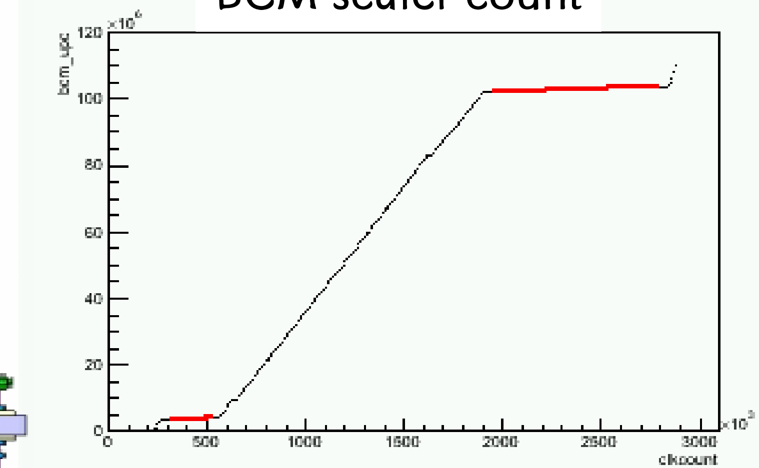
Get Total Charge from Temperature
Then Calibrate BCM count



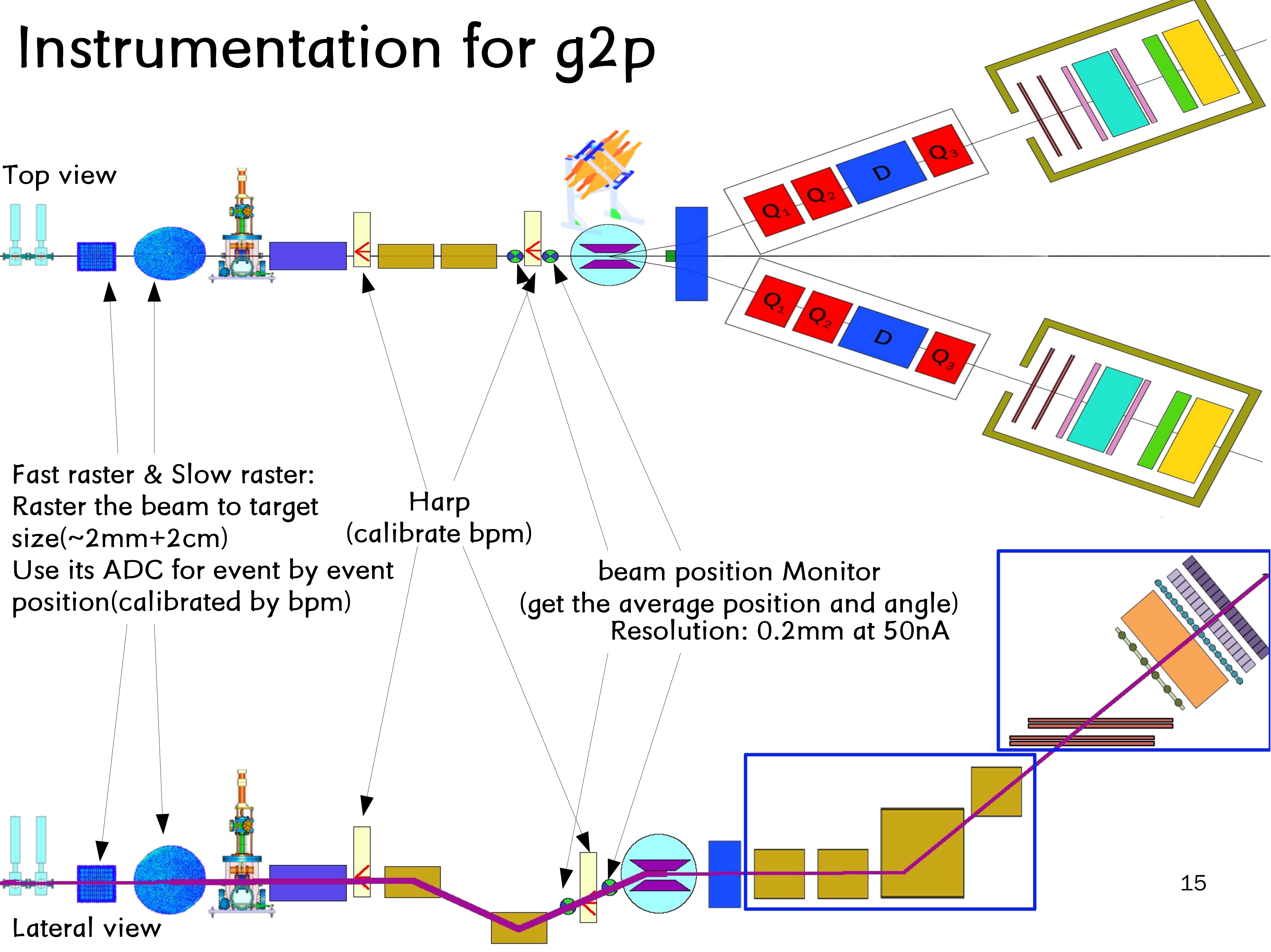
Temperature



BCM scaler count



Instrumentation for g2p



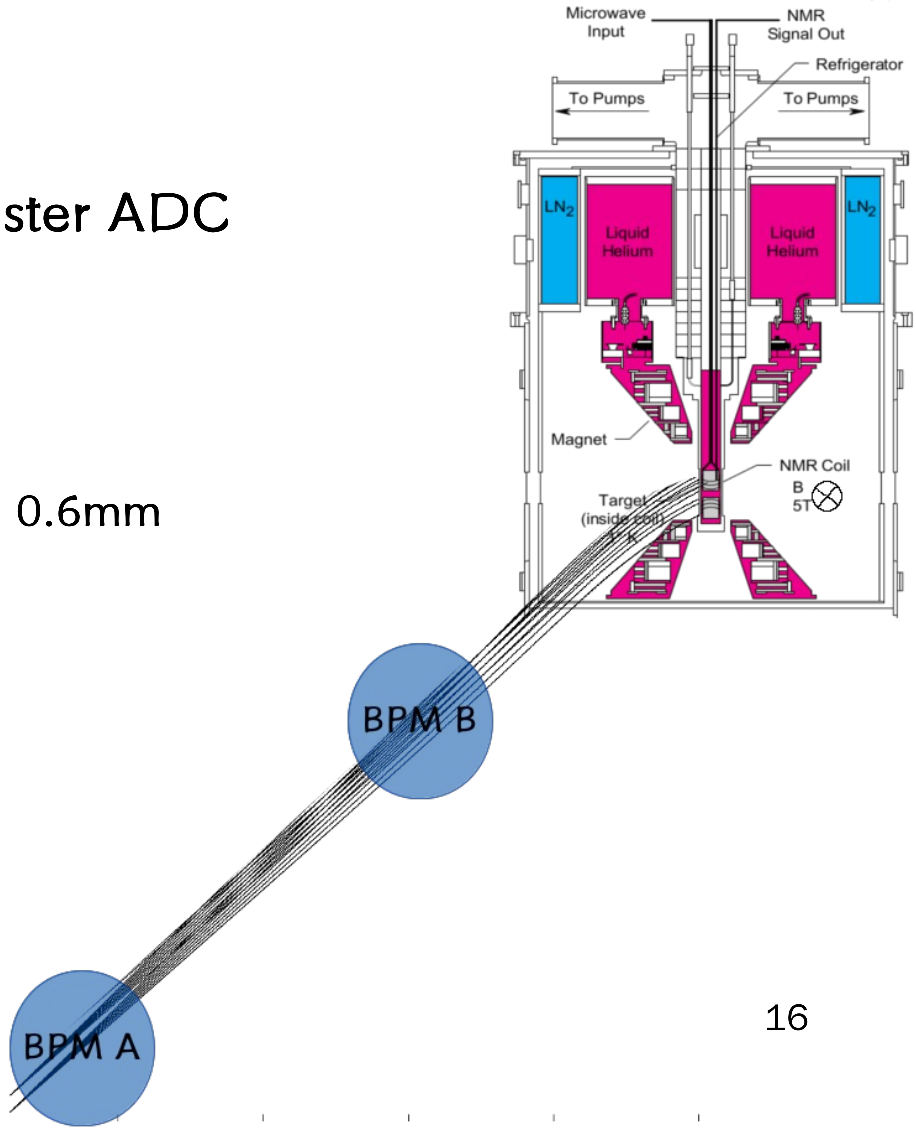
Beam position reconstruction

--Get the beam position at target for each event

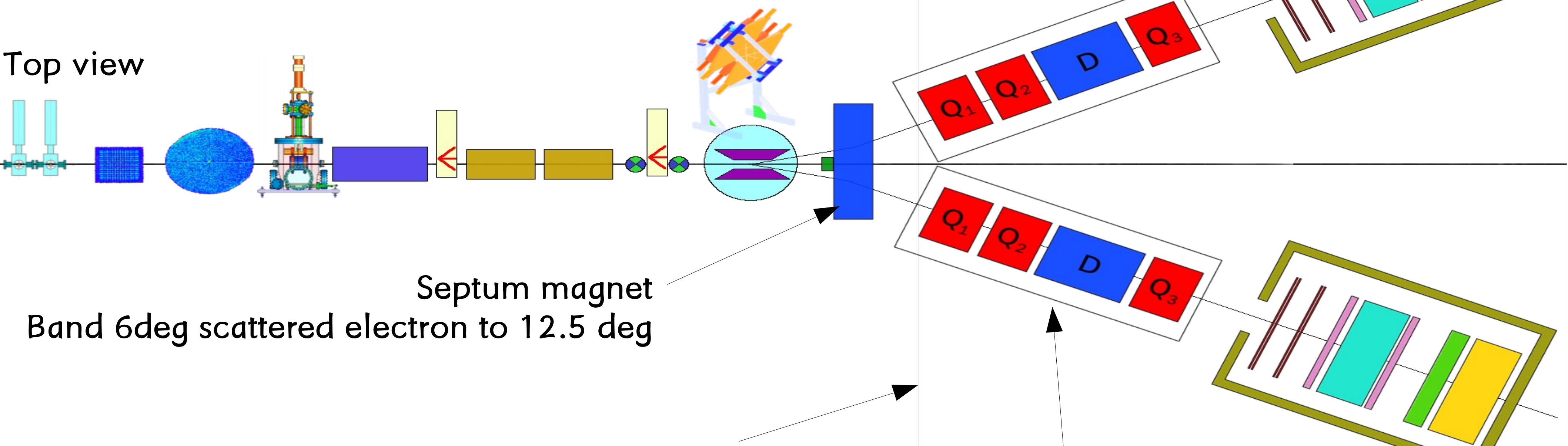
- Use harp to calibrate BPM
- Use simulation to get transportation function from BPM to target
- Use BPM to calibrate raster ADC
- Final position=ave position from BPM
  + event by event position from raster ADC

Difficulties:

- Low current(low signal/noise ratio)
- BPMA and BPMB close to target
  --BPMA 0.9mm away from target,and BPMB 0.6mm
  Caused two problems:
    - larger position uncertainty at target
    - radiation damage
      --get worse signal/noise ratio



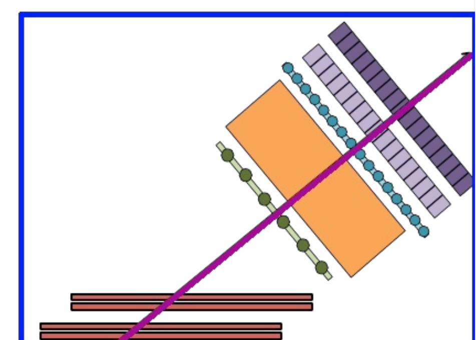
Instrumentation for g2p

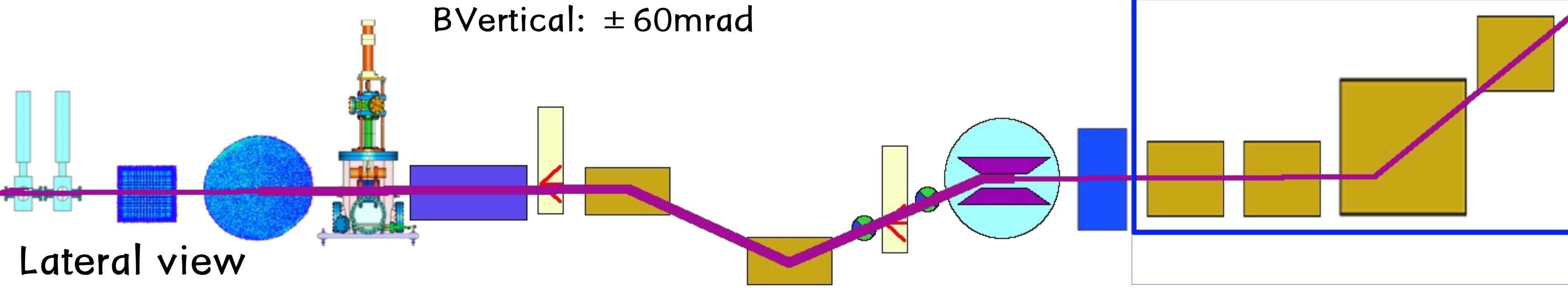


Hall A High Resolution Spectrometers
AHigh momentum resolution: 10e−4 level
over a range of 0.8−4.0GeV/c
BHigh momentum acceptance: | δ p/p|<4.5%
CWide range of angular settings
A12.5 −150 deg (LHRS)
B12.5 −130 deg(RHRS)
DSolid angle at δ p/p=0,y0=0: 6msr
EAngular acceptance:
AHorizontal: ± 30mrad
BVertical: ± 60mrad

