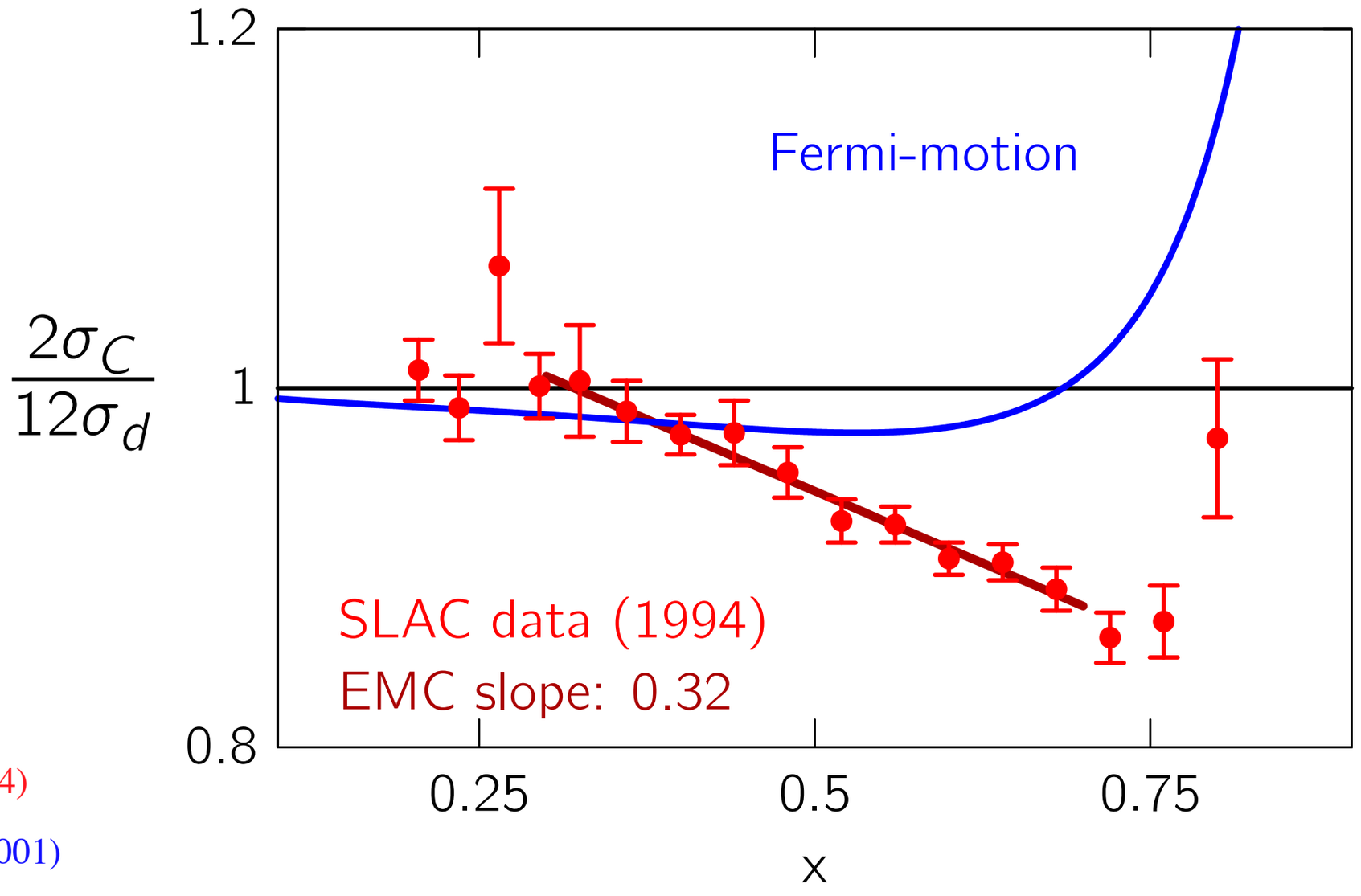
BAND Detector Update

Florian Hauenstein,
Efrain Segarra,
Rey Cruz-Torres,
CLAS Collaboration Meeting
06/20/19

The EMC Effect in DIS Scattering

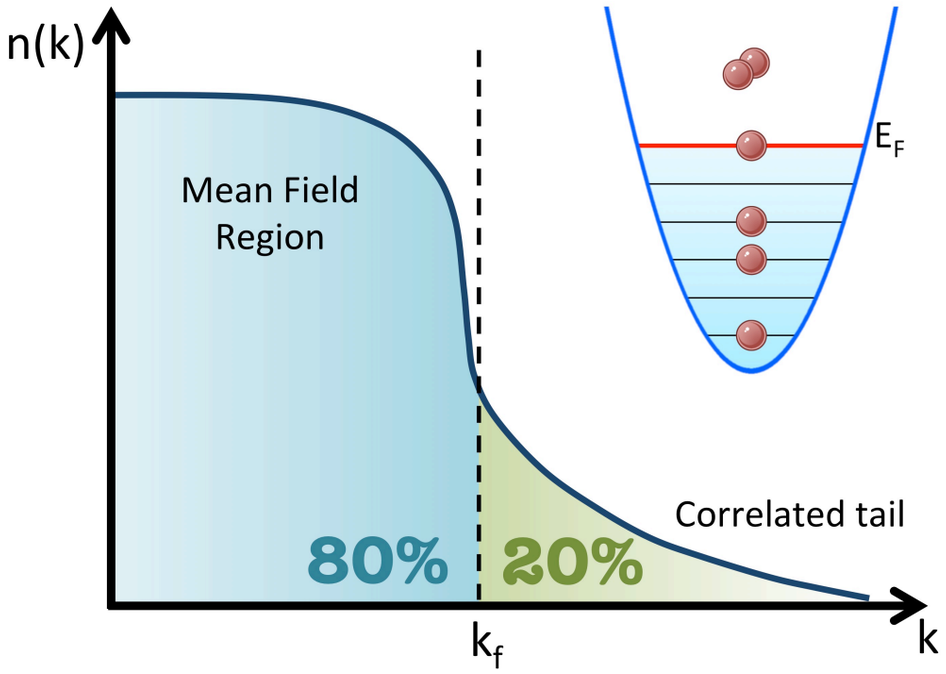


PRD 49, 4338 (1994)

