# *The $g_2^P$ Analysis Update*

Detectors & Simulation

***Jie Liu***

***University of Virginia***

# Outline

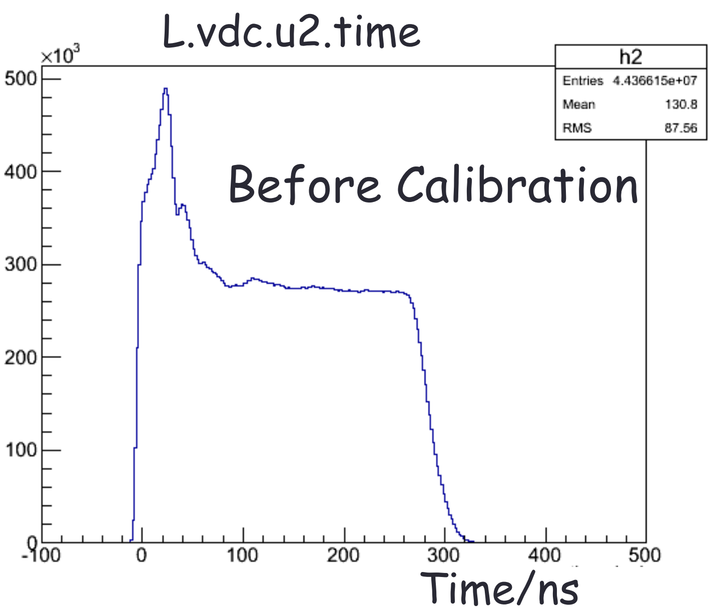
- **Detector Calibration**
  - ✓VDC $t_0$
  - ✓LHRS Cherenkov
  - ✓LHRS Pion Rejector
- **Efficiency Study**
  - ✓LHRS PID Optimization
  - ✓VDC Multi-track Efficiency
- **Data Quality Check**
  - ✓VDC $t_0$ , Tracking variable
  - ✓ Multi-track Efficiency
- **Simulation Study**
  - ✓Energy Loss Model
  - ✓Packing Fraction Simulation

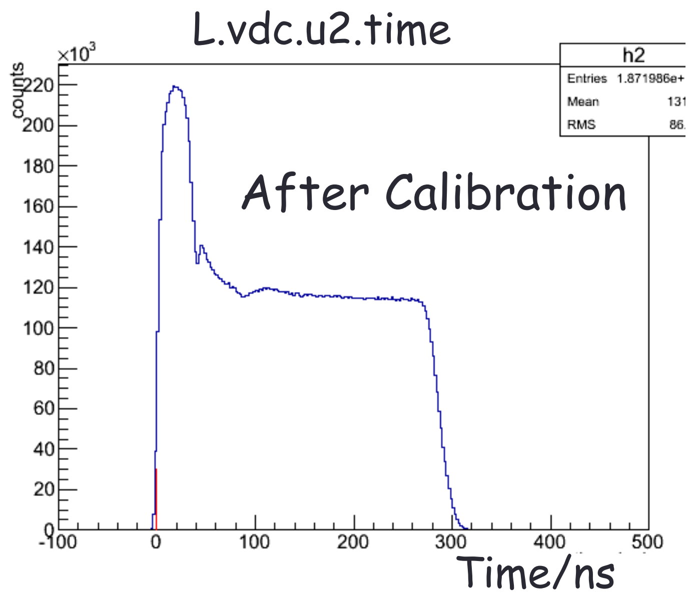
❑: Completed

❑ In progress

# VDC $t_0$ Calibration

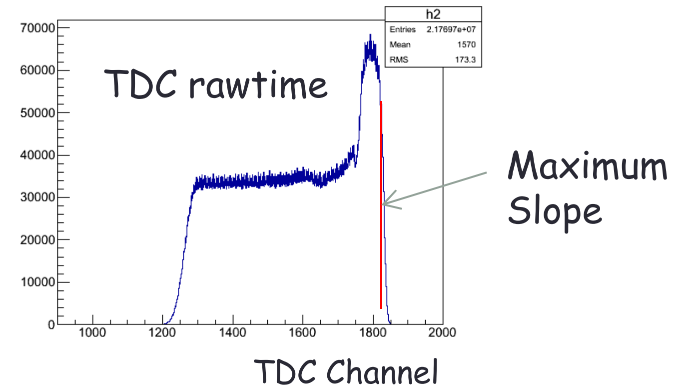
- Align timing reference $t_0$ for each VDC wire
- Time = TDC resolution * ( $t_0$ offset channel – rawtime channel)

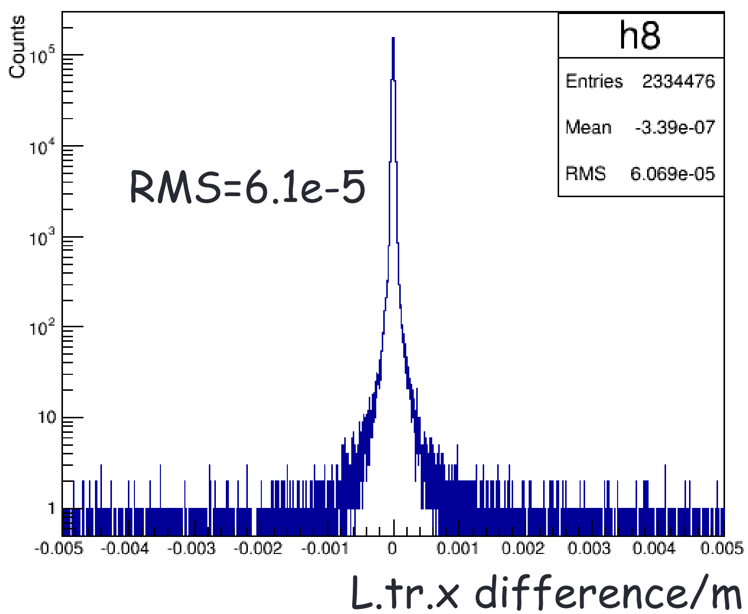


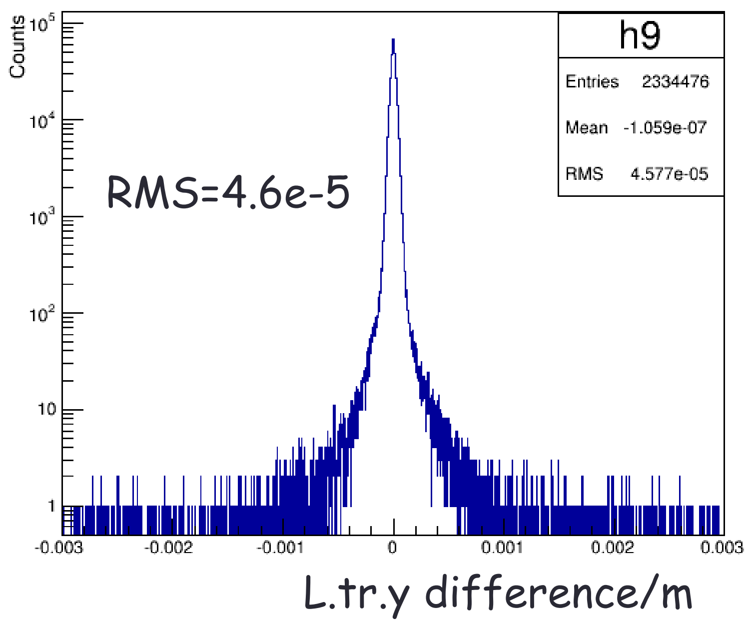



# VDC $t_0$ Effects

- Timing reference $t_0$ choice
  - ✓ Maximum slope
  - ✓ Maximum slope extrapolate to zero