Quadrupole & Dipole magnet

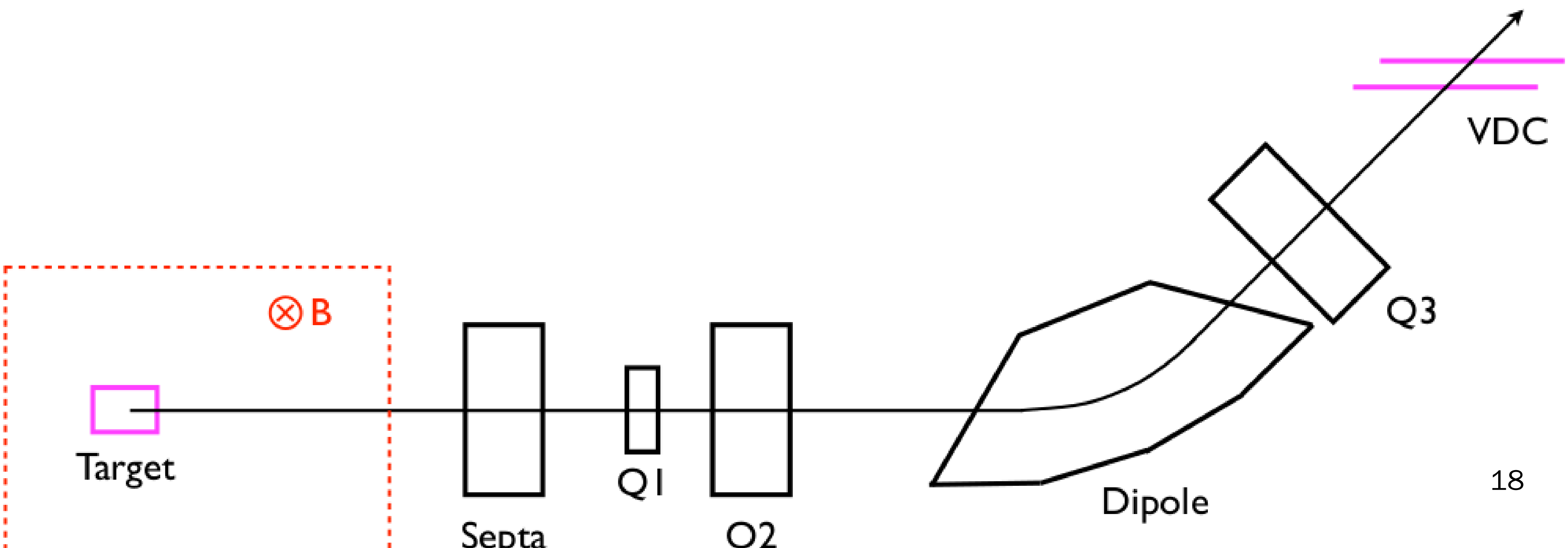
Spectrumeter Detector





Spectrumeter optics calibration

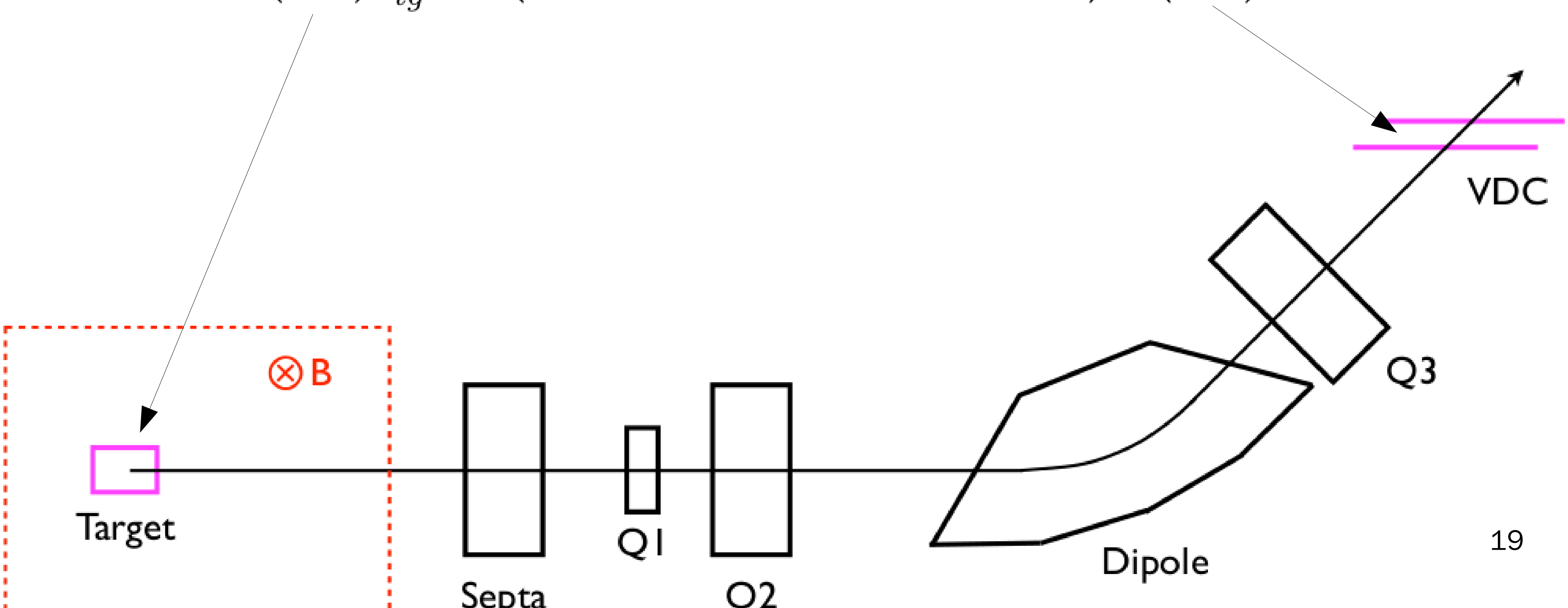
- HRS Magnets before Detector:
  - 3 quadrupole magnet to focus
  - 1 dipole to disperse on momentums
- Septum Magnet before HRS
- 2.5T/5T Target Magnet Field



Spectrumeter optics calibration

Optics study will provide a matrix to transform VDC readouts to kinematics variables which represents the effects of these magnets

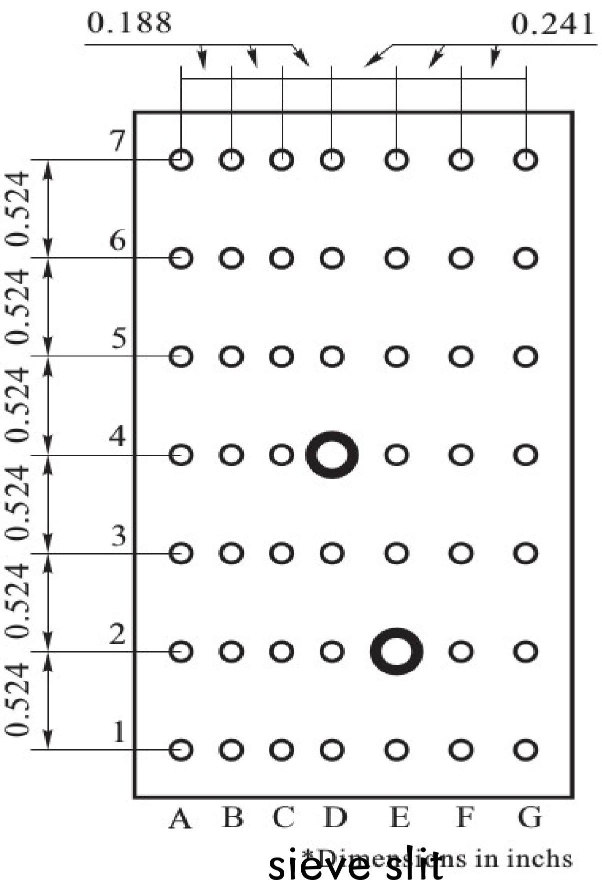
$$\begin{pmatrix} \delta \\ \theta \\ y \\ \phi \end{pmatrix}_{tg} = \begin{pmatrix} \langle\delta|x\rangle & \langle\delta|\theta\rangle & & \\ \langle\theta|x\rangle & \langle\theta|\theta\rangle & & \\ & & \langle y|y\rangle & \langle y|\phi\rangle \\ & & \langle\phi|y\rangle & \langle\phi|\phi\rangle \end{pmatrix} \begin{pmatrix} x \\ \theta \\ y \\ \phi \end{pmatrix}$$



Spectrumeter optics calibration

Will do as 2 situation:

- Without target field

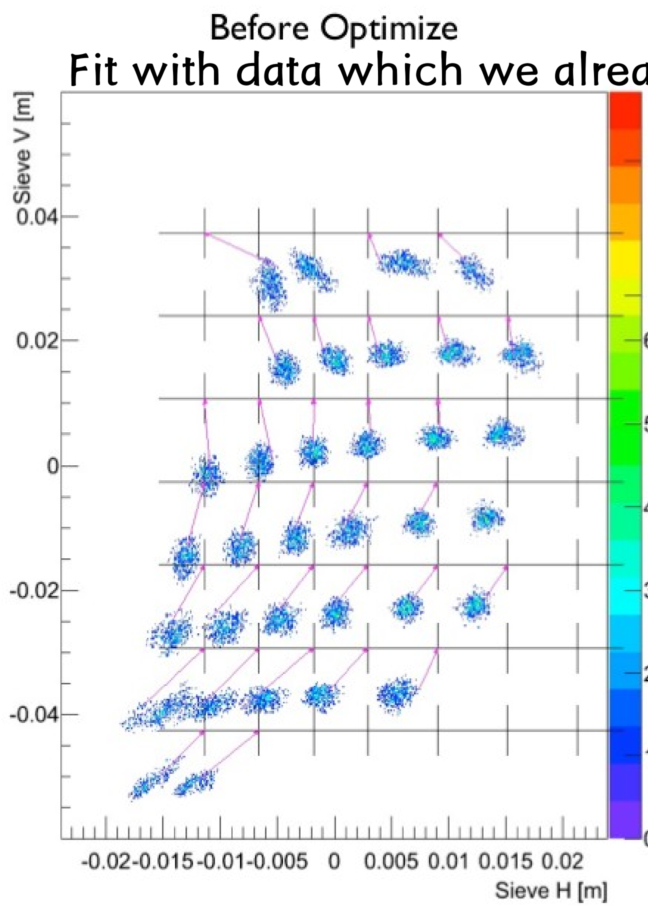


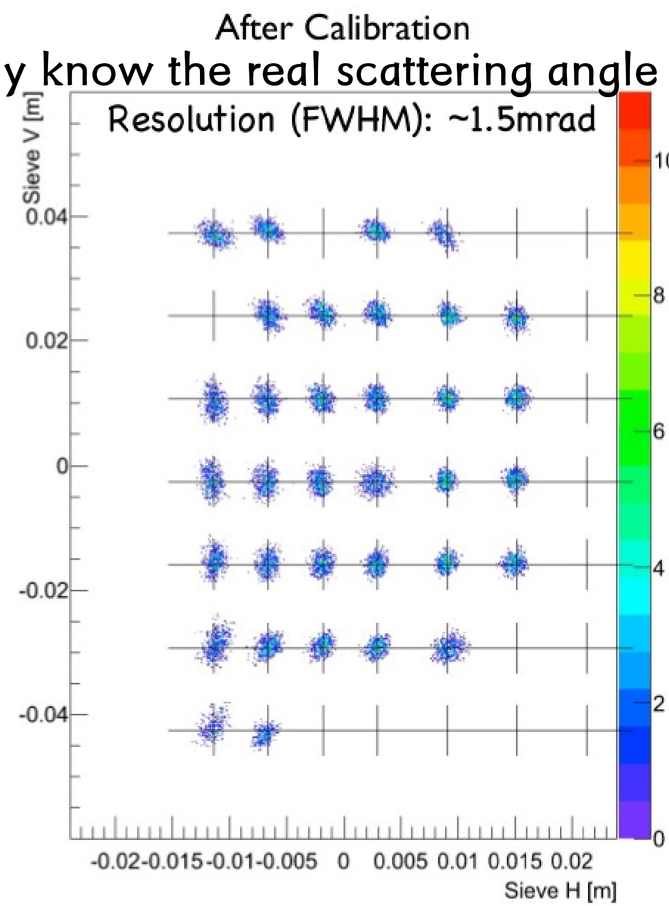
sieve slit

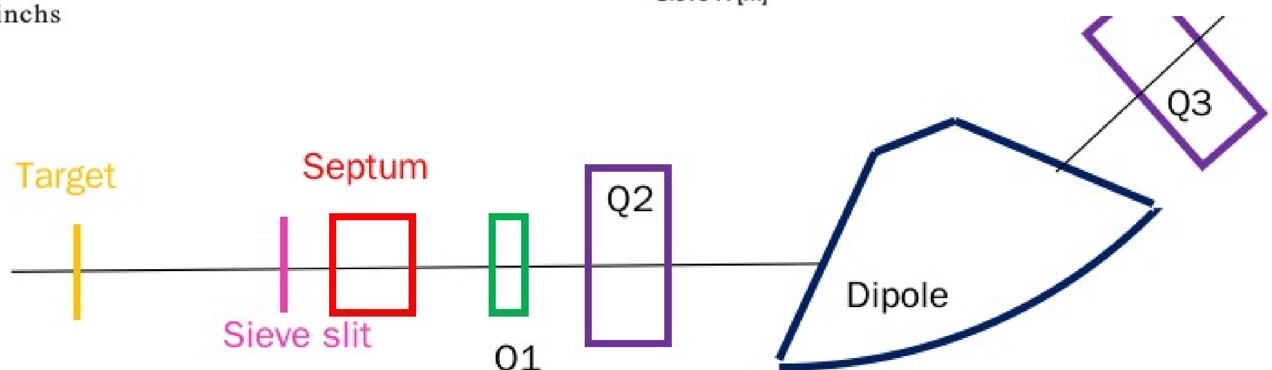
Angle calibration

- Calibrate the matrix elements

Fit with data which we already know the real scattering angle







Courtesy by Min Huang

Spectrumeter optics calibration

Will do as 2 situation:

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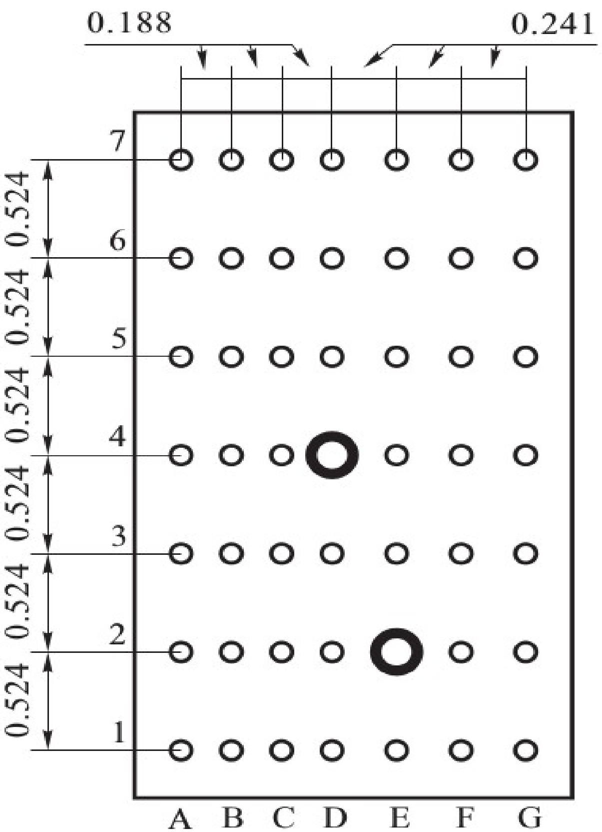
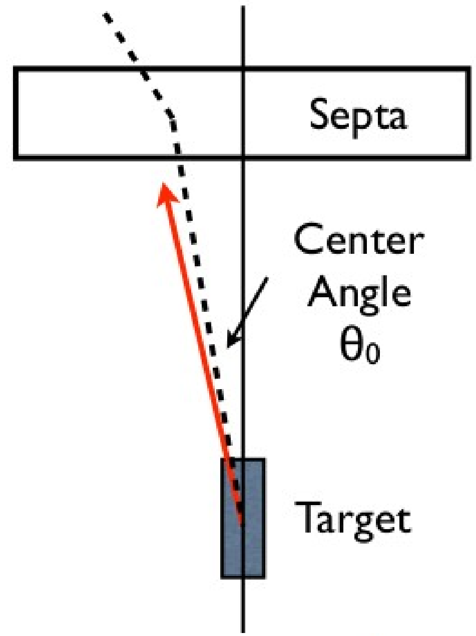