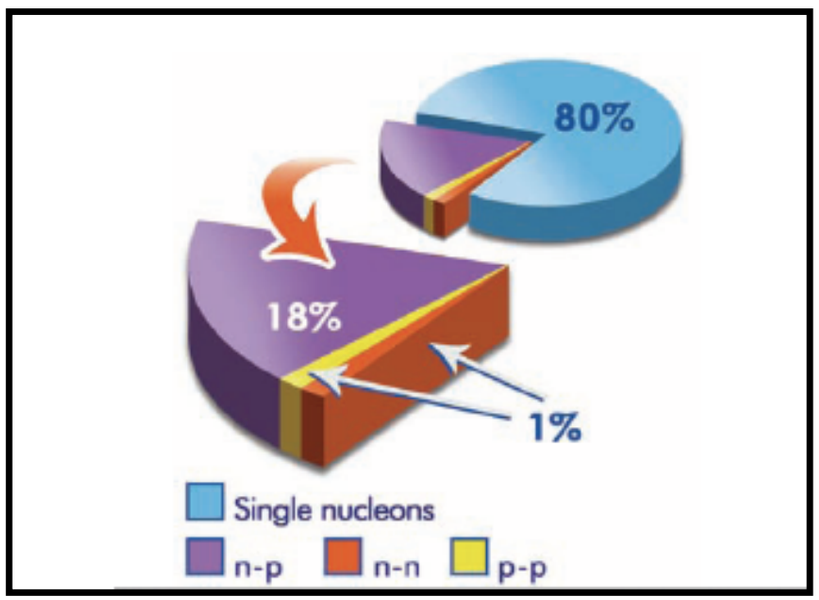
PRC 65, 015211 (2001)

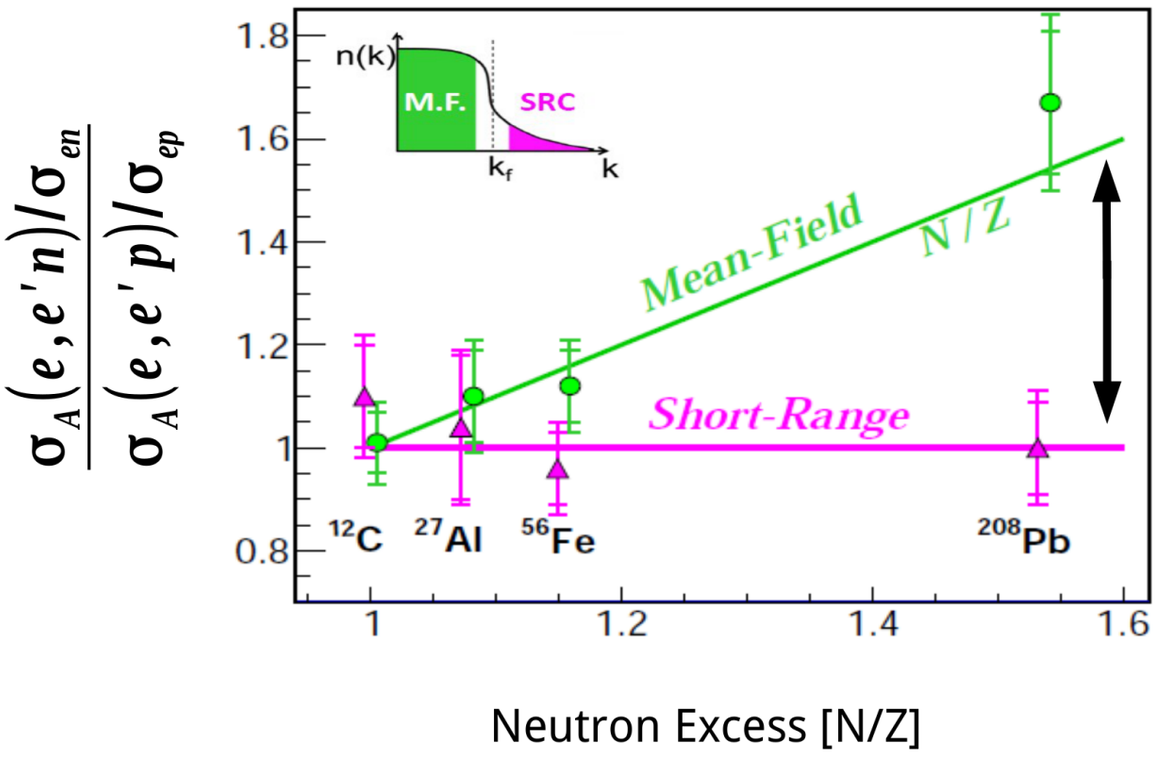
Quark distributions (F_2) in nucleons bound in nuclei different to distributions in free nucleons, here: $F_2^C \neq 6 * F_2^d$

Short Range Correlations



Subedi et al., Science 320, 1476 (2008)