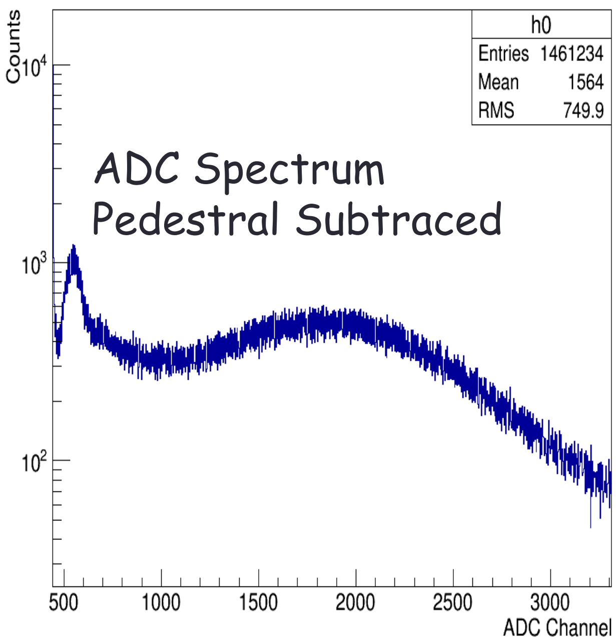


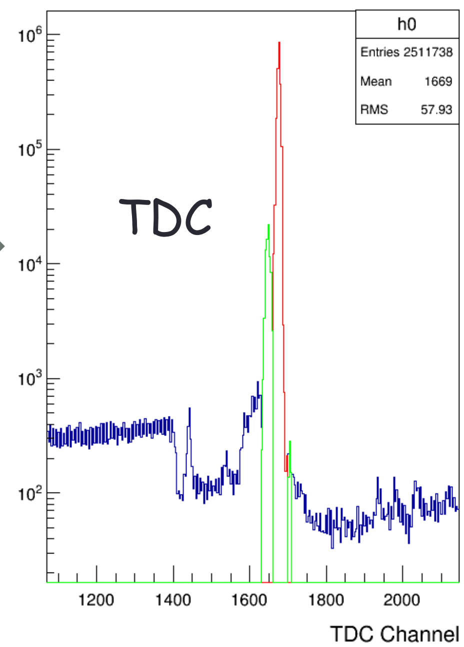



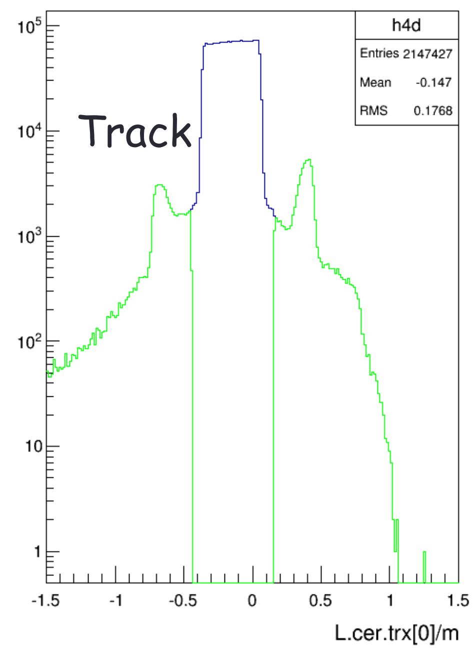
# Cherenkov Calibration

- Align single photoelectron peak
  - ✓ Contamination from both pedestal and main photoelectron peak
  - ✓ Need Timing and track information to select the clean peak