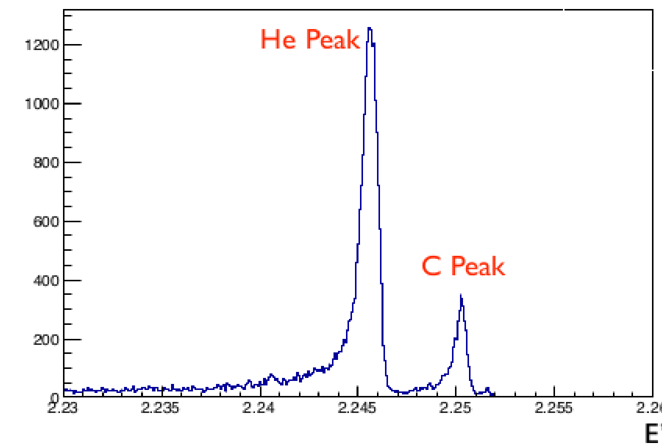
sieve slit

Angle calibration

- Determine center angle with high accuracy

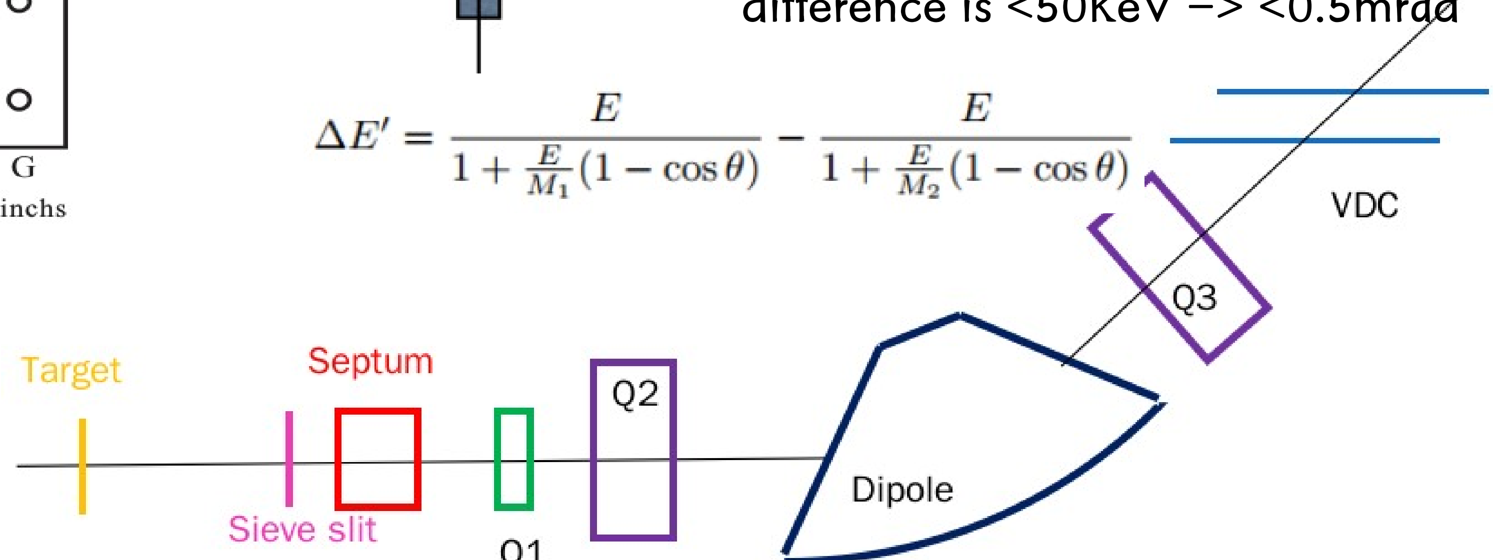


Direct measurement: ~1mrad



Idea: Use elastic scattering on different target material
The accuracy to determine this difference is <50KeV –> <0.5mrad

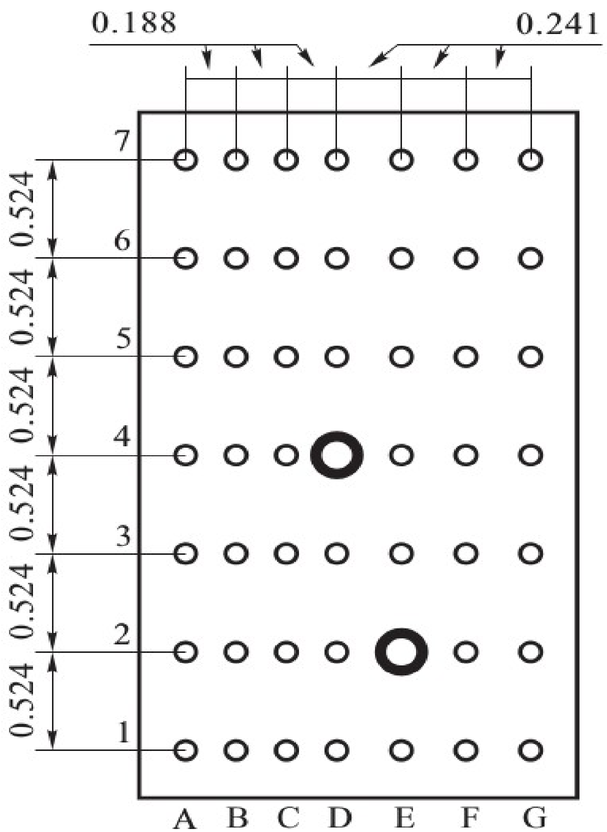
$$\Delta E' = \frac{E}{1+\frac{E}{M_1}(1-\cos\theta)} - \frac{E}{1+\frac{E}{M_2}(1-\cos\theta)}$$



Spectrumeter optics calibration

Will do as 2 situation:

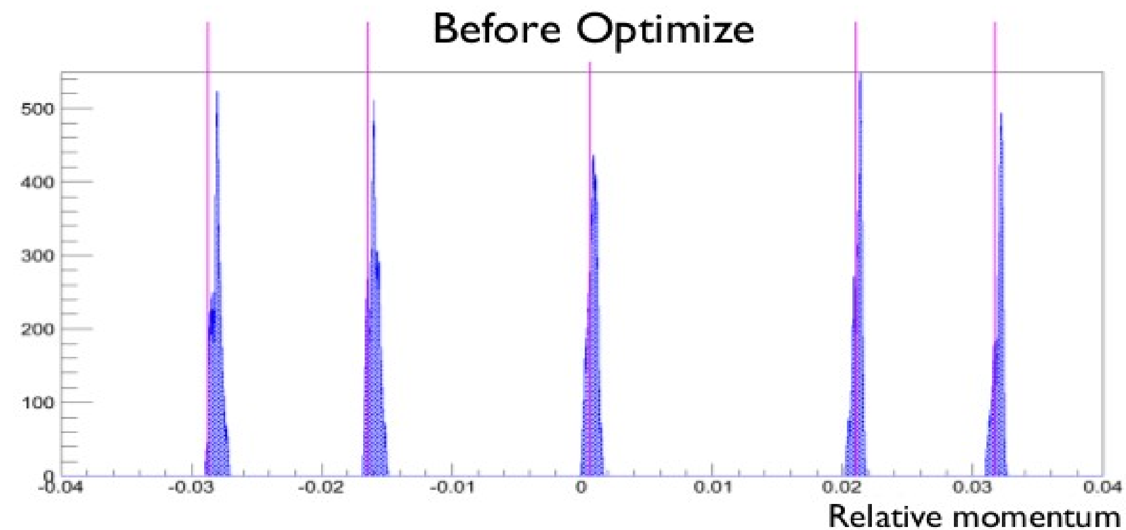
- Without target field

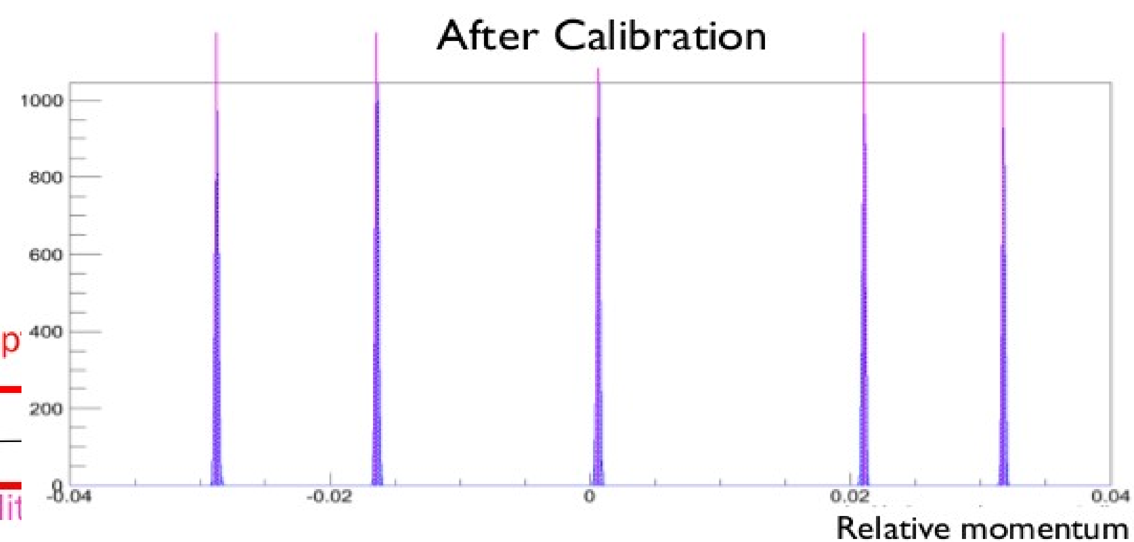


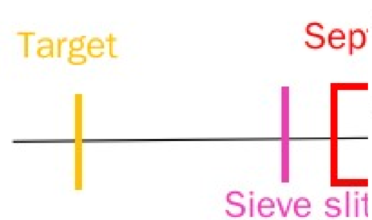
sieve slit

Momentum calibration

- Fit with data which we already know the real scattering momentum
- Elastic scattering on Carbon target
- Resolution (FWHM) ~2x10−4







Courtesy by Min Huang

Spectrumeter optics calibration

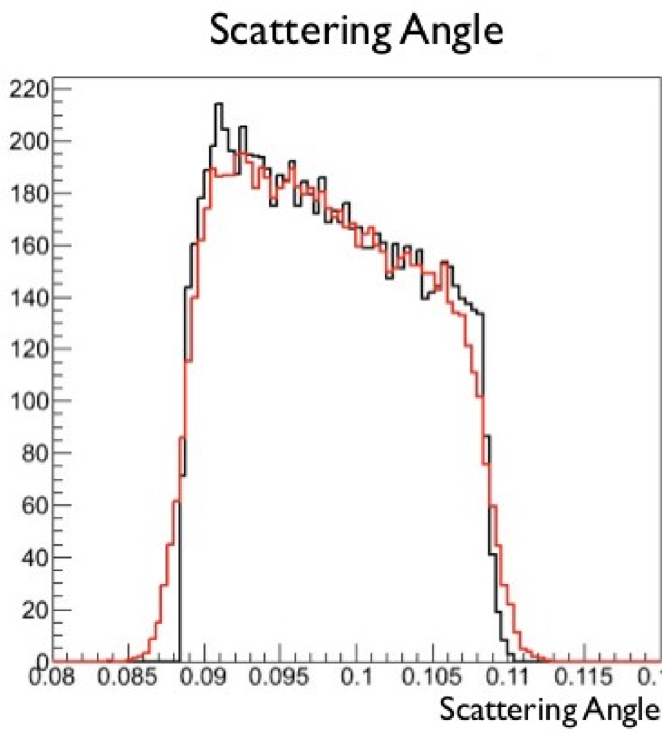
Momentum calibration

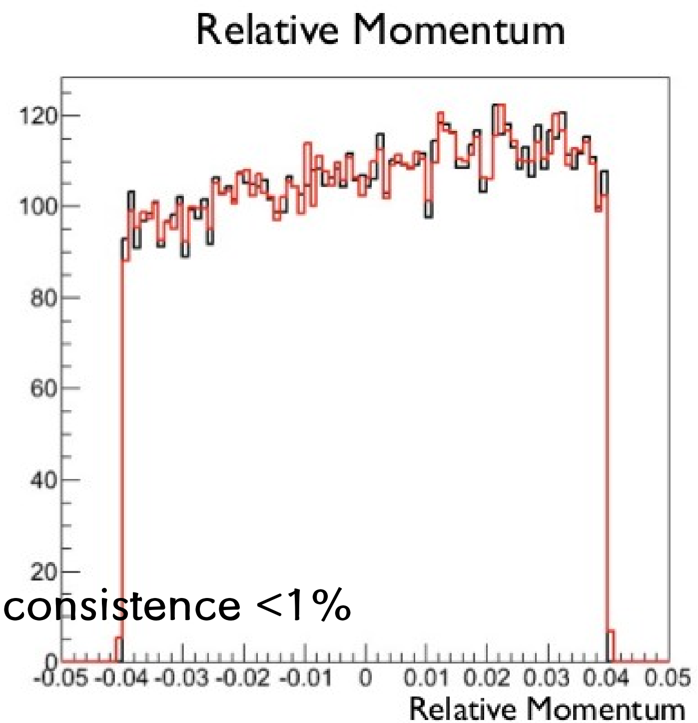
Will do as 2 situation:

- With target field

Separate to 2 part:

- Use the no target field result to deal with the reconstruction from VDC to sieve slit
- Use the field map to do a ray trace of the scattered particle from sieve slit to target