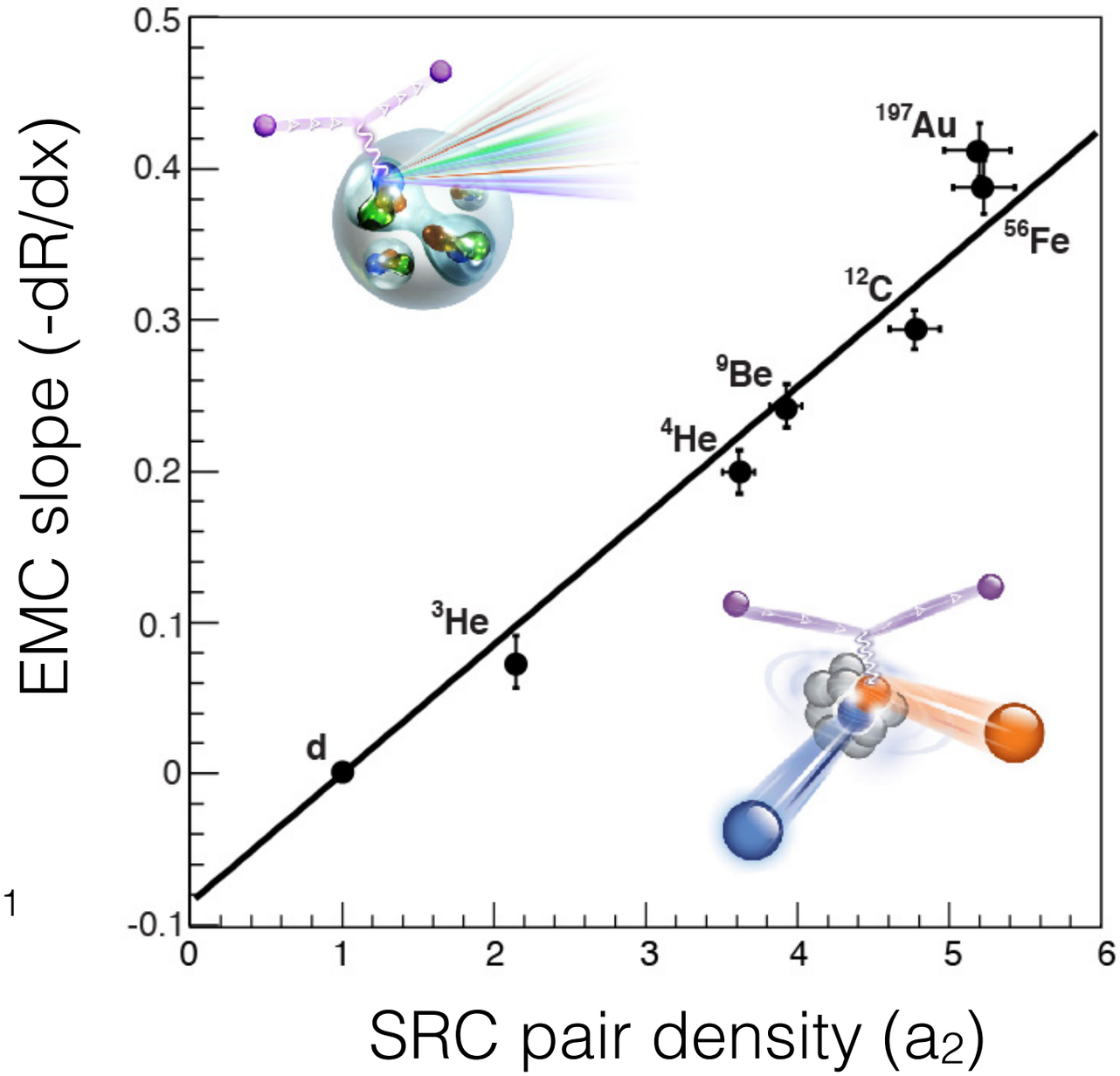




Duer et al. (CLAS collaboration), Nature 560, 617 (2018)

- NN pair with **large relative momentum and small c.m momentum**
- ~20% of nucleons in nuclei
- SRC pairs dominate nucleon momentum distribution above fermi momentum k_F
- **np dominance of SRC pairs** (about ~18 more likely than pp or nn)

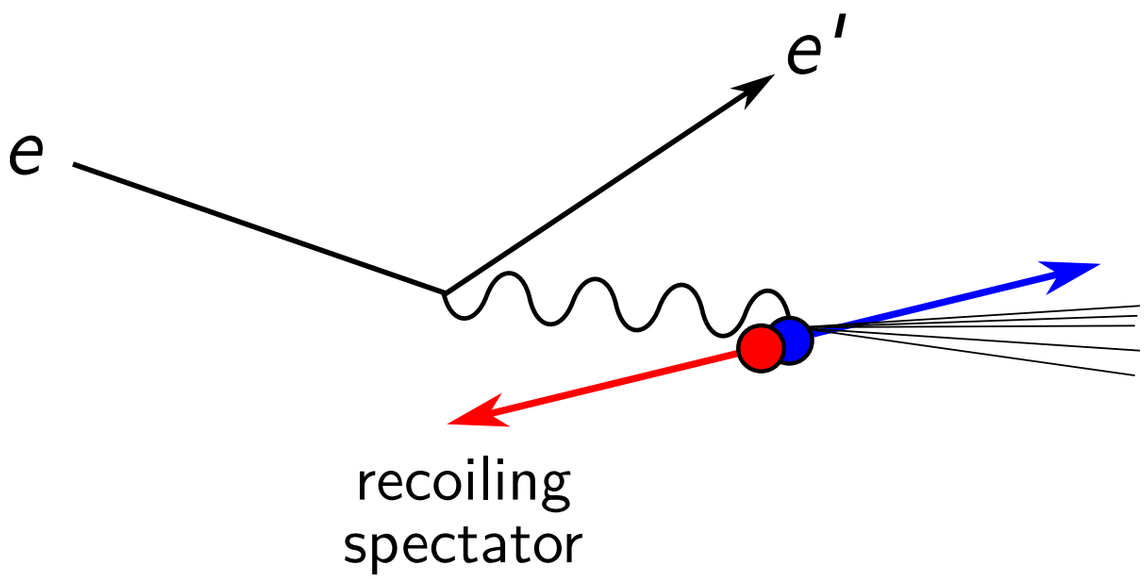
EMC and SRC Correlation

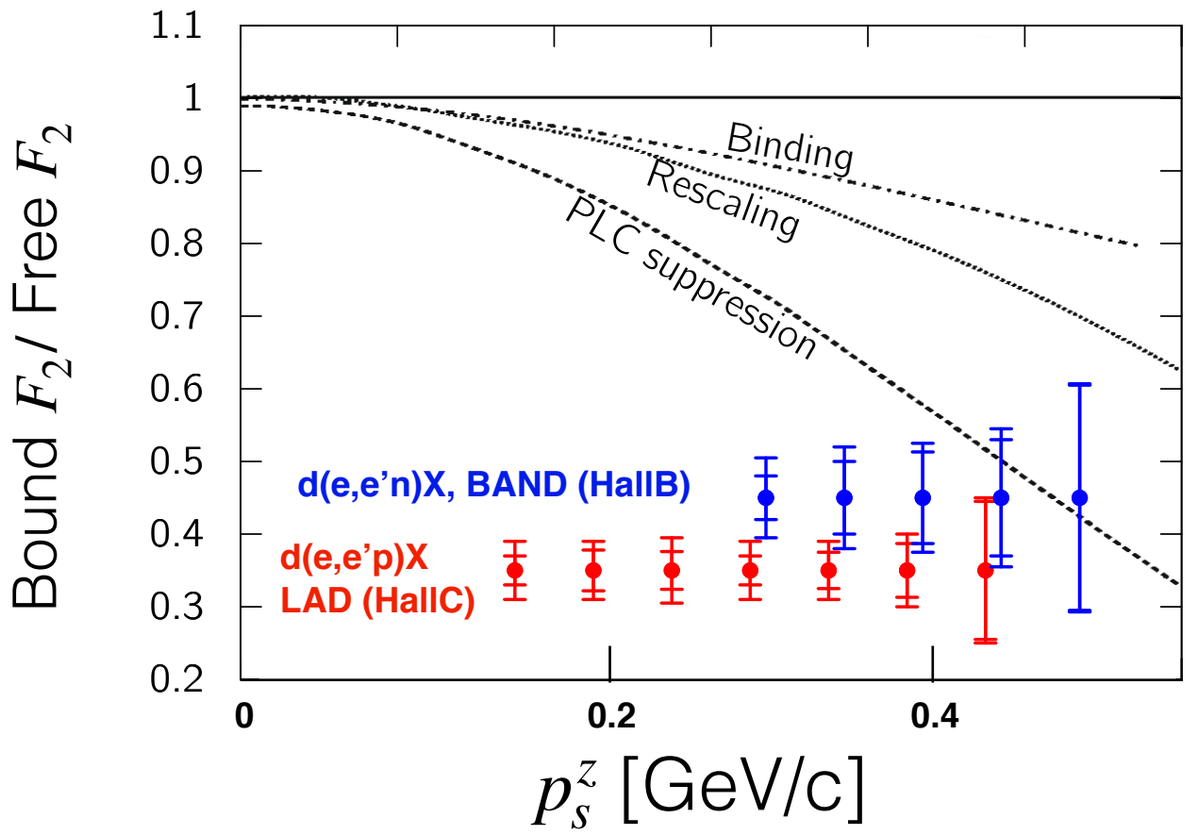


Weinstein et al., PRL 106, 052301 (2011), Hen et al.,PRC 85, 047301(2012)

- Are high-momentum nucleons responsible for the EMC effect?
- Does nucleon modification depend on nucleon momentum?