How

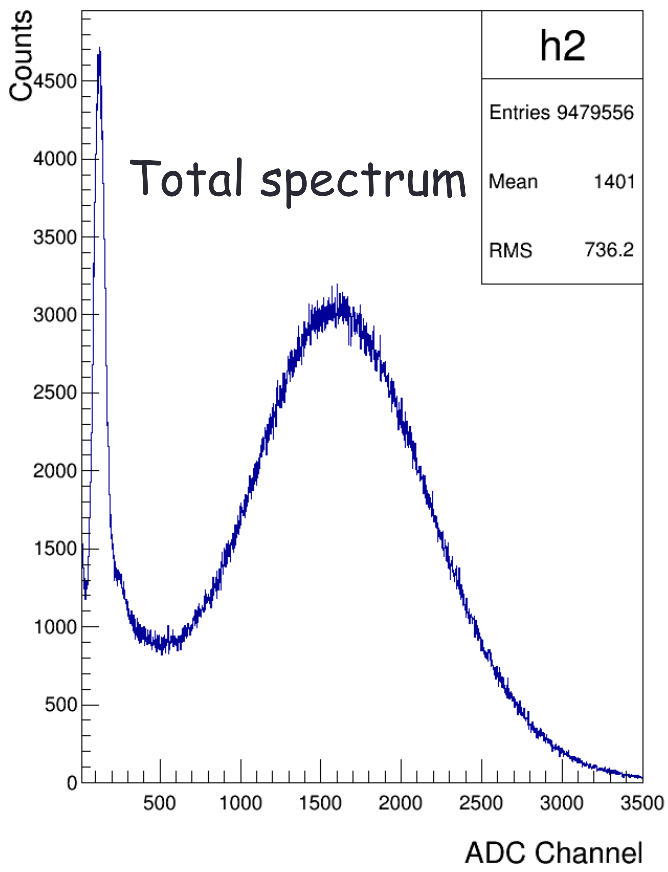


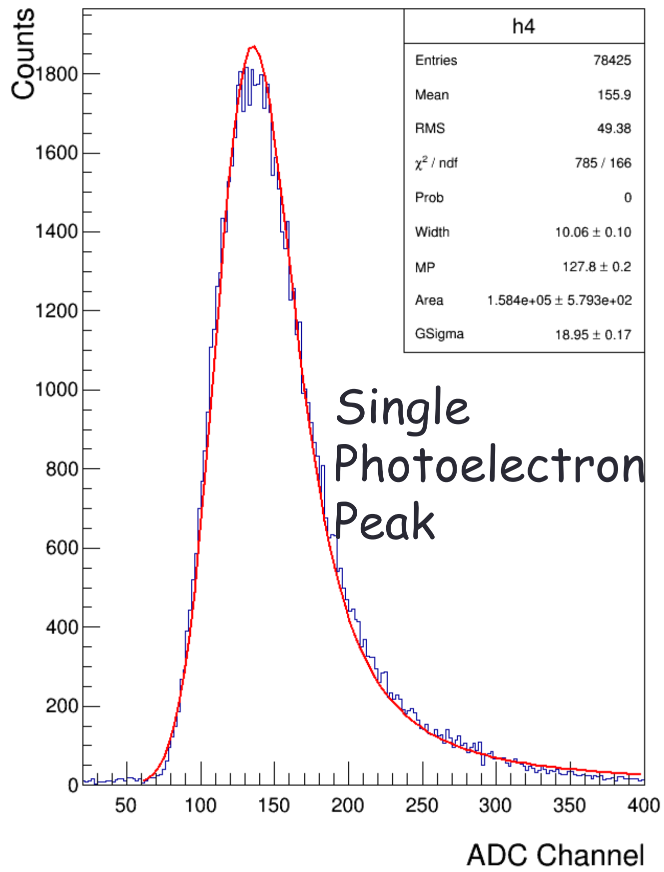




Green region: selected for Single photoelectron

# Cherenkov Calibration

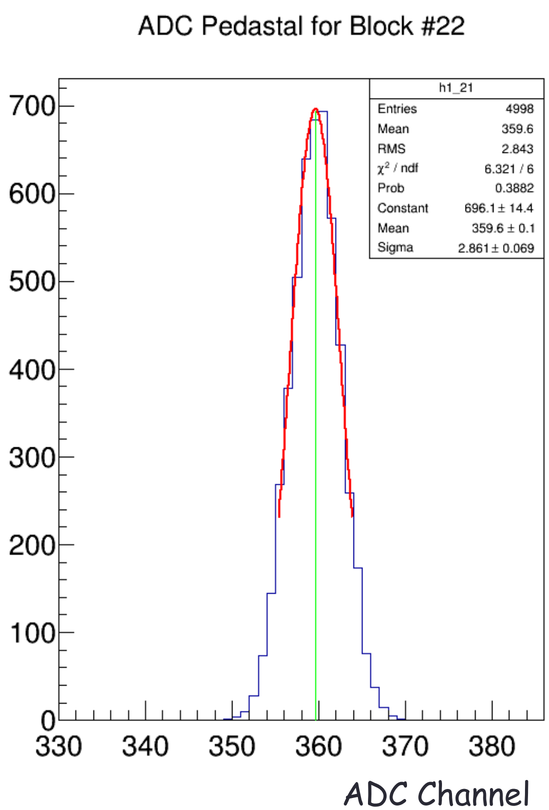
- Single photoelectron peak

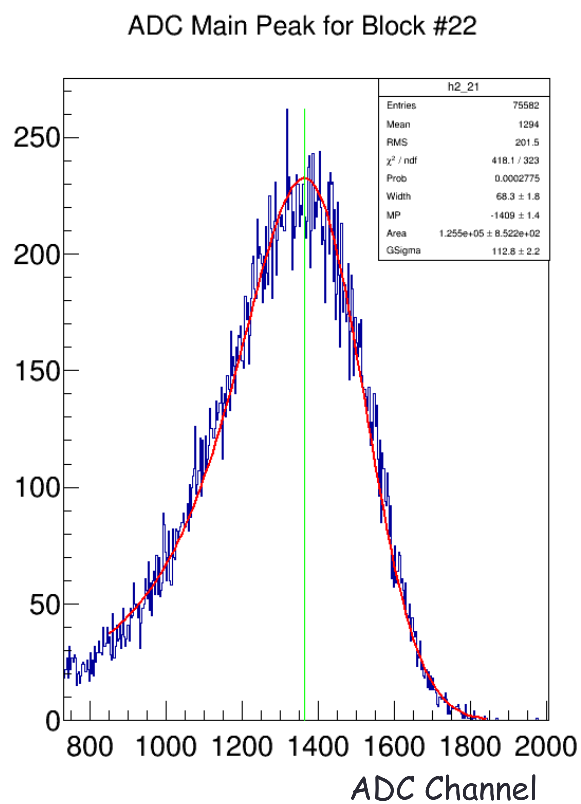


# Pion Rejector Calibration

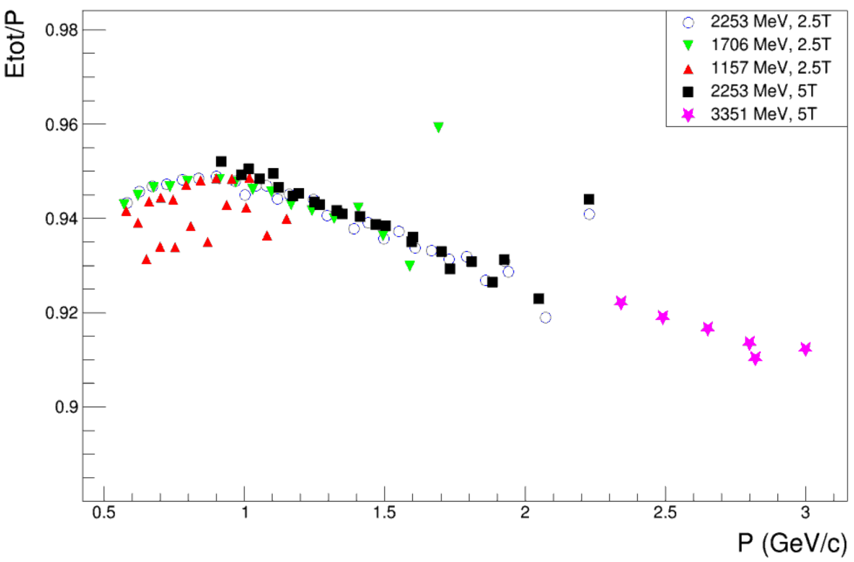
- Not a full energy absorption detector, radiation length $\sim 11.4\ X_0$
- Align Pedestal and Main Electron peak first for blocks in one layer



# Pion Rejector Calibration

- Optimize additional gain factor for each layer
- Longitudinal shower model
  - ✓ $\frac{dE}{dt} = E_0 * \beta * (\beta * t)^{\alpha-1} * \frac{e^{-\beta * t}}{\Gamma(\alpha)}$
  - ✓ $\frac{\alpha - 1}{\beta} = ln\frac{E}{E_c} - 1$
  - ✓ Critical Energy $E_c = 15.8 MeV$