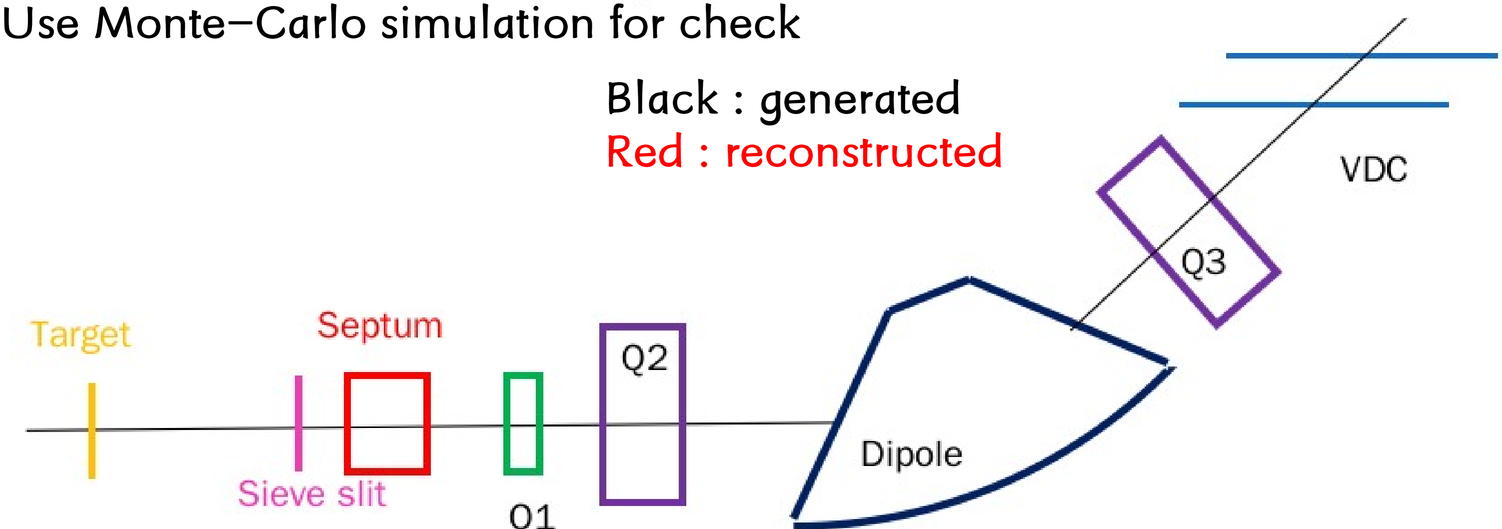


good consistence <1%

Use Monte−Carlo simulation for check

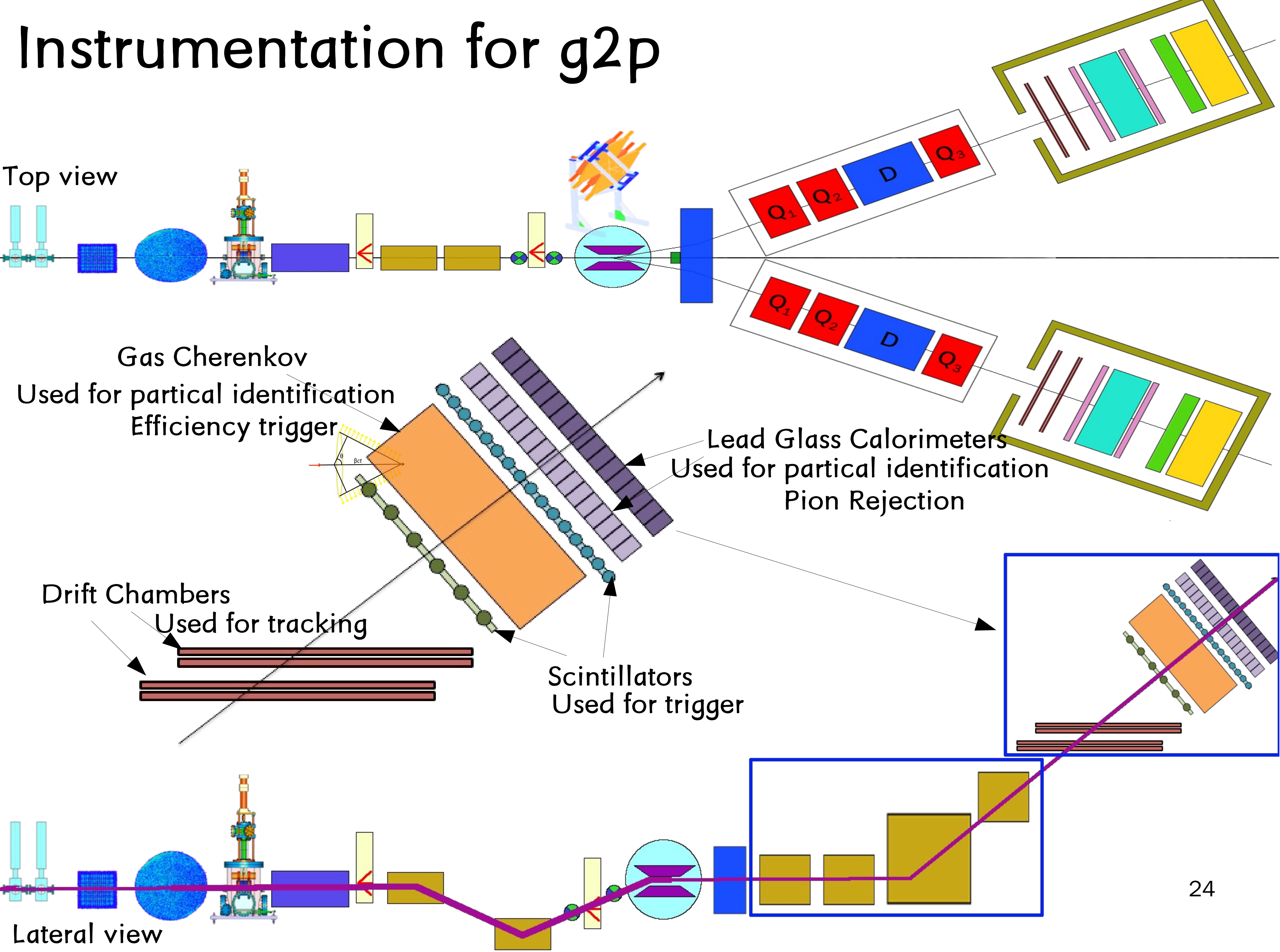
Black : generated

Red : reconstructed



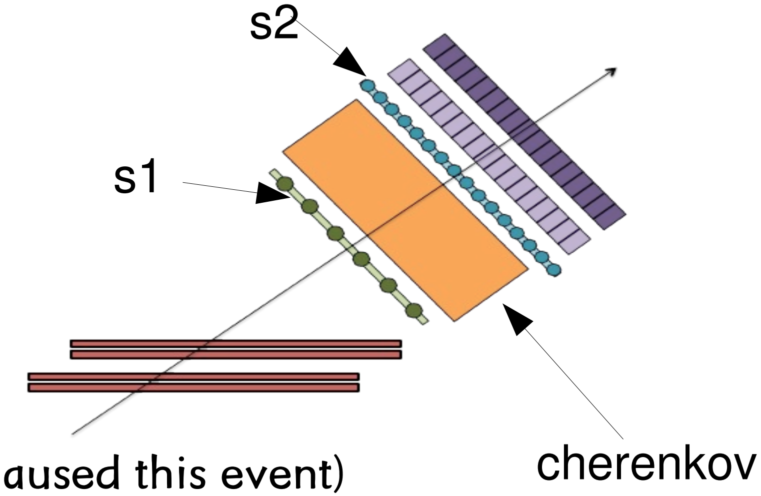
Courtesy by Chao Gu

Instrumentation for g2p



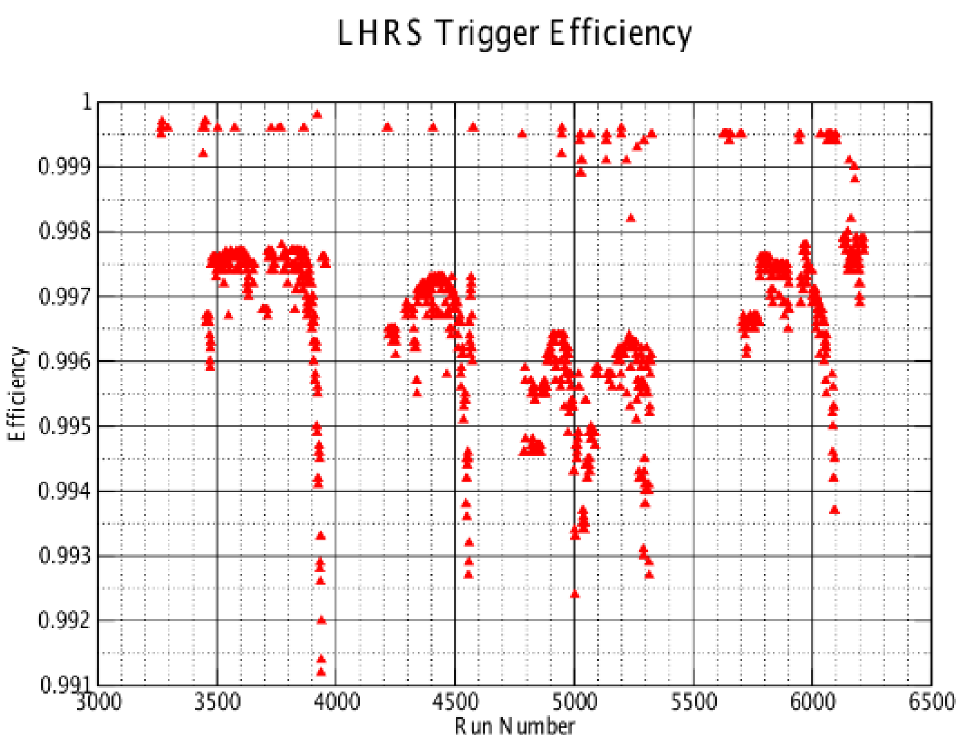
Trigger efficiency

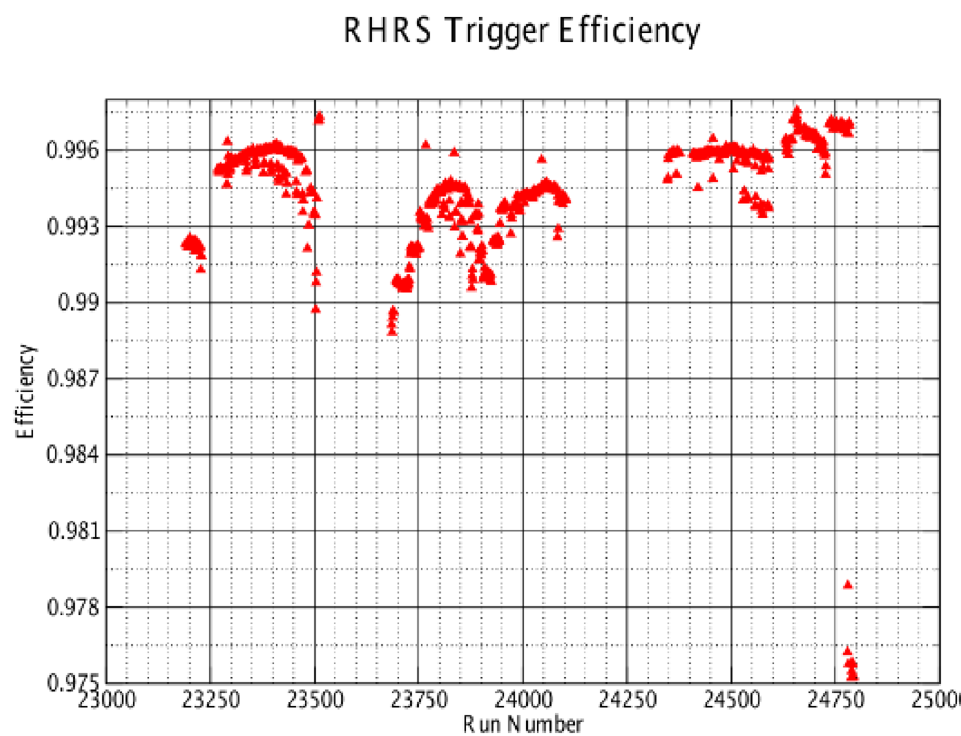
- Main trigger: s1 & s2
- Efficiency trigger:
  Either s1 or s2 have signal but not both
  & cherenkov have signal



Each event will have event type info(which trigger caused this event)

Trigger efficiency define: $Eff = \frac{T_{main}}{T_{main} + T_{eff}}$





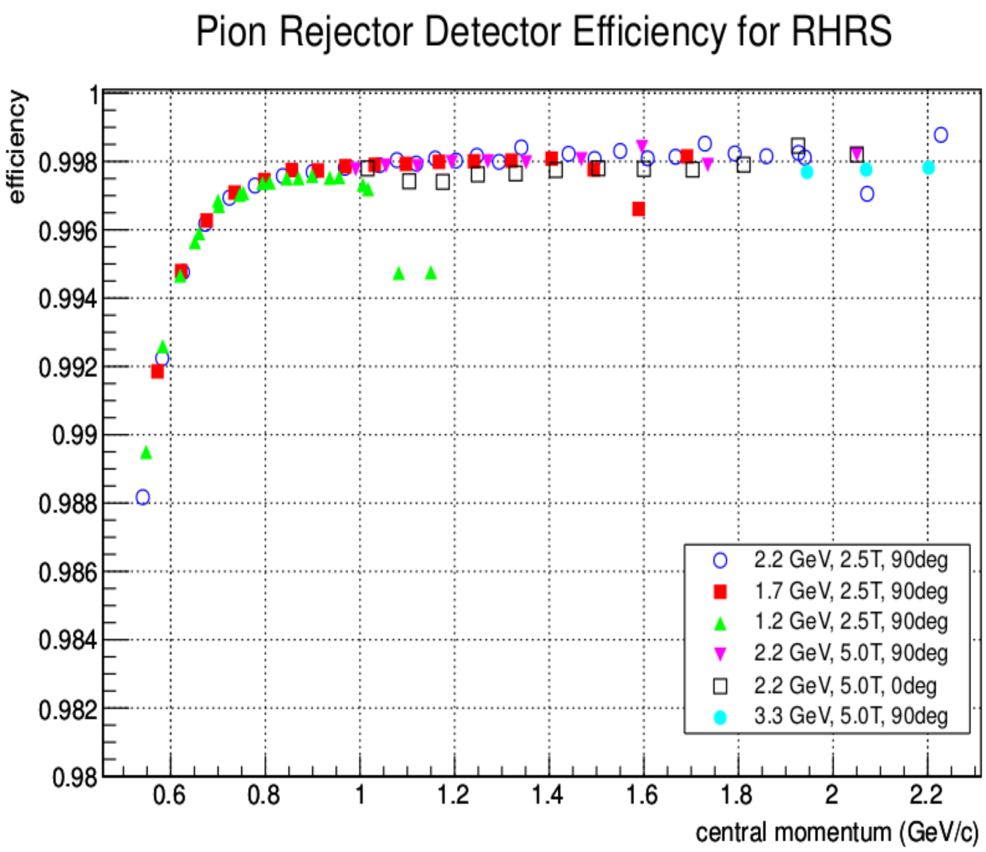
Trigger efficiency during experiment,higher than 99.1%