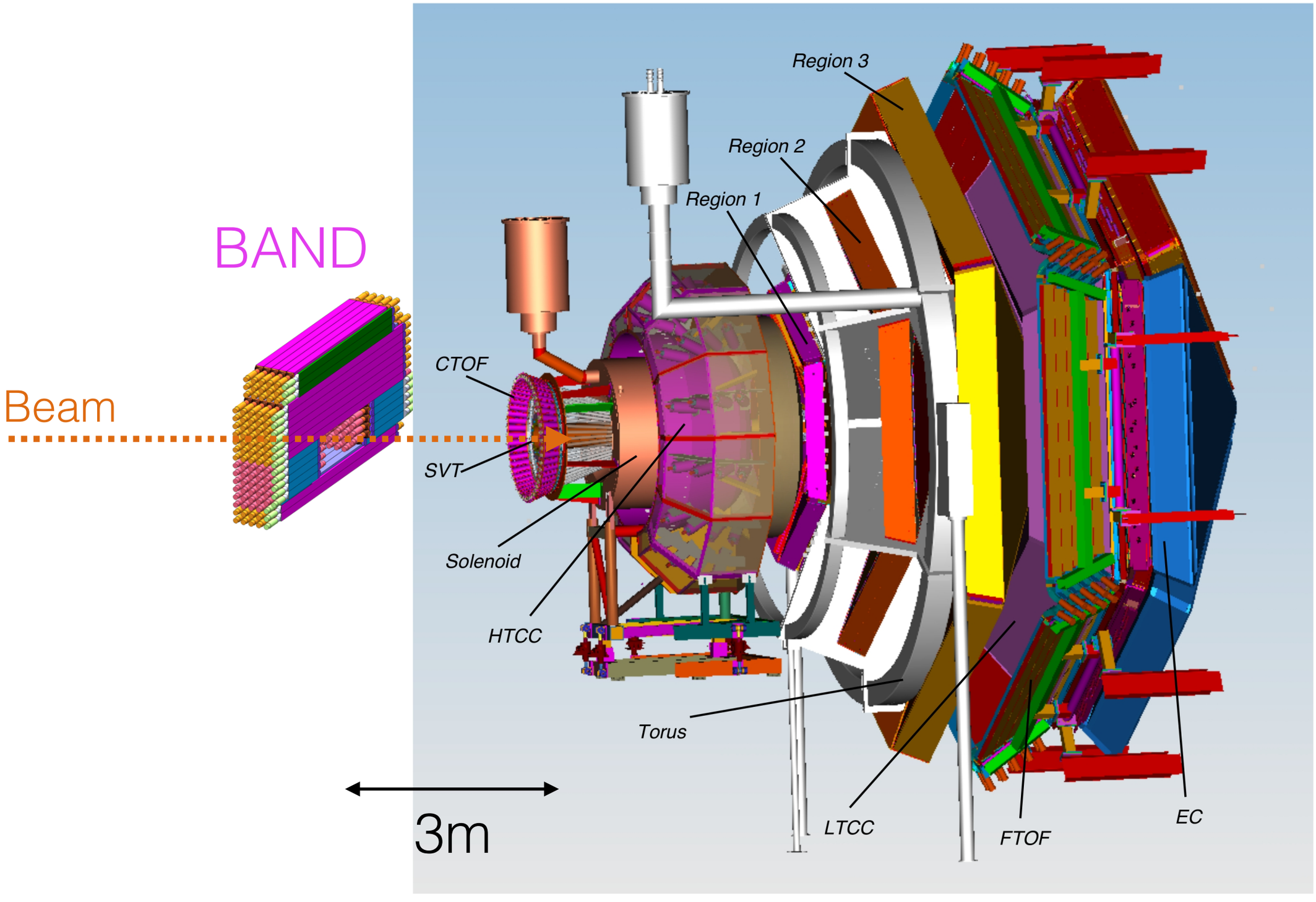
Tagged DIS on Deuterium





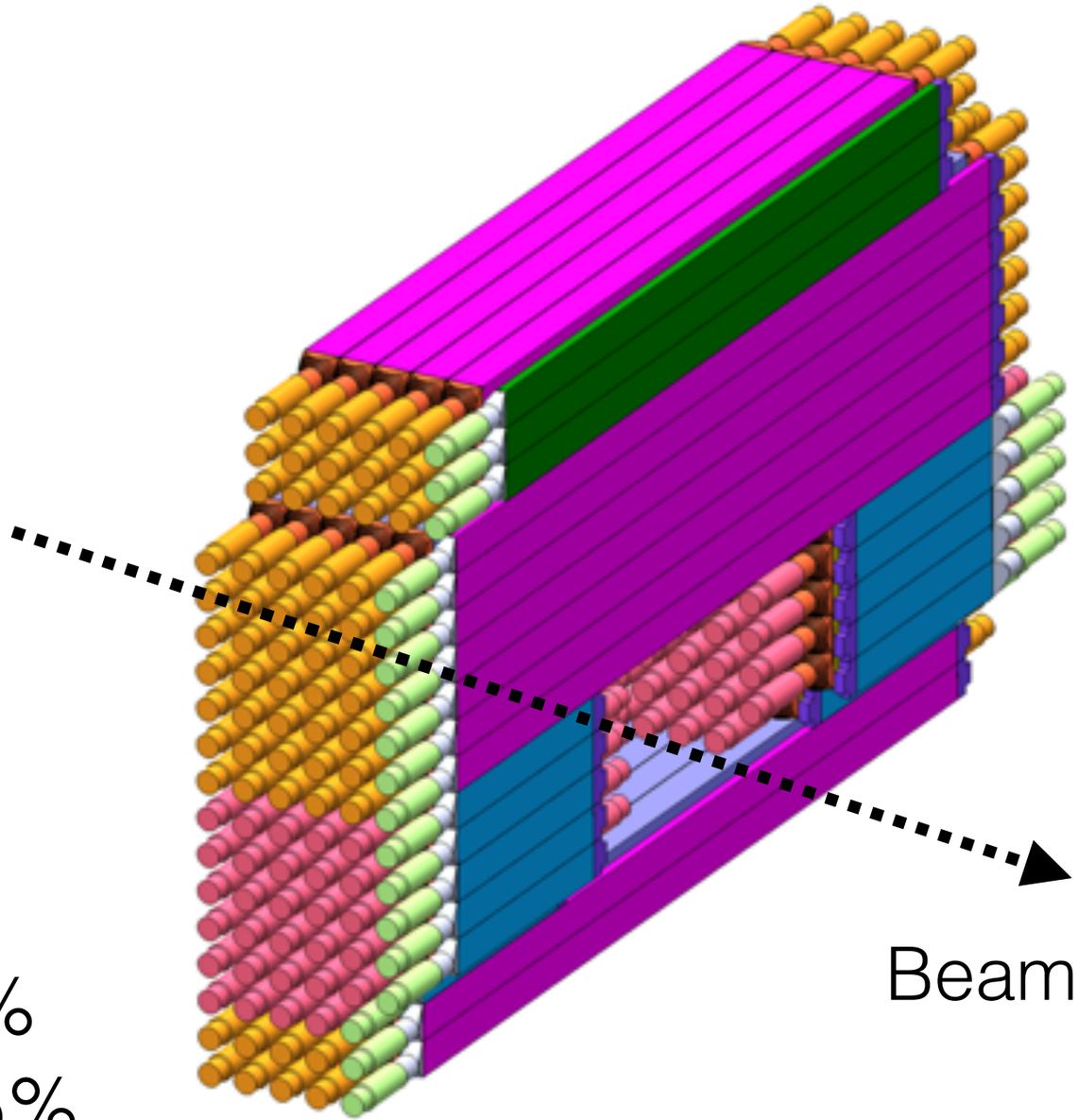
- "Tag" interacting nucleon by measuring spectator
- How does the bound nucleon structure function depend on nucleon momentum?
- Explain the EMC effect