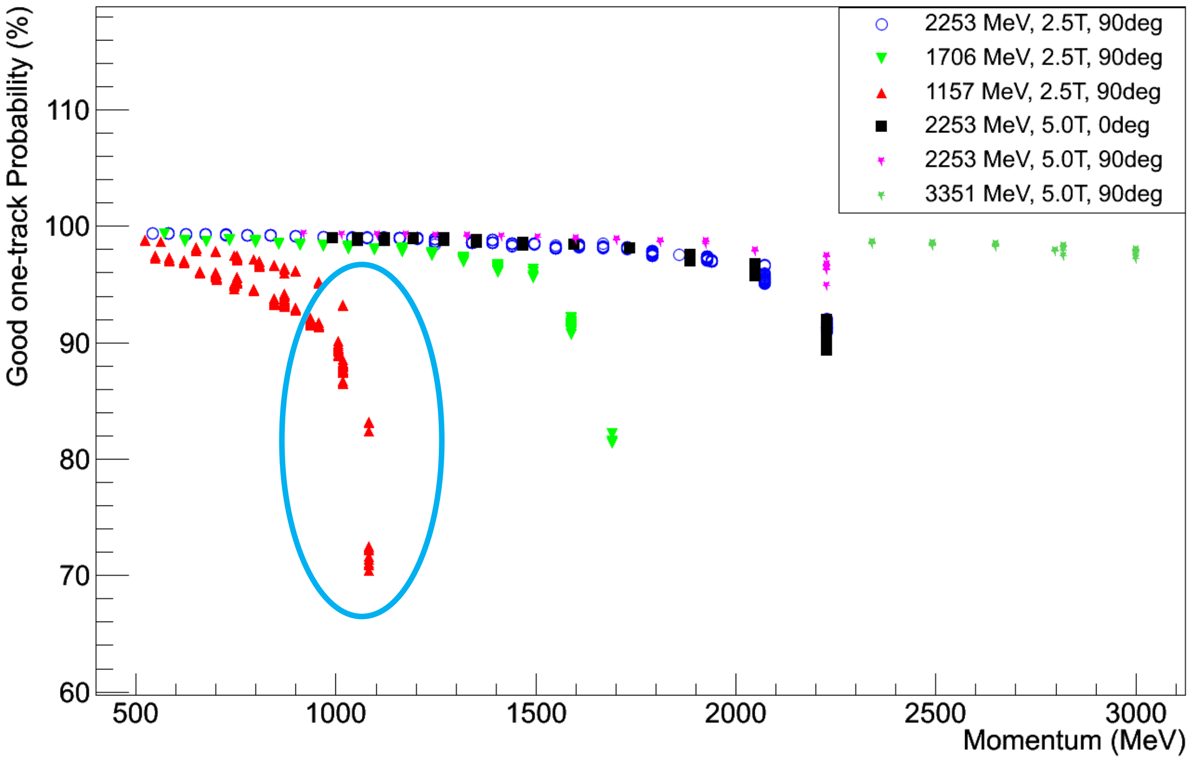

- Additional Gain Factor $\rho$ , $\mu$

$$\rho * prl1.e + \mu * prl2.e = \int \frac{dE}{dt}$$

# VDC Multi-track Efficiency

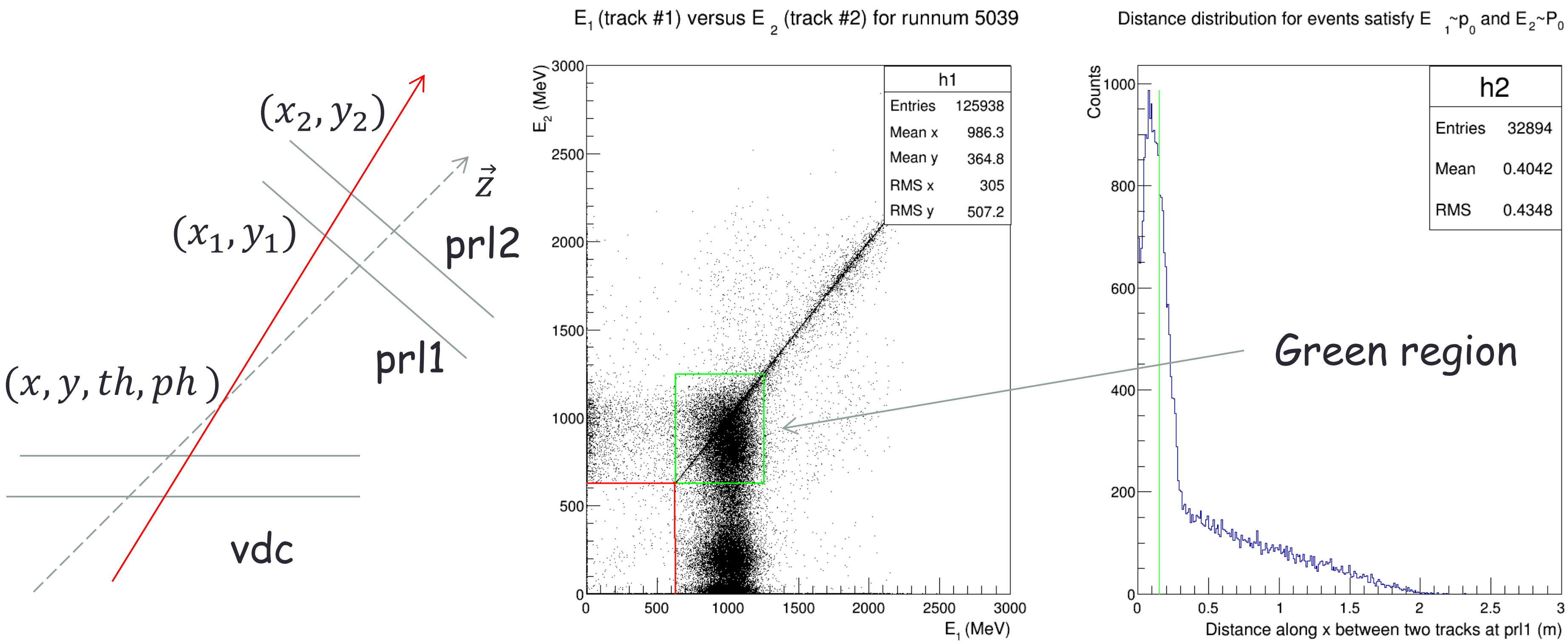
- **Motivation**: VDC one track events probability gets as low as 70% around elastic region

LHRS One-track Events Probability



# VDC Multi-track Efficiency

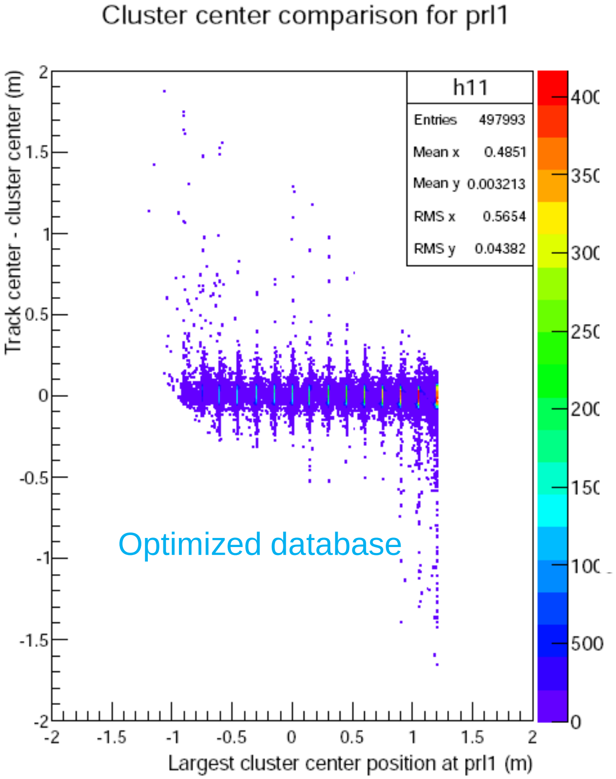
- **Method**: point the track from VDC to calorimeters and sum up the total energy in the surrounding lead glass blocks 3*2.