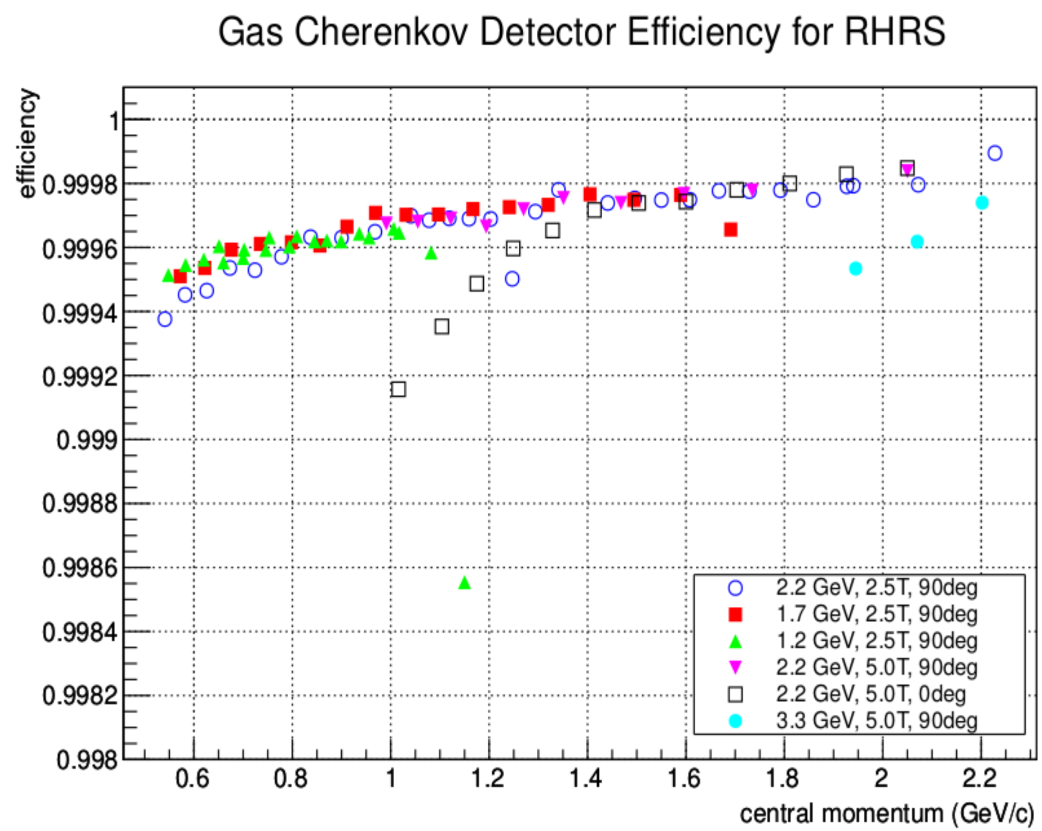
Courtesy by Ryan Zielienski

Detector efficiency --Performance of detector

(for example cherenkov efficiency)

- Select events that have only one track
- Select range that only have pure electron(electron sample) in lead glass calorimeters
- Get the events fired in cherenkov
- Detector efficiency=survive electron/electron sample
- Same procedure for lead glass calorimeter efficiency



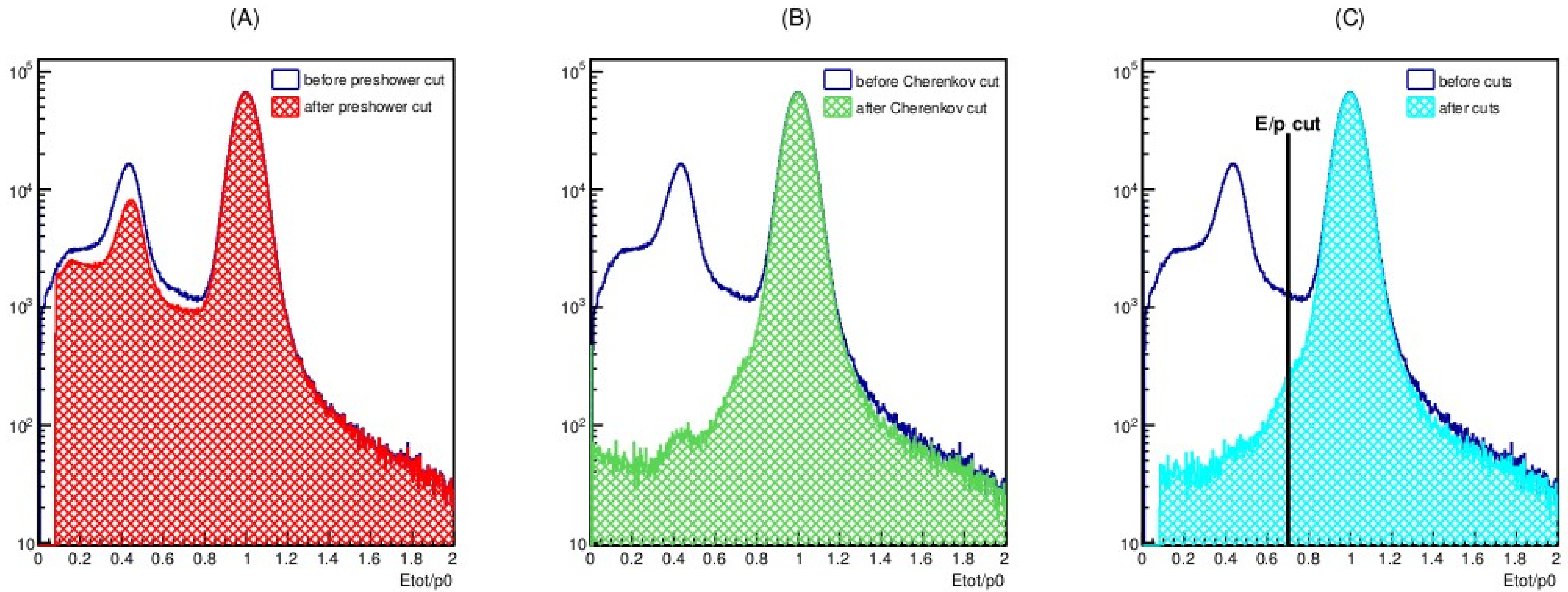


Courtesy by Melissa Cummings & Jie liu

Cut efficiency --maximize pion supression

3 cuts:

- Gas cherenkov threshold cut
- First layer of lead glass cut (E_preshower/p)
- Total energy deposite in calorimeter(Etot/p)

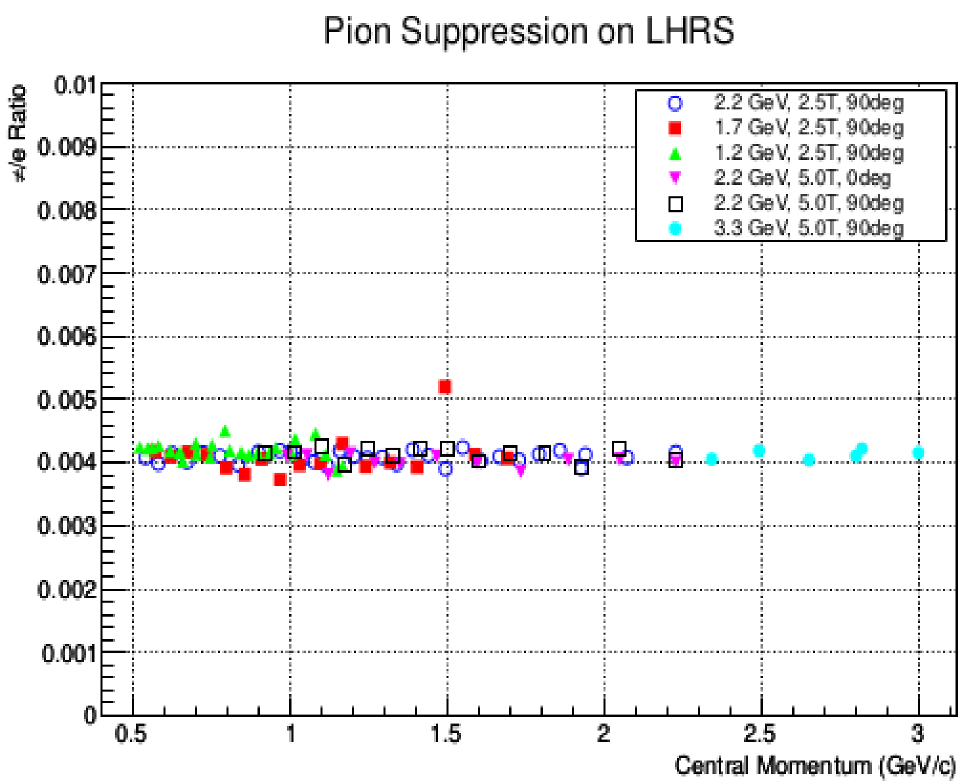


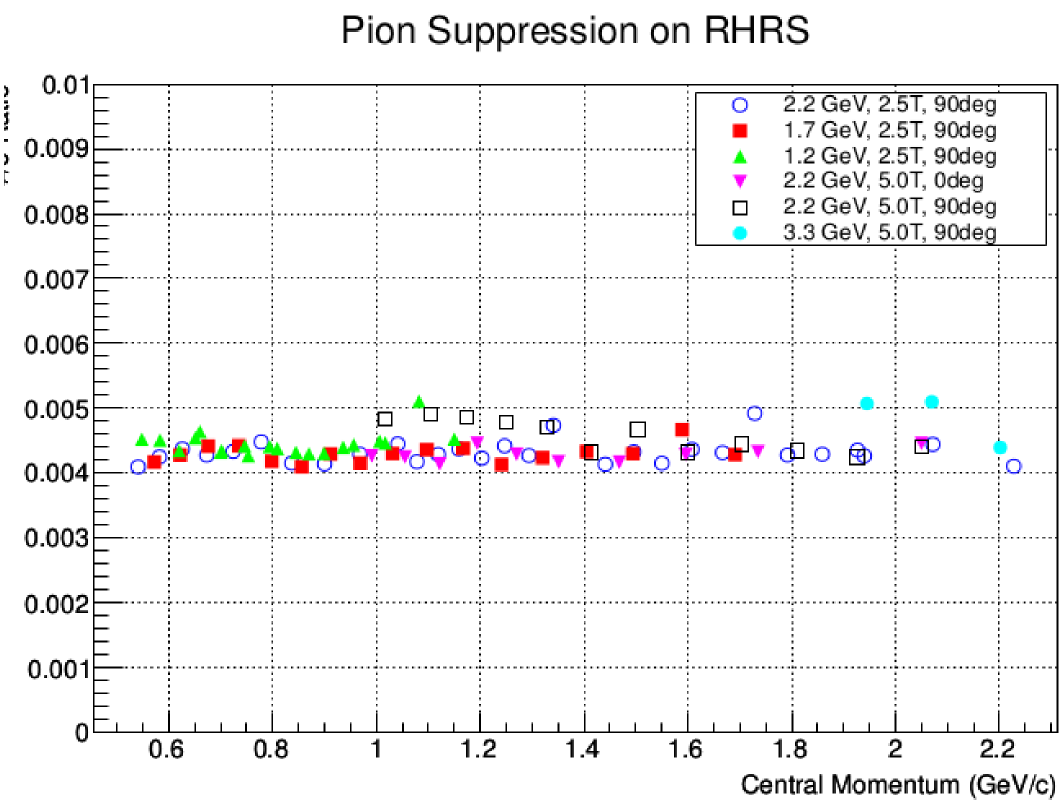
Etot/p before and after 3 different detector cut(right arm)

Gas cherenkov shows the pretty high pion supression(removes most of the contamination)

Courtesy by Melissa Cummings & Jie liu

Cut efficiency --maximize pion supression





Courtesy by Melissa Cummings & Jie liu

Multi-track efficiency

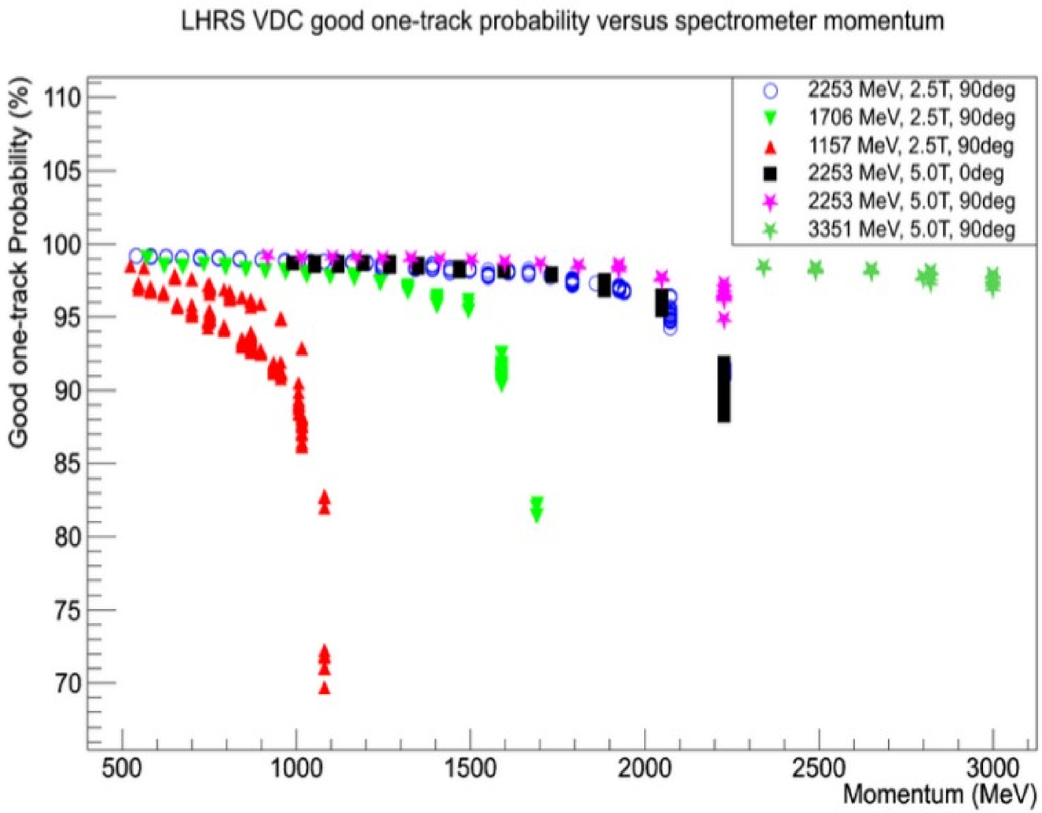
- Only 71% of events just have one track around elastic region
- Need to study the multi-track situation to select more events