CLAS12 and BAND

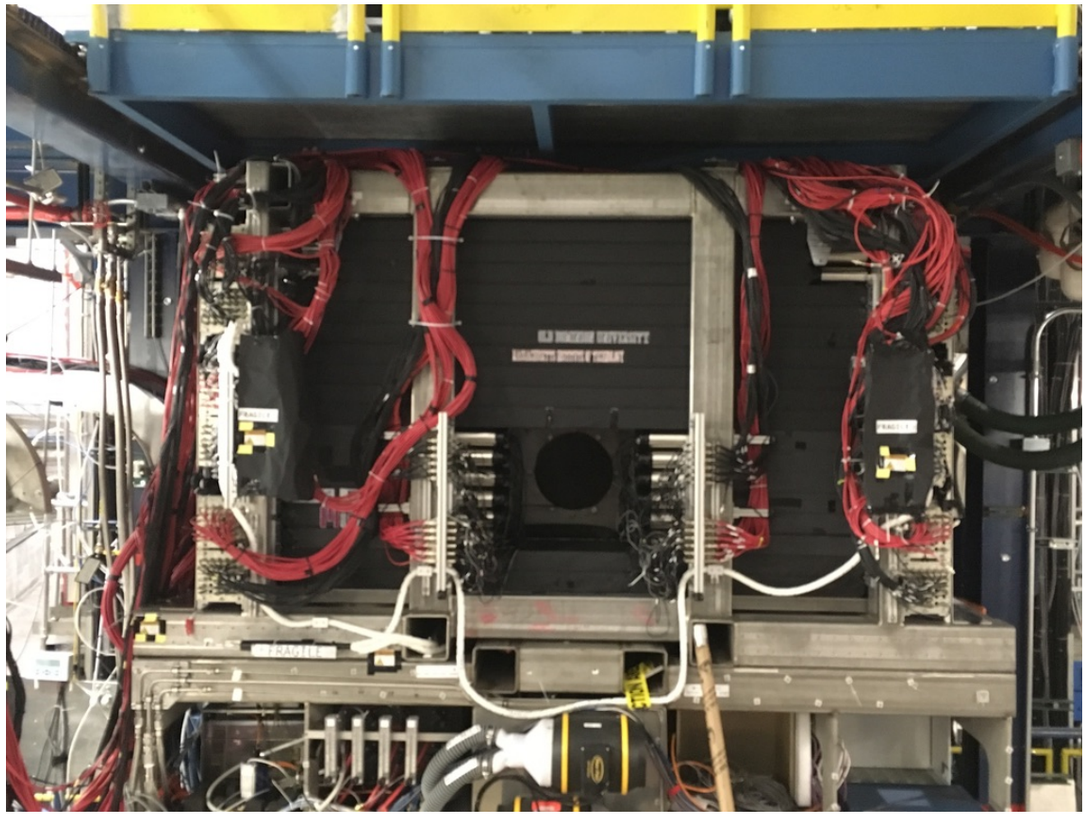


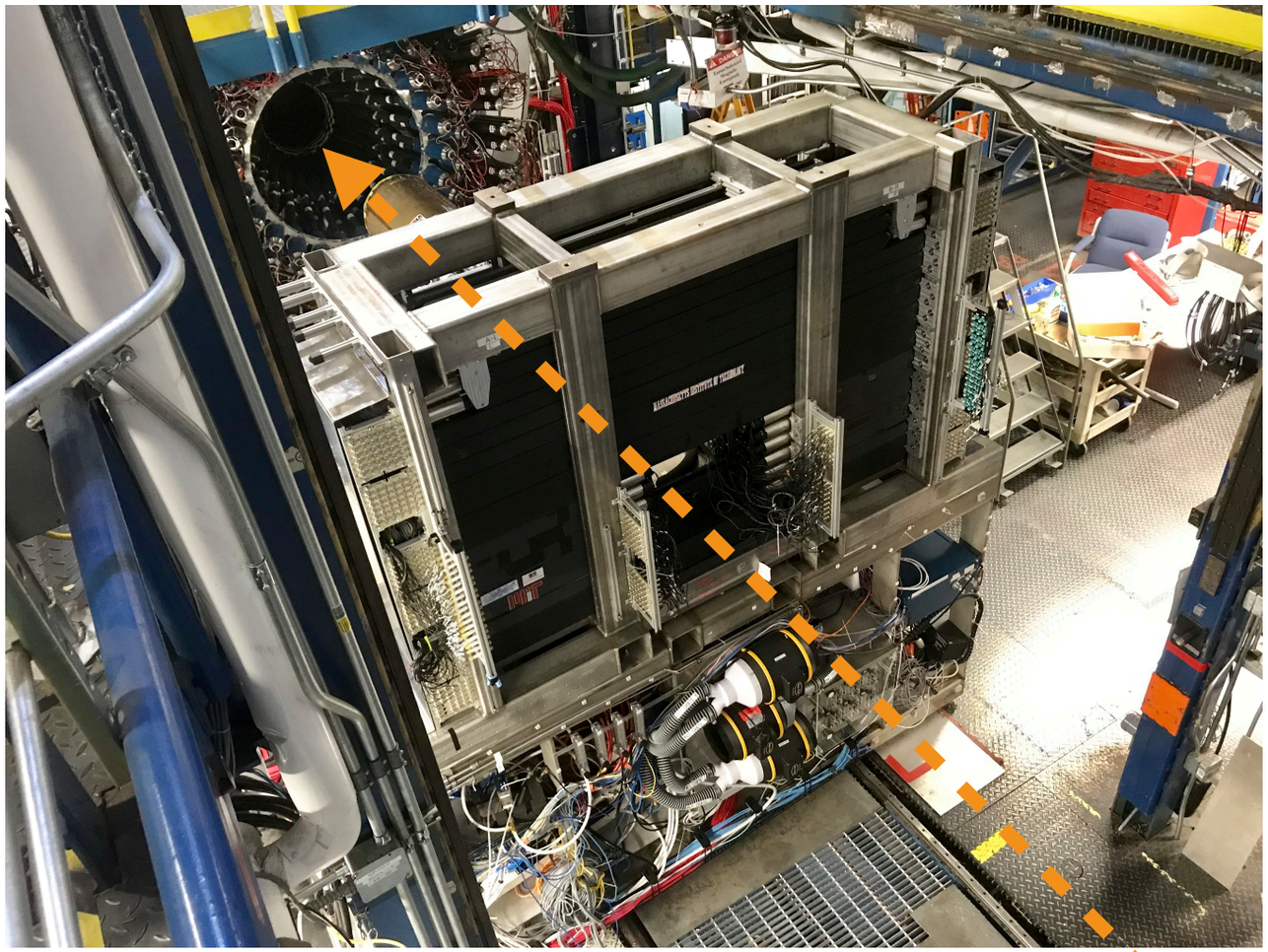
Overview of BAND

- 5 layers thick (36cm total) with veto layer (1cm thick)
- 140 scintillator bars
- Bar resolution < 200 ps
- 3 meters upstream of target
- 155° < θ < 176°, 200 msr
- Design neutron efficiency ~35% and momentum resolution ~1.5%
- Laser system for calibrations —> see Andrew's talk



BAND in HallB





Base Level Calibrations

Cosmic Data