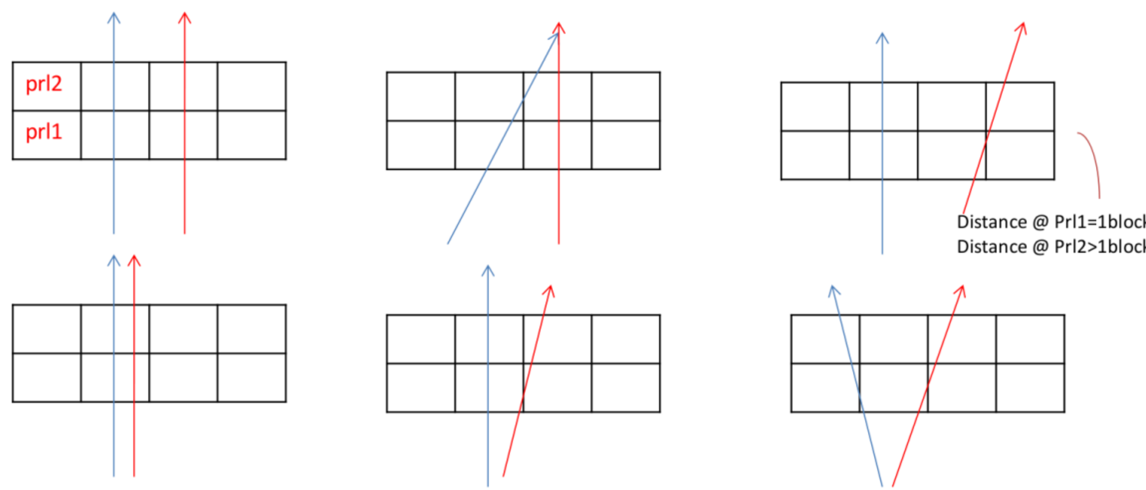


# VDC Multi-track Study

**Requirements:**

- ✓ A good position database for lead glass ( can reconstruct from data).
- ✓ A detailed case study for cluster energy contamination between tracks.



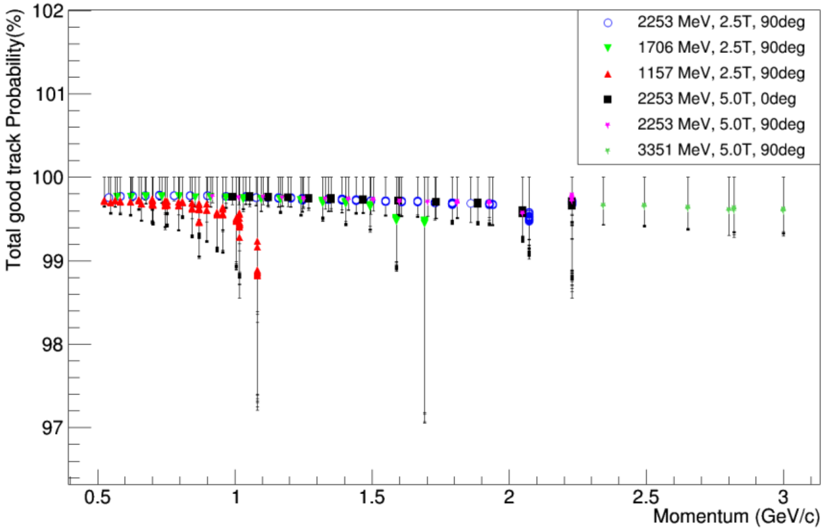




Several kinds of cluster overlap between two tracks

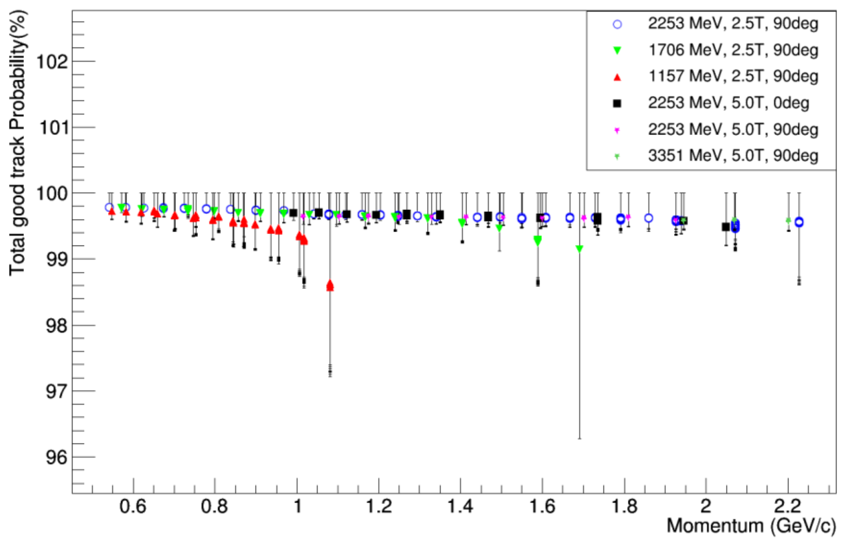
# VDC Multi-track Efficiency

- The VDC efficiency systematic uncertainty down to below 1% for most kinematic settings.