Number of tracks	0	1	2	3	4	5	6	7	More than 7
LHRS	0.00112	0.71366	0.18048	0.07134	0.02103	0.00762	0.00283	0.00108	0.00084

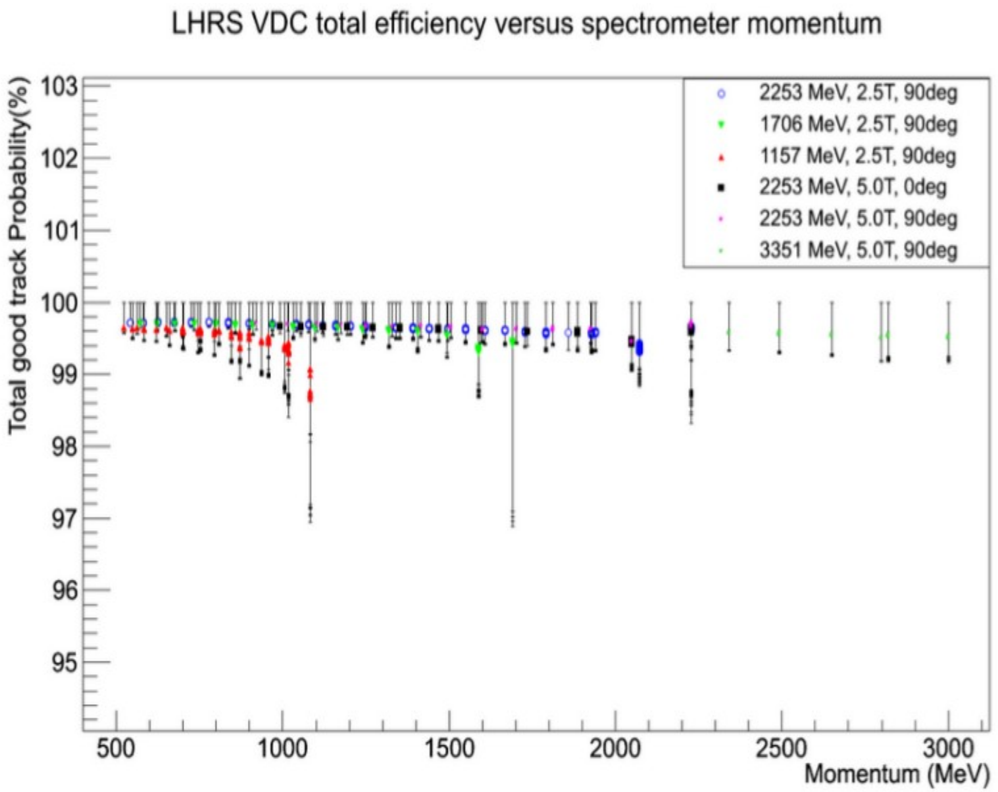
Track probability in electron sample for 1.157GeV, 1081.97MeV, 2.5T

Courtesy by Jie liu

Multi-track efficiency



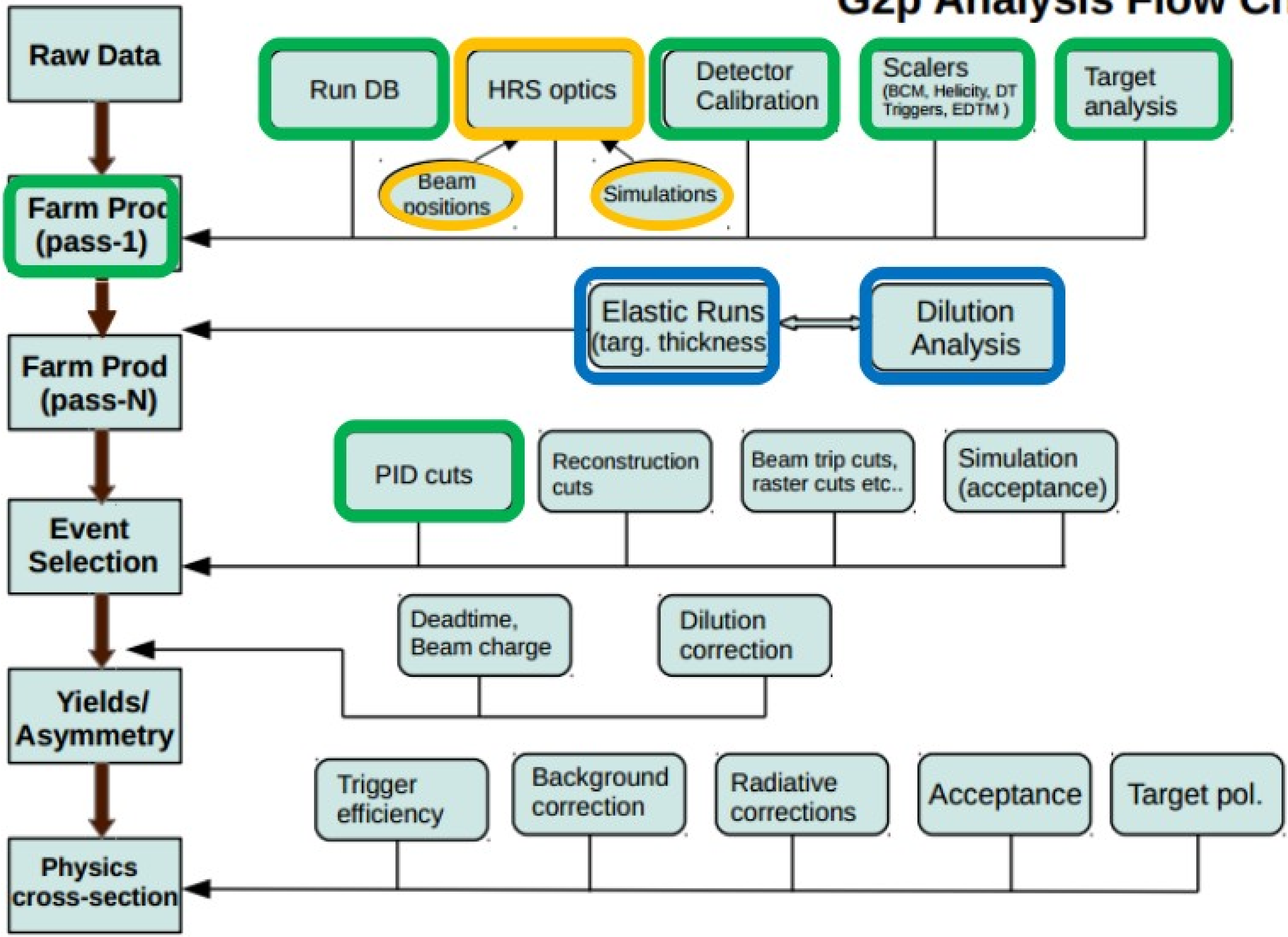
VDC efficiency with only one track select



Total VDC efficiency after multi-track study

Courtesy by Jie liu

G2p Analysis Flow Chart



Courtesy by Kalyan Allada

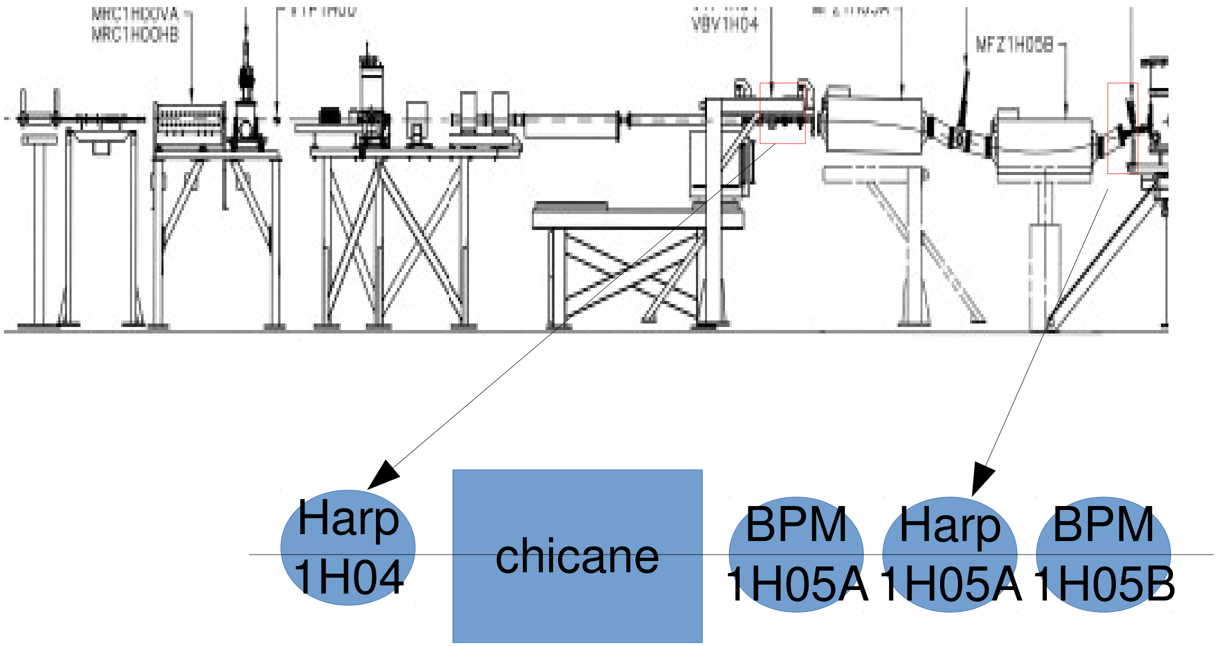
Summary

- The g2p experiment, ran in spring of 2012, took data covering Mp < W < 2 GeV, 0.02 < Q2 < 0.2 GeV2
- Target analysis is done
- Detector calibrations and PID cuts are done
- HRS optics is still continuing because of complicate situation of septum and target magnet
- Will provide a precision measurement of g2p in the low Q2 region for the first time
- Results will shed light on several physics puzzles