- HV Gains ✓
- ADC calibration ✓
- TDC/FADC phase offset ✓
- TDC time walk ✓
- Effective velocity ✓

Source Data

- Bar attenuation ✓
- Timing offsets ✓

Laser Data

Prod Data

- Neutron efficiency
- Neutron momentum resolution

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Cosmic Data

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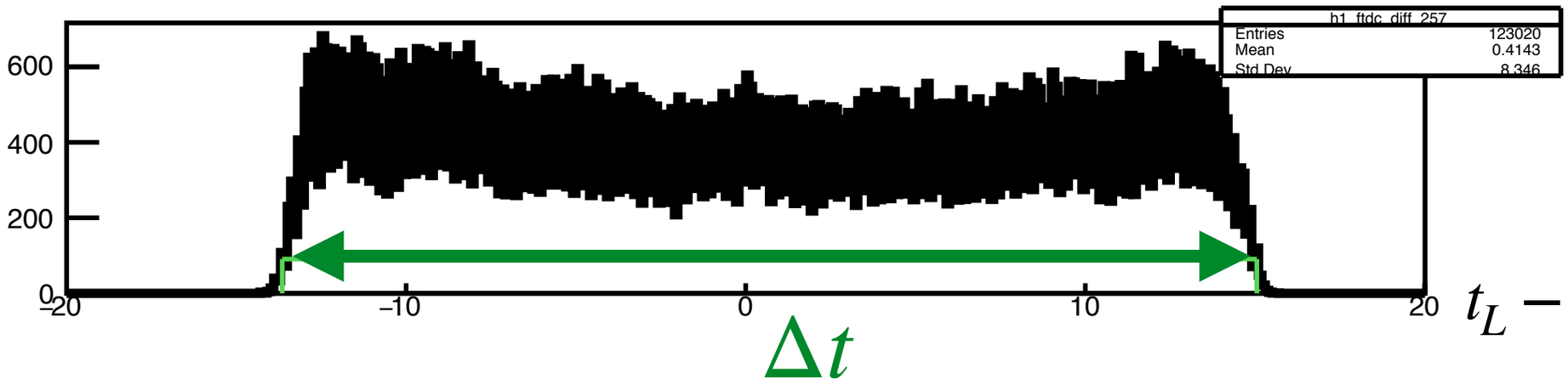
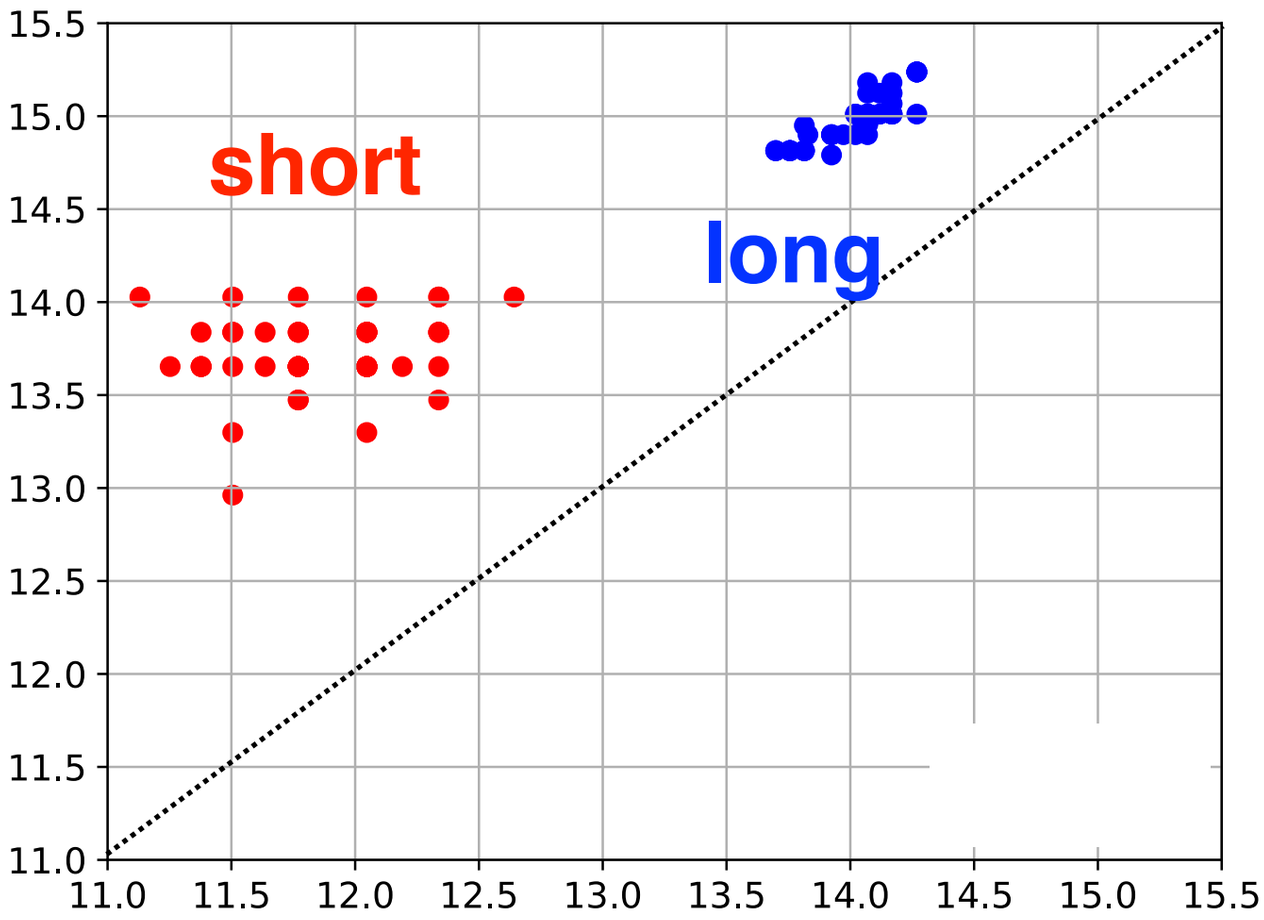
L-R Calibration and Effective Velocity