LHRS VDC total efficiency



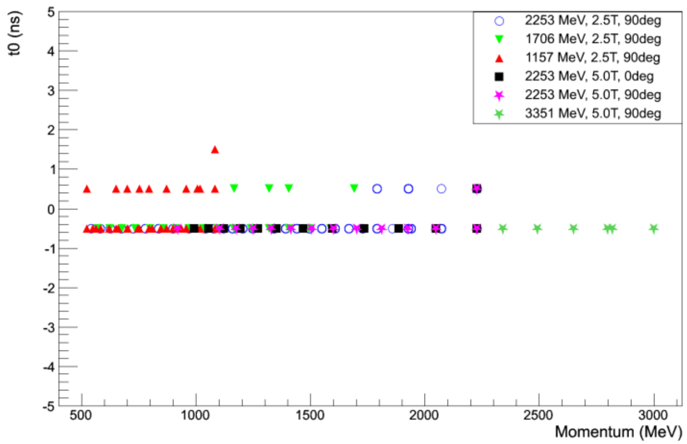

RHRS VDC total efficiency



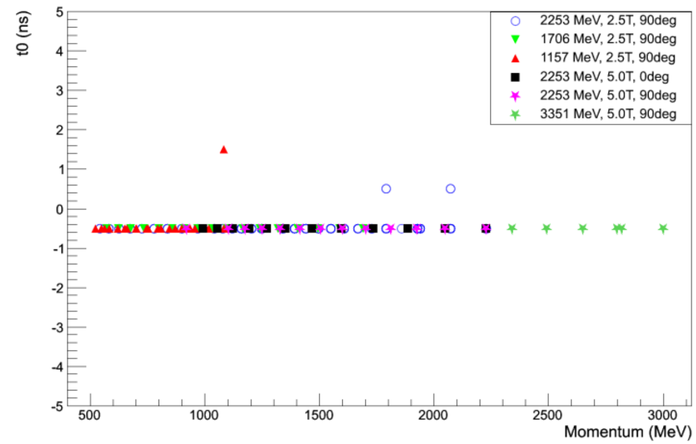
# VDC $t_0$ Check

- $t_0$ check for all production runs for VDC each player

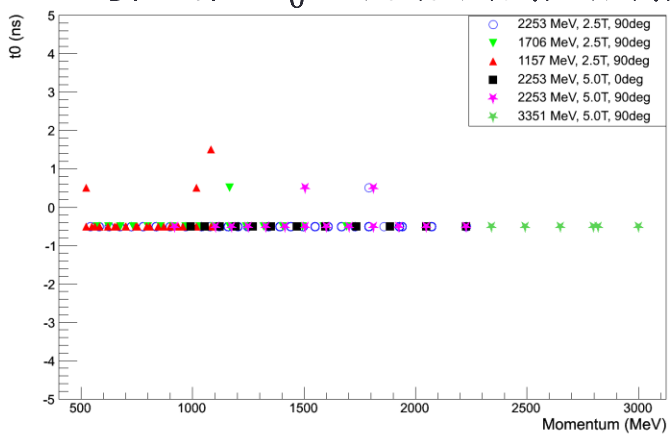
L.vdc.u1 $t_0$ versus Momentum



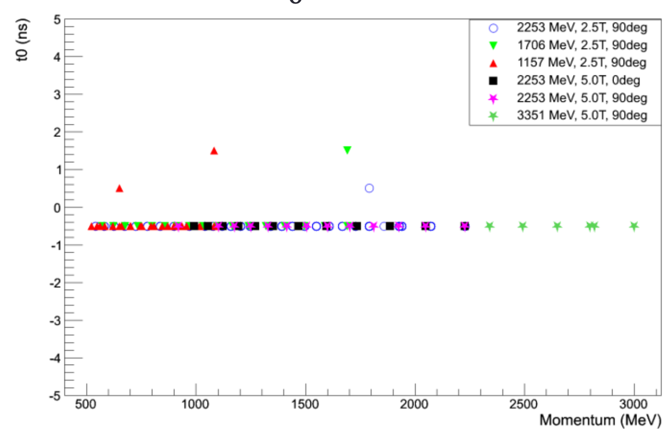

L.vdc.u2 $t_0$ versus Momentum




L.vdc.v1 $t_0$ versus Momentum



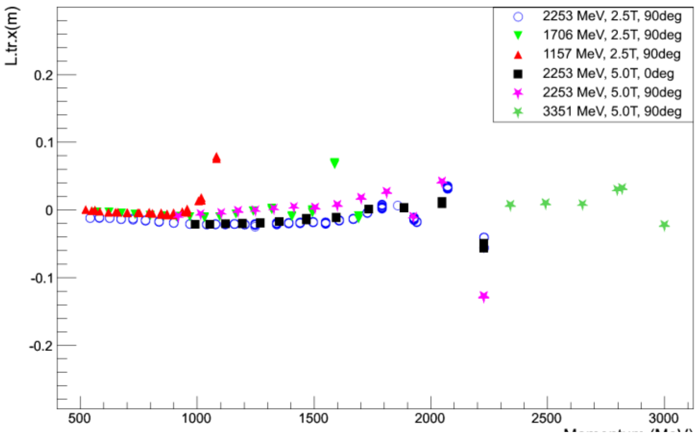

L.vdc.v2 $t_0$ versus Momentum



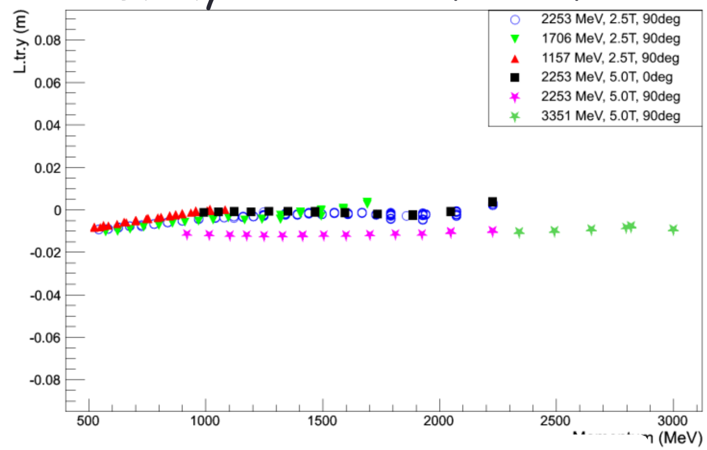
# VDC Track Variable Check

- Track Variable mean value check for all production runs

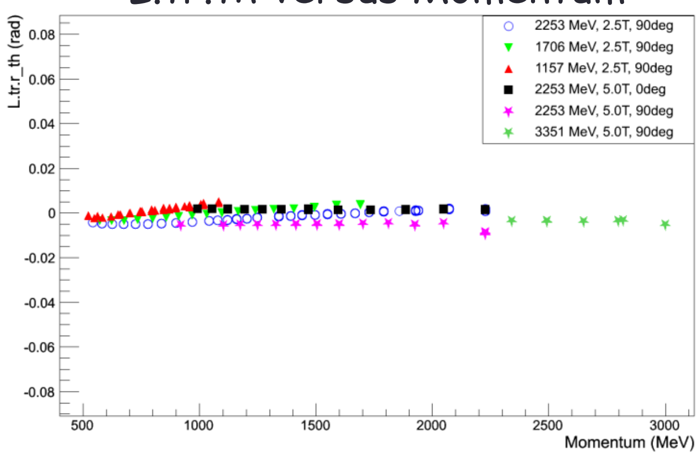
## L.tr.x versus Momentum



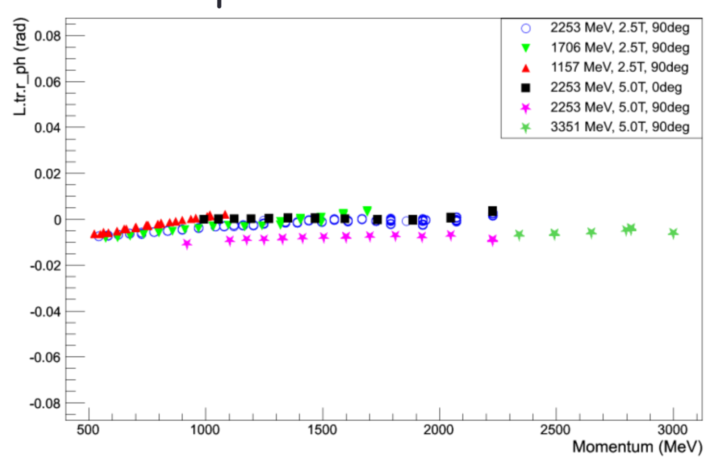

## L.tr.y versus Momentum




## L.tr.th versus Momentum

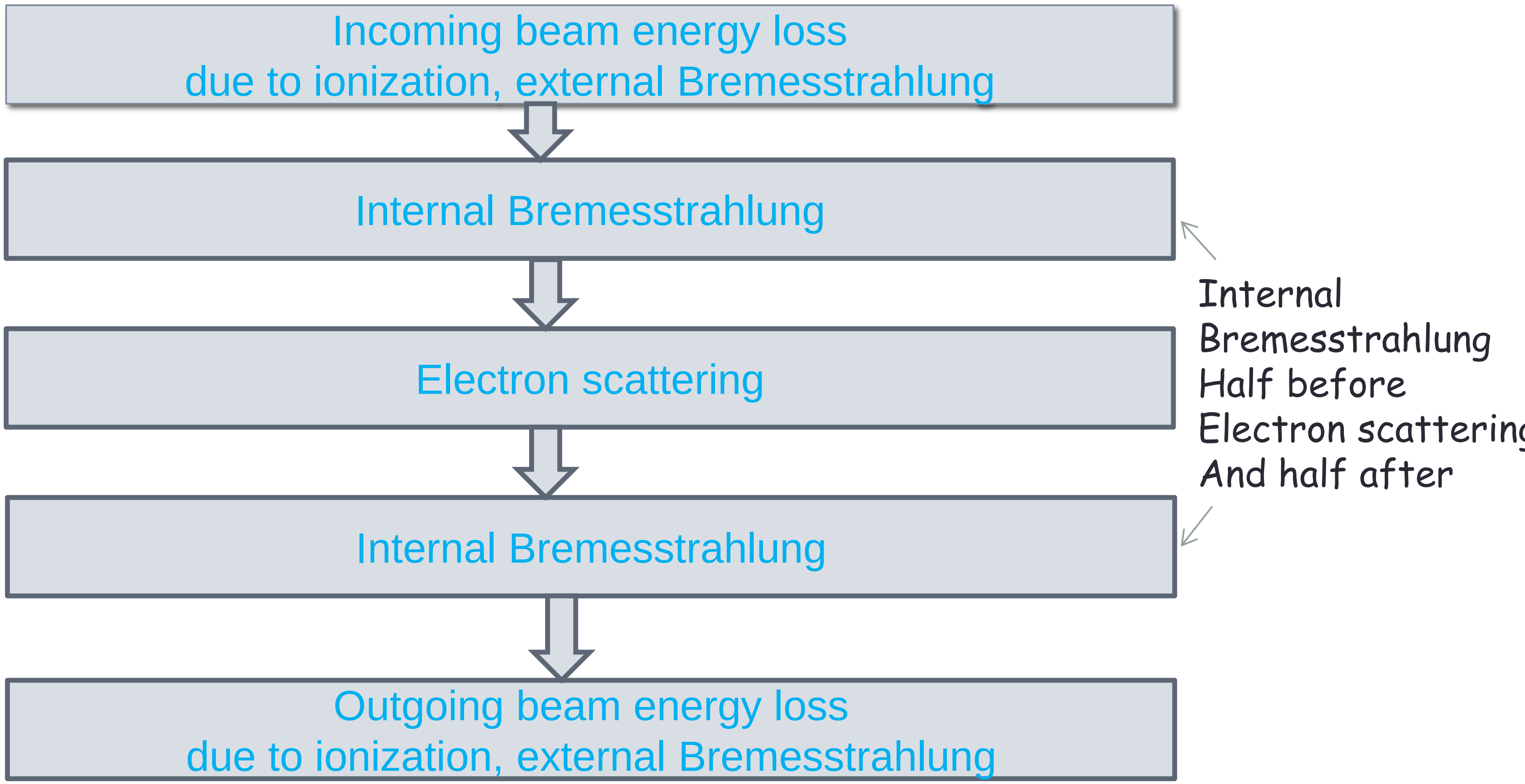



## L.tr.ph versus Momentum



# Energy Loss Model

- Use g2sim to simulate the real experiment, energy loss step by step

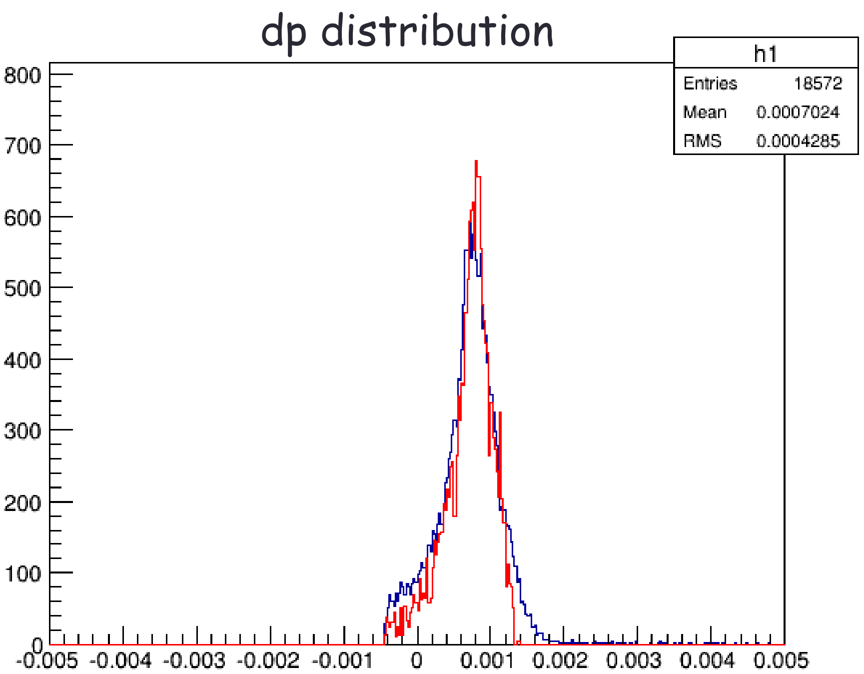


# Energy Loss Model

- **Bremesstrahlung**