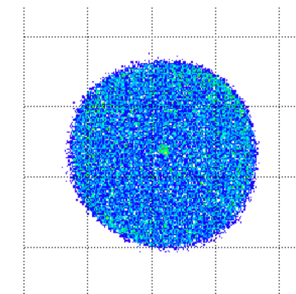
Backup slides

Super Harp ---------> Calibrate 2 BPMs

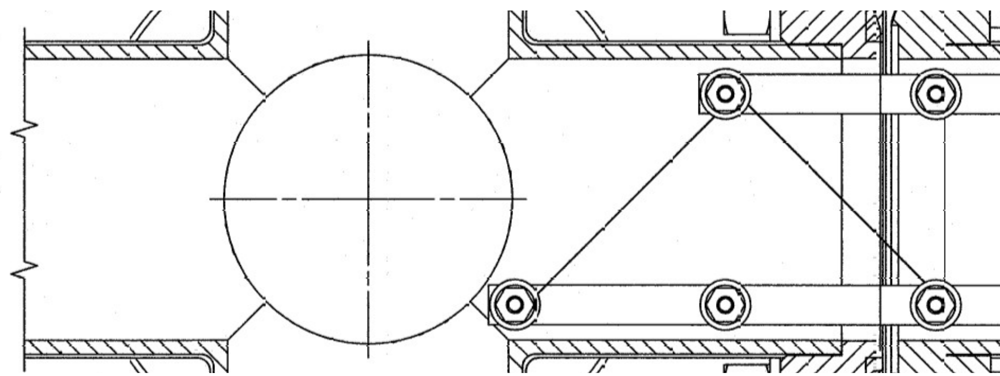
50um wires
Worked in pulsed beam mode



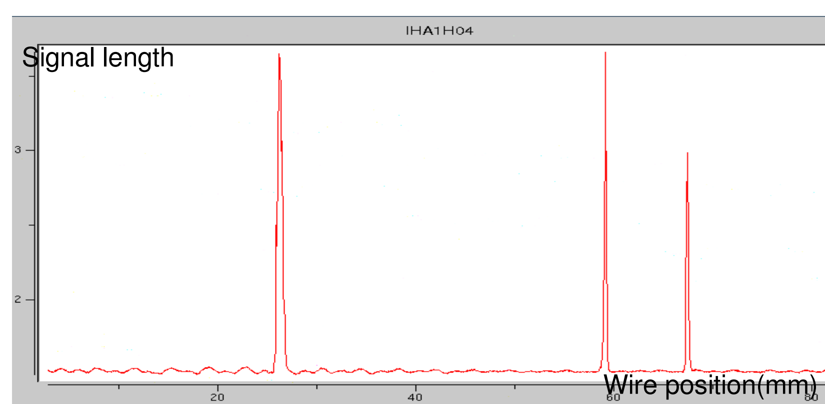
Slow raster shape in Calibrated BPM

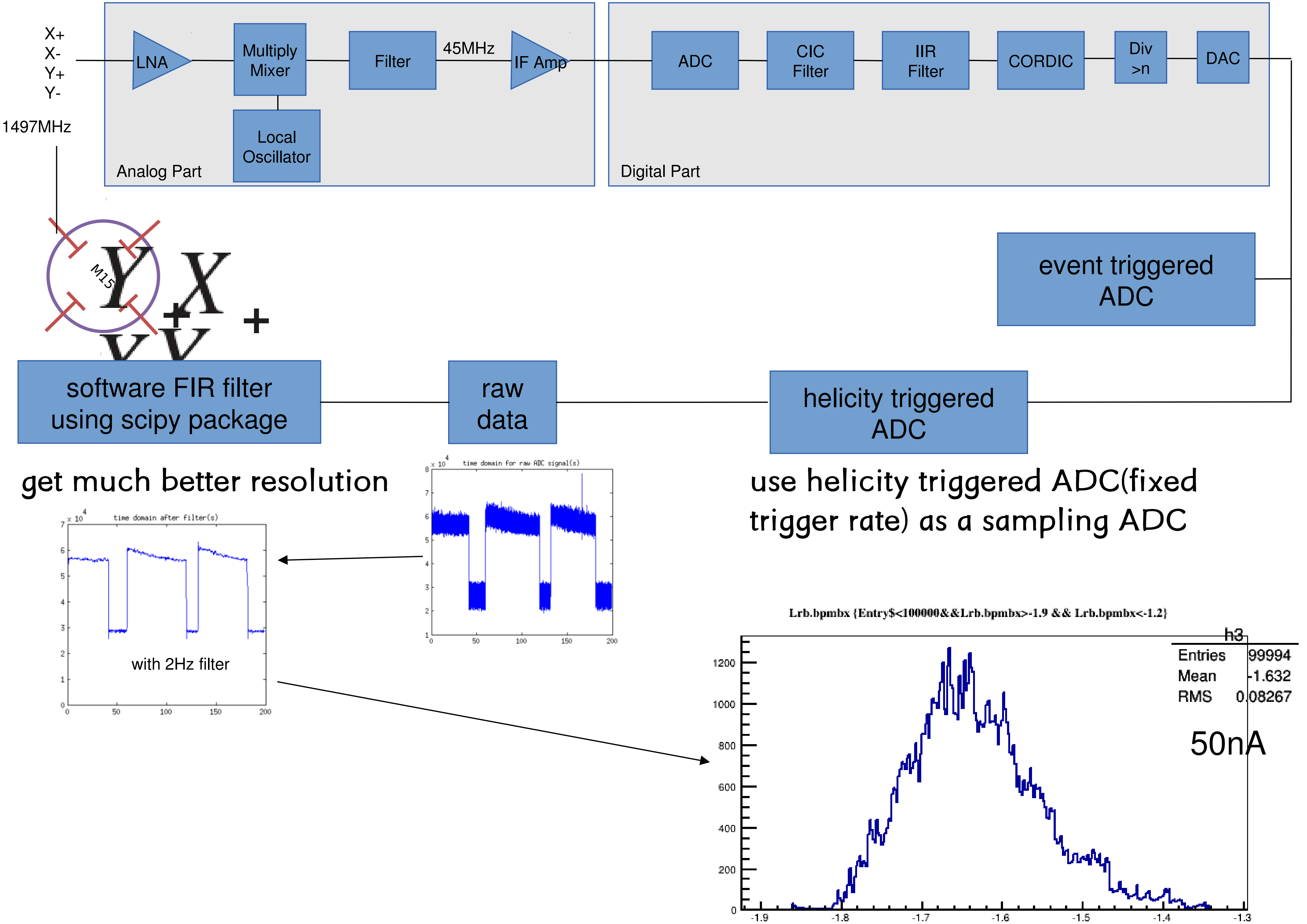


Calibrated in Straight Through Configuration



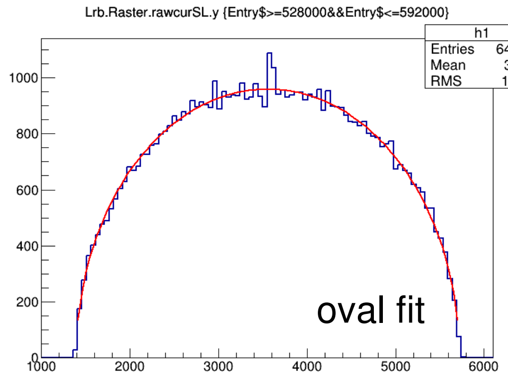
Did the harp scan in ~5uA pulsed beam
At the same position took run in 100~50nA CW beam



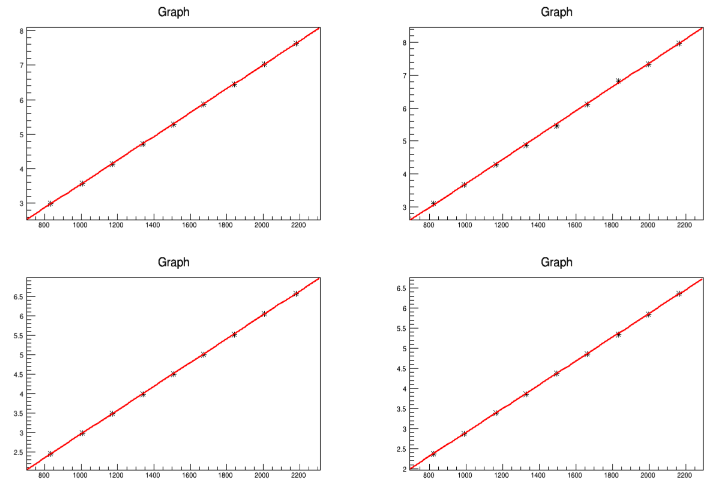


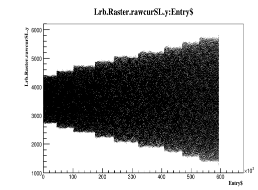
X+
X-
Y+
Y-
1497MHz
LNA
Multiply Mixer
Local Oscillator
Filter
45MHz
IF Amp
Analog Part
ADC
CIC Filter
IIR Filter
CORDIC
Div >n
DAC
Digital Part
event triggered ADC
M15
software FIR filter using scipy package
raw data
helicity triggered ADC
get much better resolution
use helicity triggered ADC(fixed trigger rate) as a sampling ADC
time domain for raw ADC signal(s)
time domain after filter(s)
with 2Hz filter
Lrb.bpmbx {Entry$<100000&&Lrb.bpmbx>-1.9 && Lrb.bpmbx<-1.2}
h3
Entries 99994
Mean -1.632
RMS 0.08267
50nA

raster size calibration

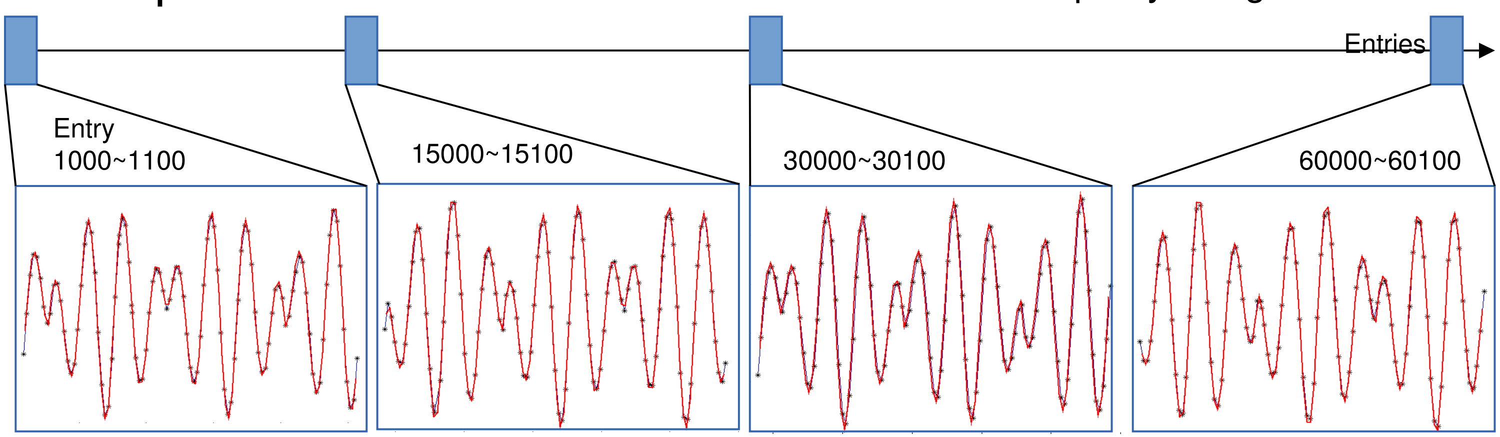


different size VS different ADC diff





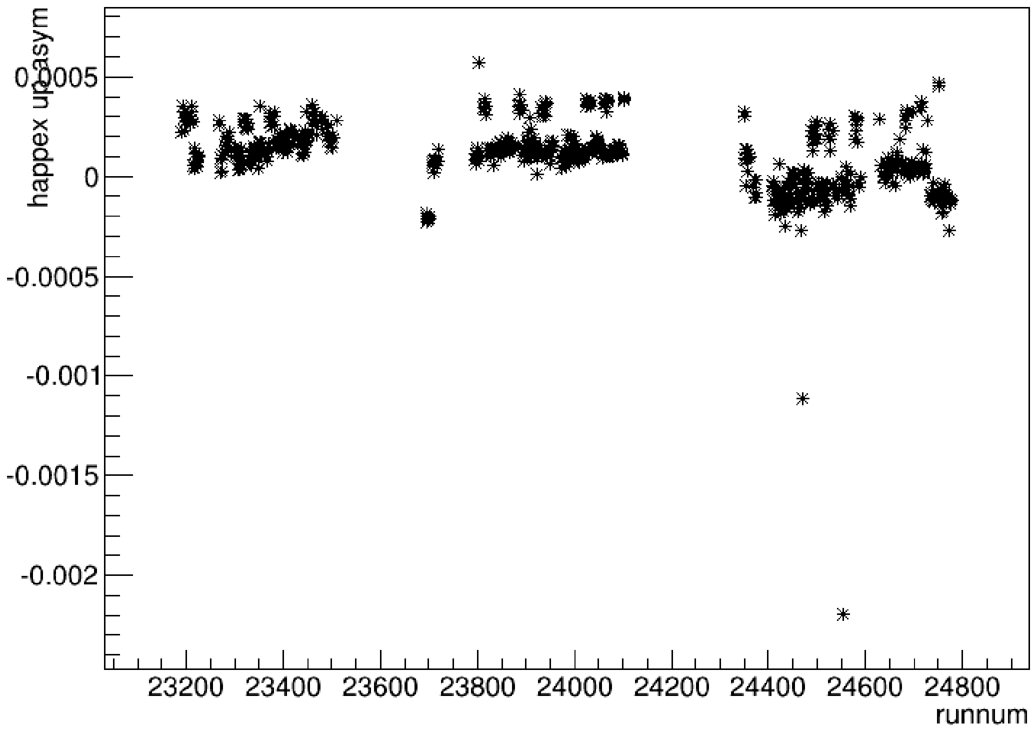
raster phase reconstruction -- reconstruct raster shape by using fast clock



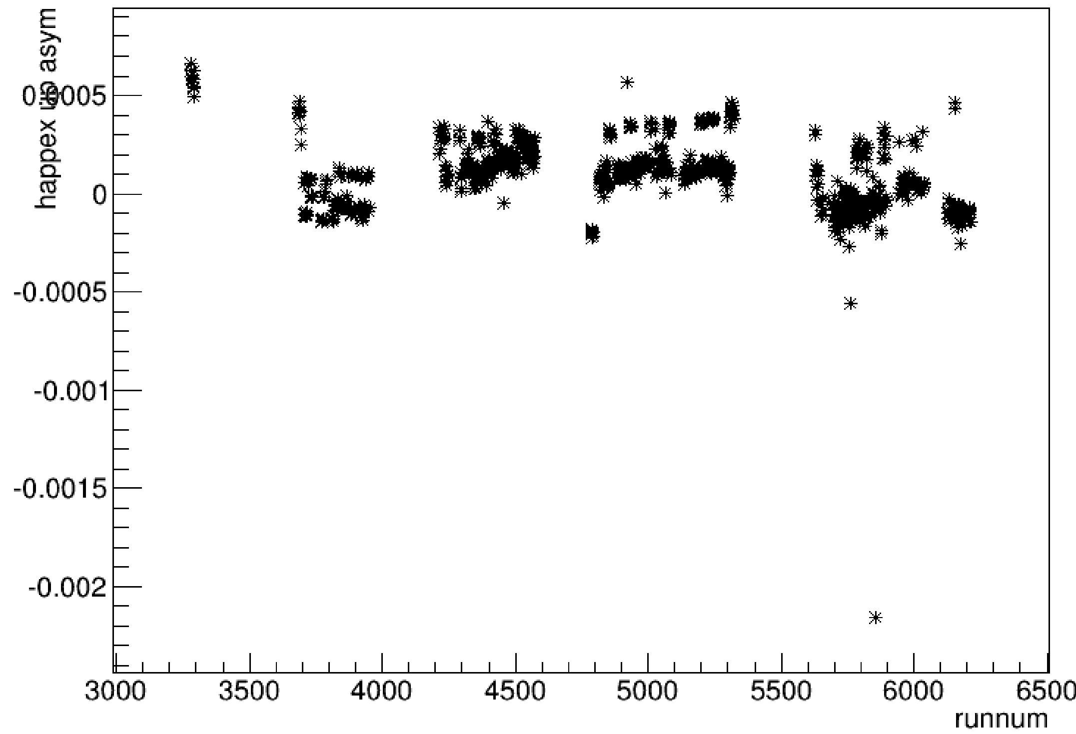
Red line: **Fit result**
Blue line and star asterisk: **real data**