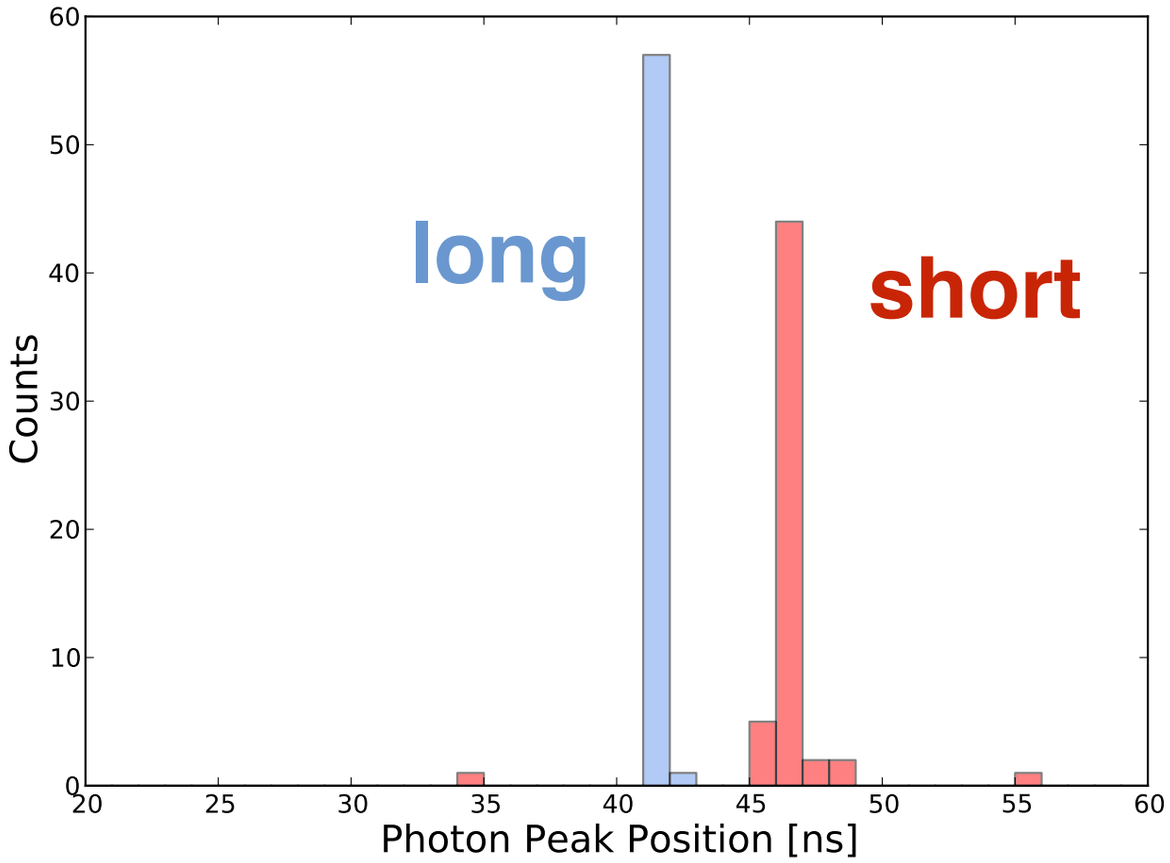




$$v_{\text{eff}} = \frac{s_{\text{bar}}}{\Delta t}$$

(Discrete steps due to binned 0.1ns)