  - ✓ External Bremesstrahlung
  - ❑ sample an energy loss $I_e(E_0, E, t) = bt(E_0 - E)^{-1}\,[\frac{E}{E_0} + \frac{3}{4}(\frac{E_0 - E}{E_0})^2]\,(\ln\frac{E_0}{E})^{bt}$
  - Internal Bremesstrahlung
  - ❑ equivalent radiator approximation
- **Ionization**
  - ✓ Landau distribution
  - ✓ Mean Energy Loss fluctuation Model
  - ❑ Excite with two energy levels or ionization with energy loss according to $E^{-2}$
  - ❑ Can be used for any thickness of media
  - ❑ Approach the Landau distribution at the limit of validity of Landau theroy

# Simulation versus Data

- Comparison between simulated dp versus optics run dp

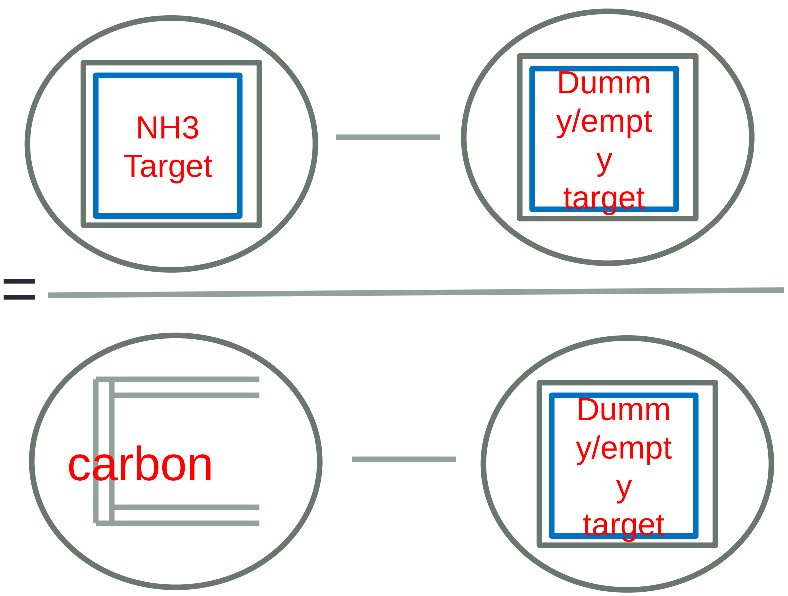



- ❑ Blue: from data, C w/o He optics
- ❑ Red: is from simulation: ionization fluctuation + internal + external brem.
- ❑ Total sieve holes

2.2 GeV, straight through Carbon without LHe run

# Packing Fraction Study--Simulation

- Packing Fraction: Ratio of $NH_3$ volume to the whole cell
- Method: Compare the experiment yields with the simulated yields