Get rid of uncertainty caused by ADC accuracy limit

Charge asymmetry during experiment



Charge asymmetry for right arm



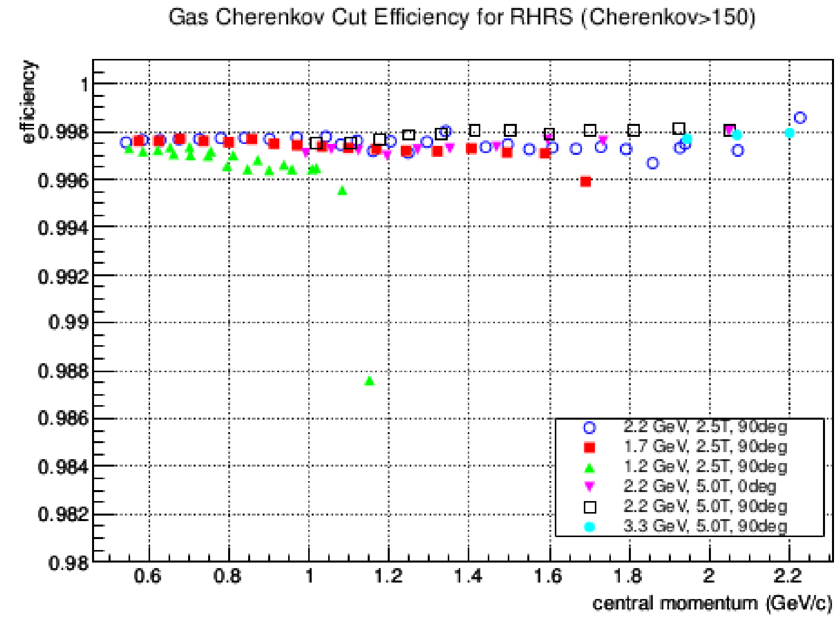
Charge asymmetry for left arm

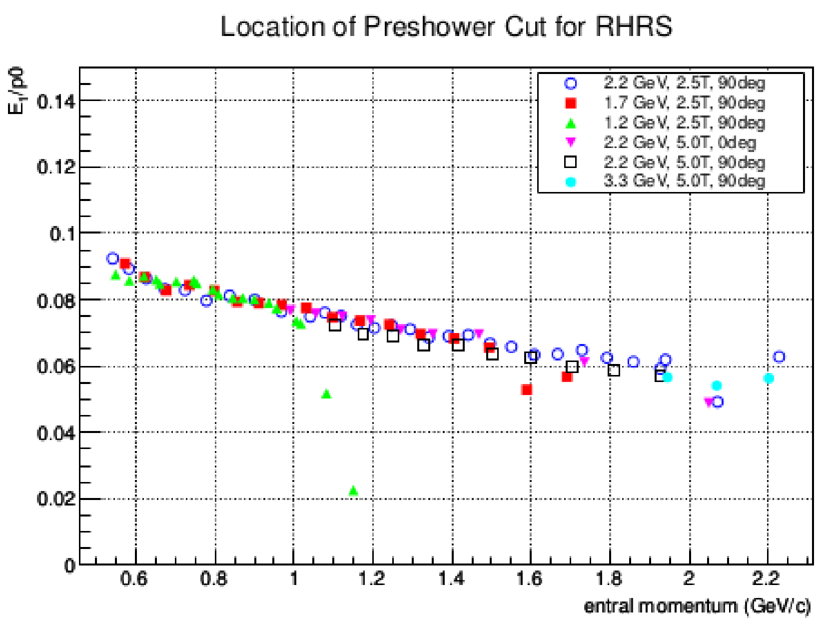
Cut efficiency --maximize pion supression

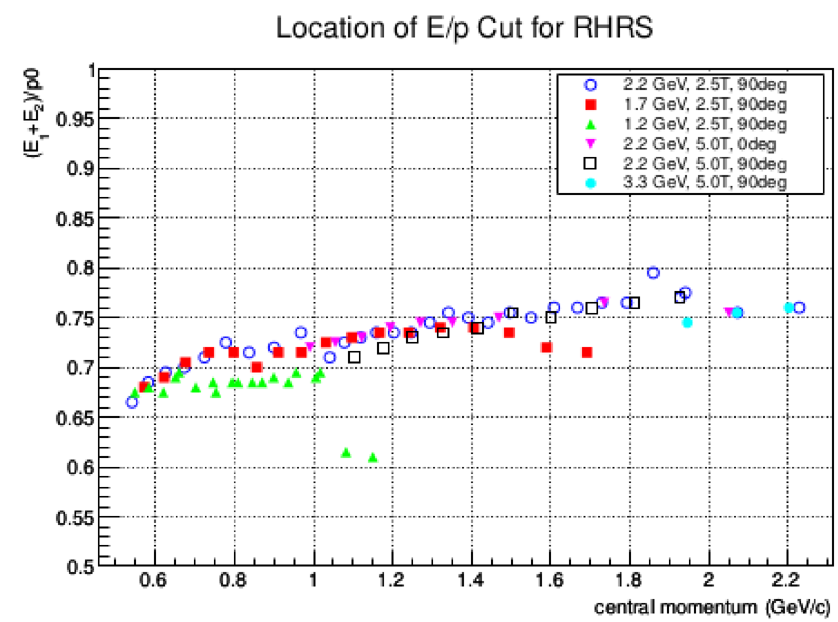
3 cuts:

- Gas cherenkov threshold cut
- First layer of lead glass cut (E_preshower/p)
- Total energy deposite in calorimeter(Etot/p)

Cut efficiency=survive pion/pion sample



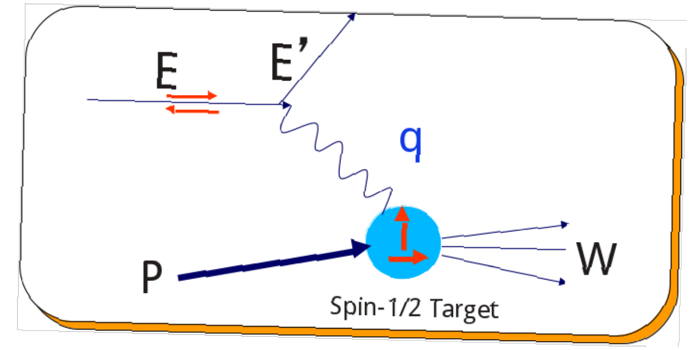




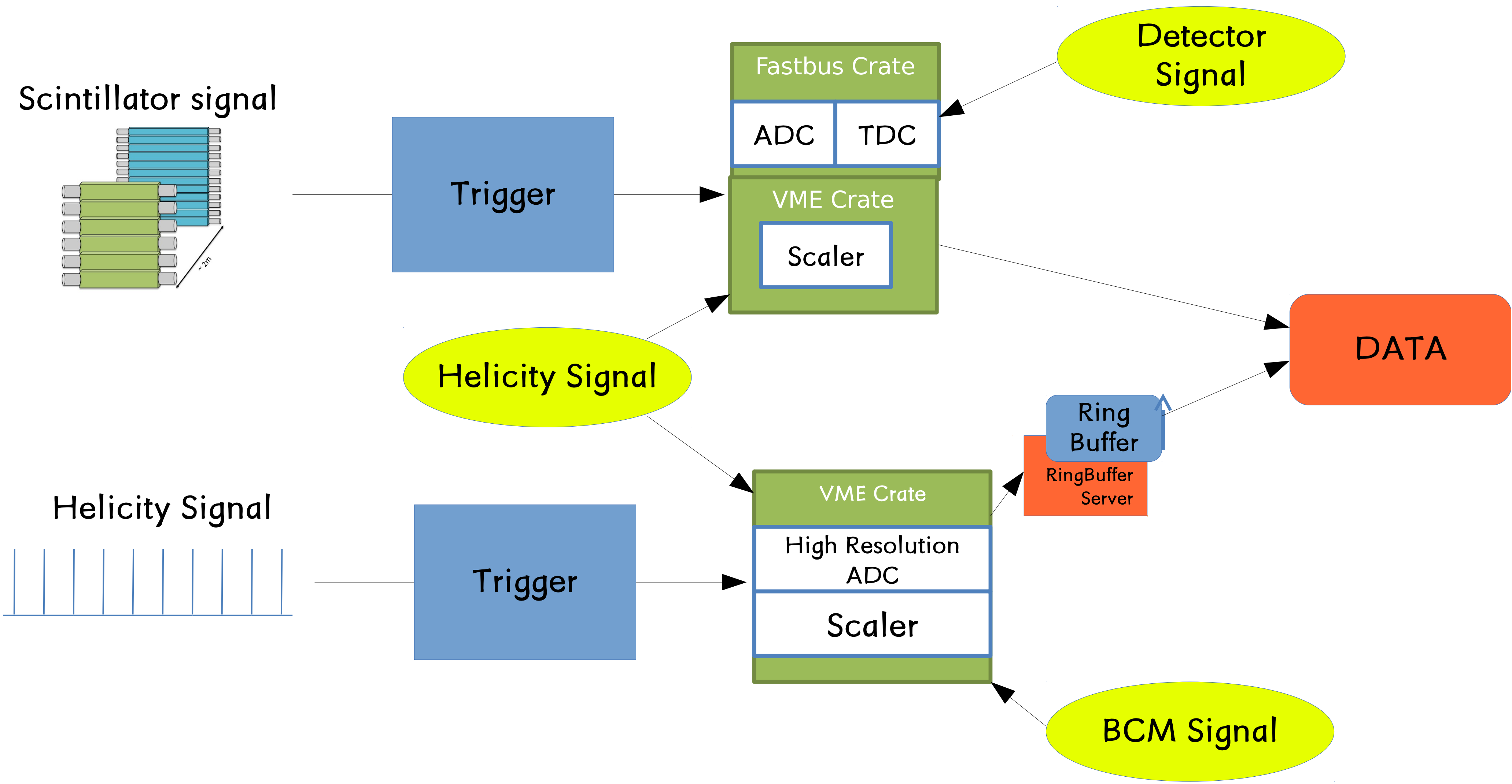
Courtesy by Melissa Cummings & Jie liu

Data Acquisition System

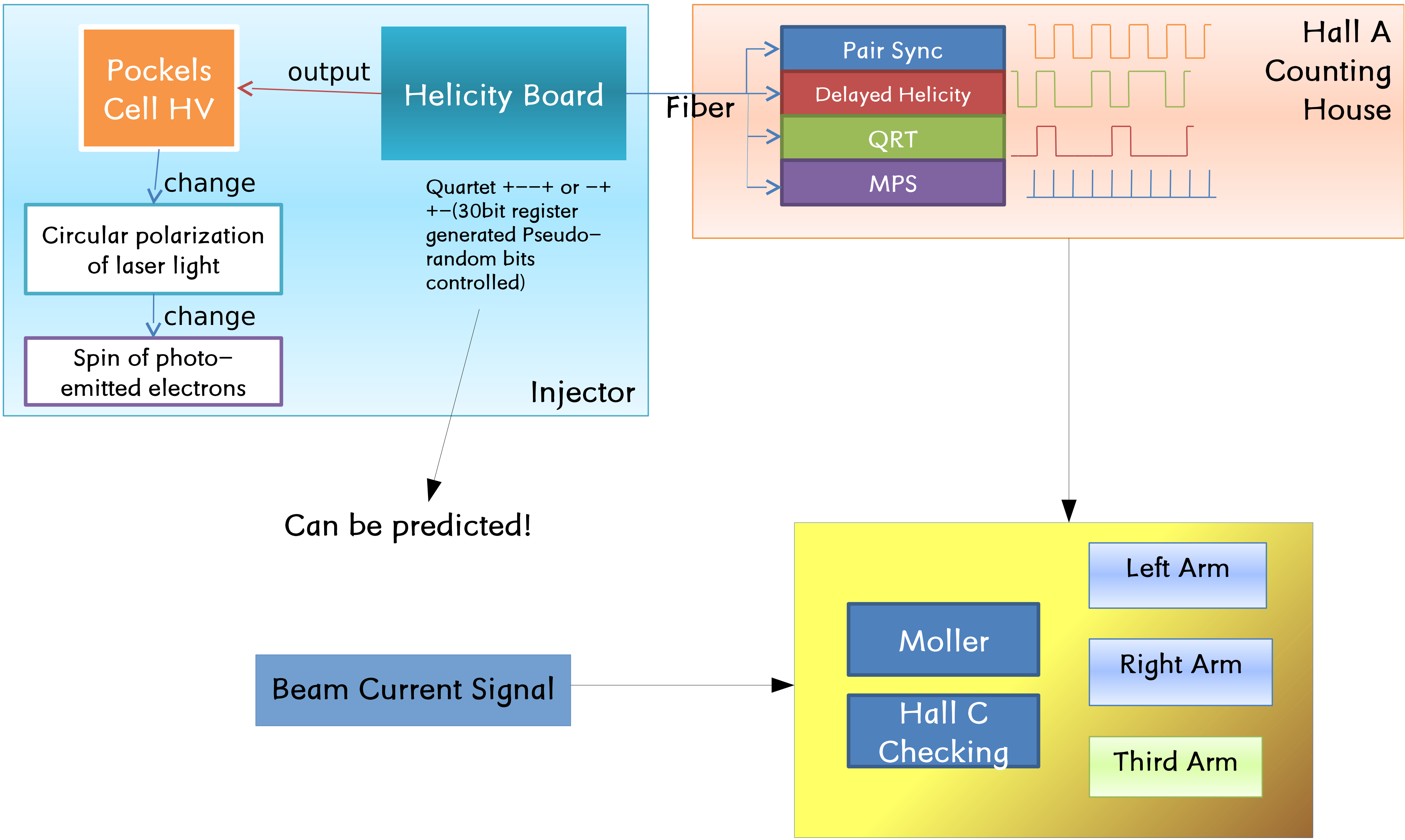
--Single arm DAQ



- LHRS and RHRS DAQ operate independently (singles)
- 3 fastbus crates, 2 VME crate on each arm

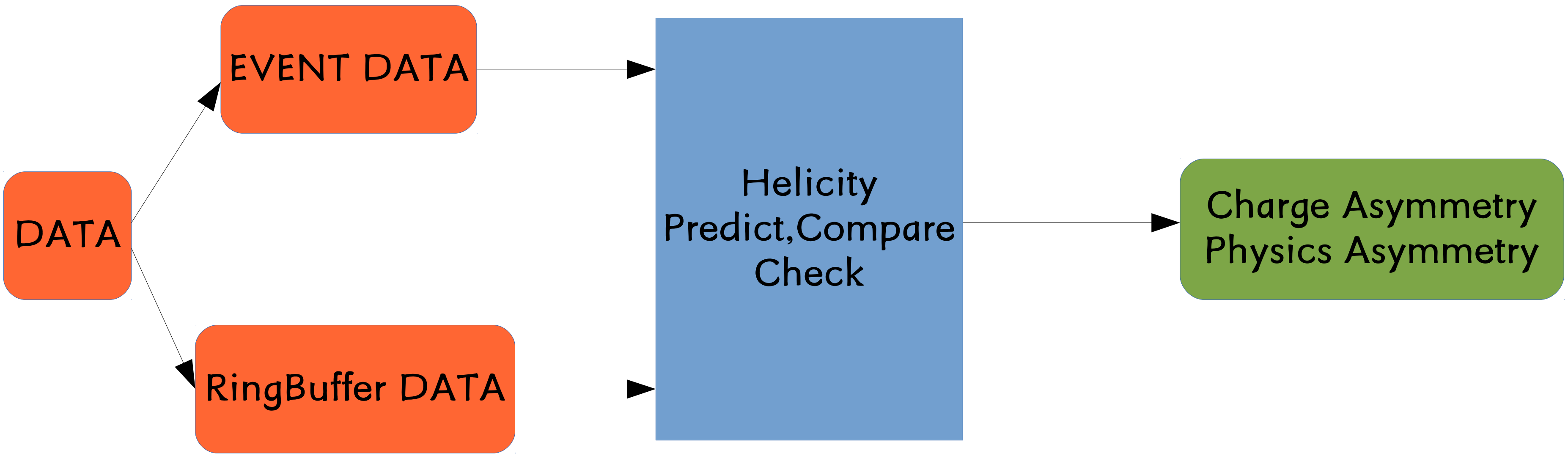


Helicity and BCM diagram



Get Asymmetry

Each event have helicity information



Each element in ringbuffer contains 1 helicity status and 1 bcm information