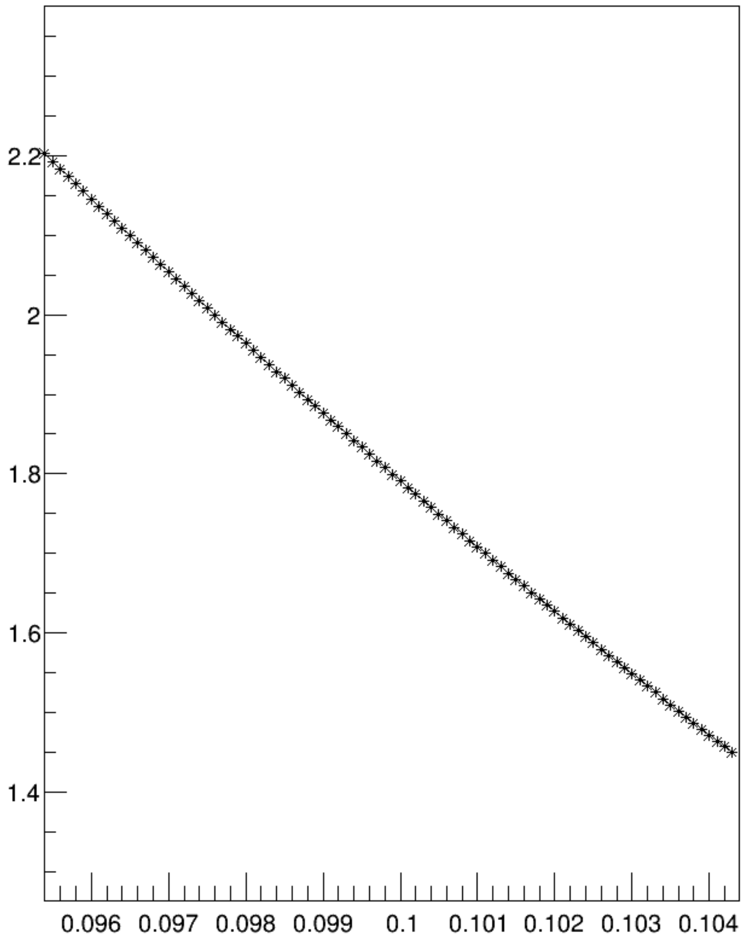

$$\frac{Y_{\exp\_target} - Y_{\exp\_dummy}}{Y_{\exp\_carbon} - Y_{\exp\_LHe}} =$$

Nose filled with LHe

$$= \frac{[\frac{d_{NH3}}{M_{NH3}} T_{cell} * pf * (\sigma_N + 3*\sigma_H) + \frac{d_{He}}{M_{He}} T_{cell} * (1-pf) * \sigma_{He}] - \frac{d_{He}}{M_{He}} T_{cell} * \sigma_{He} + \frac{d_{He}}{M_{He}} (T_{total} - T_{cell}) * (\sigma_{He1} - \sigma_{He2})}{\frac{d_C}{M_C} T_C * \sigma_C + \frac{d_{He}}{M_{He}} (T_{total} - T_{endcap}) * \sigma_{He3} - \frac{d_{He}}{M_{He}} (T_{total} - T_C) * \sigma_{He2} + \frac{d_{He}}{M_{He}} T_{endcap} * \sigma_{Al}}$$

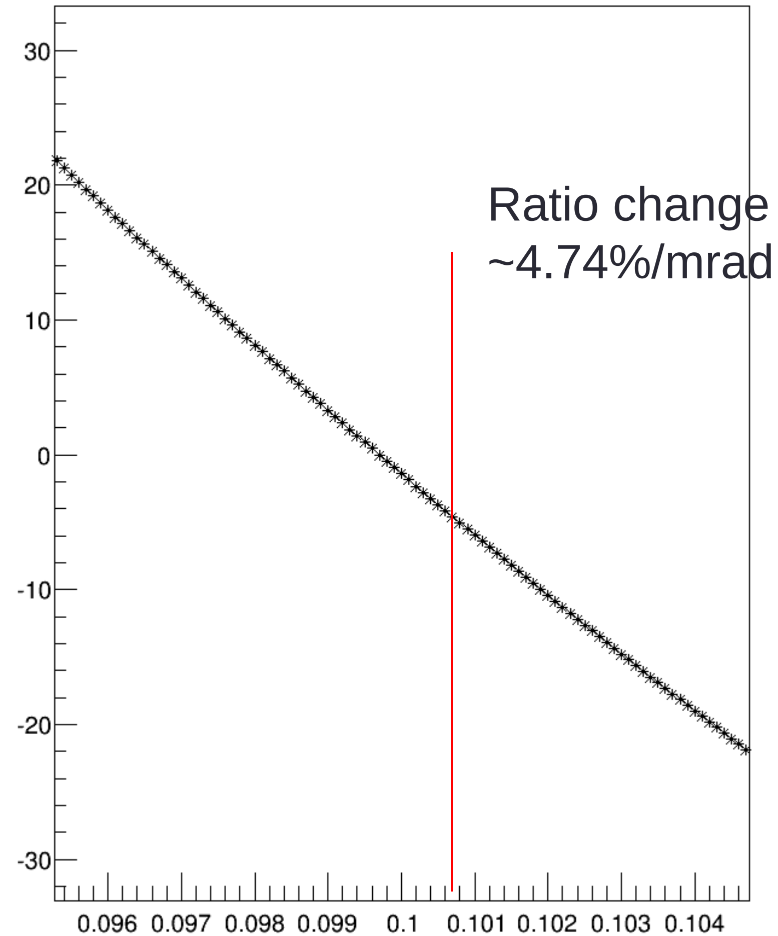
# Packing Fraction Study--Simulation

$\sigma_N/\sigma_{He}$ vs. scattering angle




Scattering angle/mrad

$\delta(\sigma_N/\sigma_{He})$ vs. scattering angle




Scattering angle/mrad

# Packing Fraction Study--Simulation

- 2.2GeV, 5T, Longitudinal, Material 18

| Runs | Type | Exp. Yields | Beam x/mm | Beam y/mm | Beam th/mr | Beam ph/mr |
|---|---|---|---|---|---|---|
| 5649 | Carbon | 855025 | 0.22 | -3.84 | -0.54 | 0.10 |
| 5650 | Empty | 481113 | 0.16 | -3.59 | -0.30 | 0.02 |
| 5651 | Dummy | 480956 | -0.23 | -3.76 | -0.53 | -0.40 |
| 5652 | Production | 832366 | 0.34 | -3.65 | -0.40 | 0.19 |

- $p_f = 0.51$
- assume run 5652, 5649, 5650, relative beam shift is small, bpm absolute uncertainty 1mrad
- $\delta\left(\frac{\sigma_{He}}{\sigma_{He1}}\right) = \delta\left(\frac{\sigma_{He2}}{\sigma_{He1}}\right) = \delta\left(\frac{\sigma_{He3}}{\sigma_{He1}}\right) = 0,\ \delta\left(\frac{\sigma_{N}}{\sigma_{He1}}\right) = 4.74\%,\ \delta\left(\frac{\sigma_{H}}{\sigma_{He1}}\right) = -0.95\%,\ \delta\left(\frac{\sigma_{C}}{\sigma_{He1}}\right) = 3.63\%$
- ${}^{\delta_{Pf}}/_{Pf} = 7.61\%$, 1mrad uncertainty

# Graduate Plan

- Shorterm
  - ❑ dp simulation study and simulation package (1 month)

- Longterm
  - ❑ Finalize thesis topic and publish
  - ❑ Expected graduate by summer 2016, depends
  - ❑ Prefer an academic work