Timing Alignment

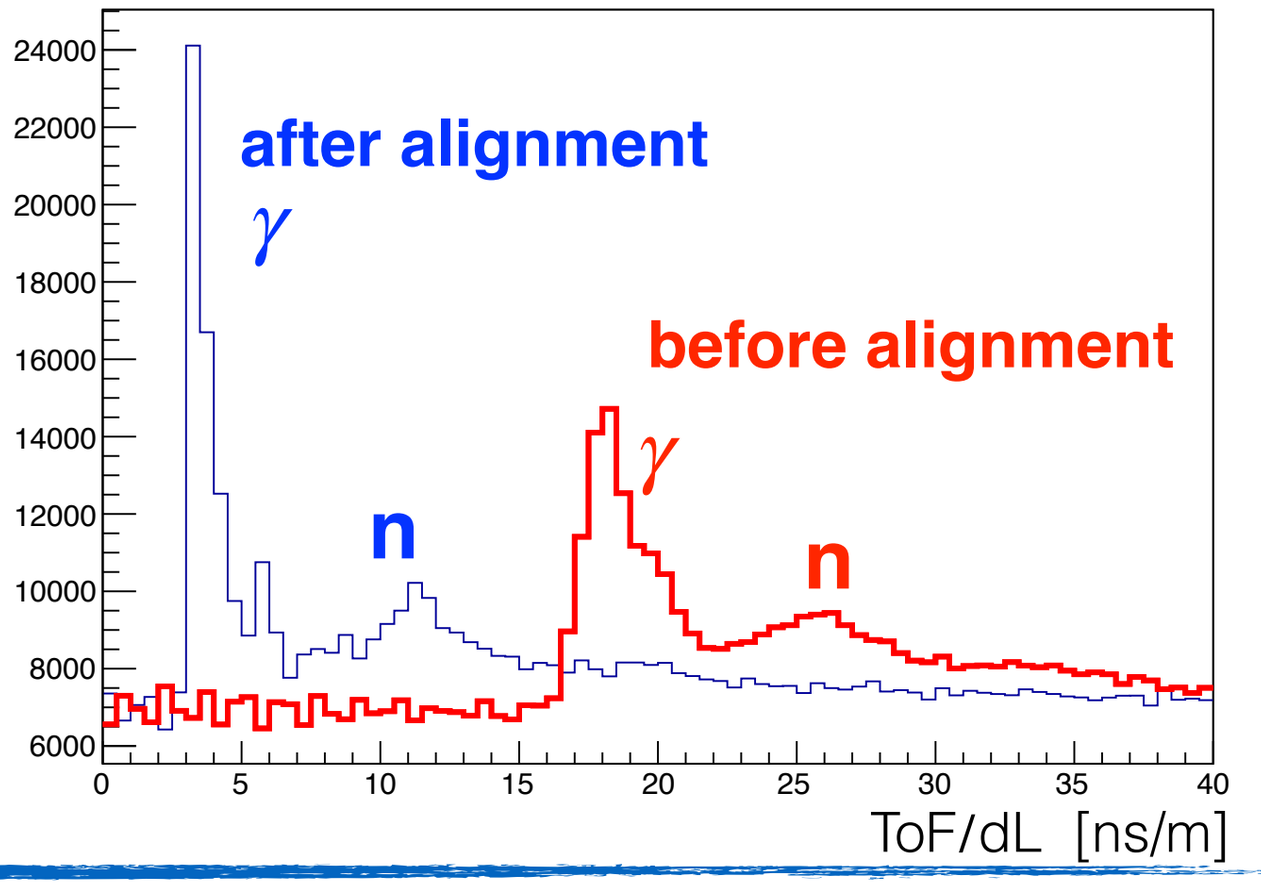


Photon peak position before final timing alignment (after pre-calibration with laser)

—> Apply correction per bar

ToF/dL spectrum before and after photo peak alignment

—> Improved resolution



DIS Selection Cuts

$Q^2 > 2$ [GeV^2]

$W > 2.2$ [GeV]

PID of event builder for e’, no quality/fiducial cuts

Only 1 hit in BAND for neutral PID

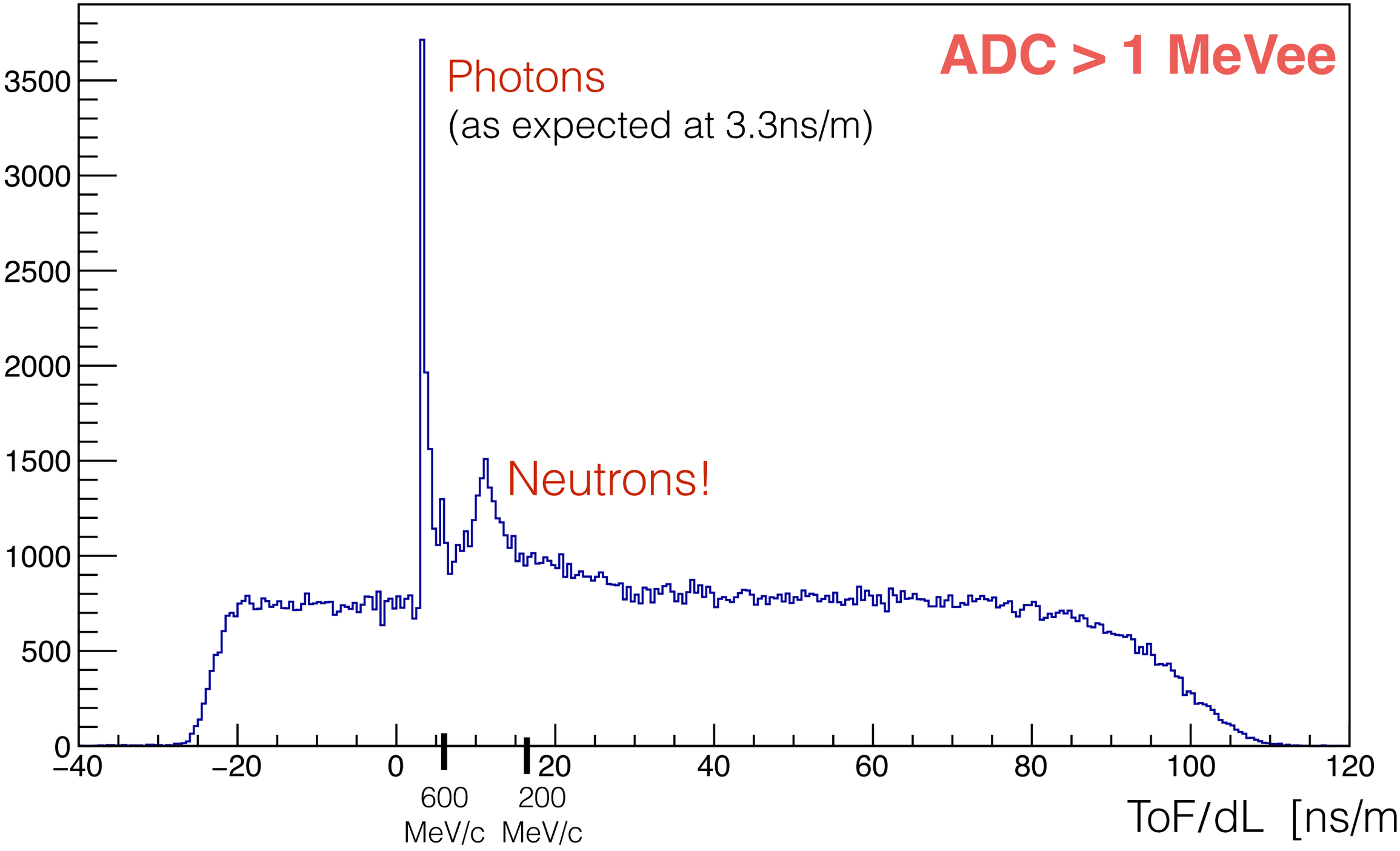
Runs 6327 - 6333, coatjava 5b.7.8

Beam energy 10.6 GeV

Beam current 50nA

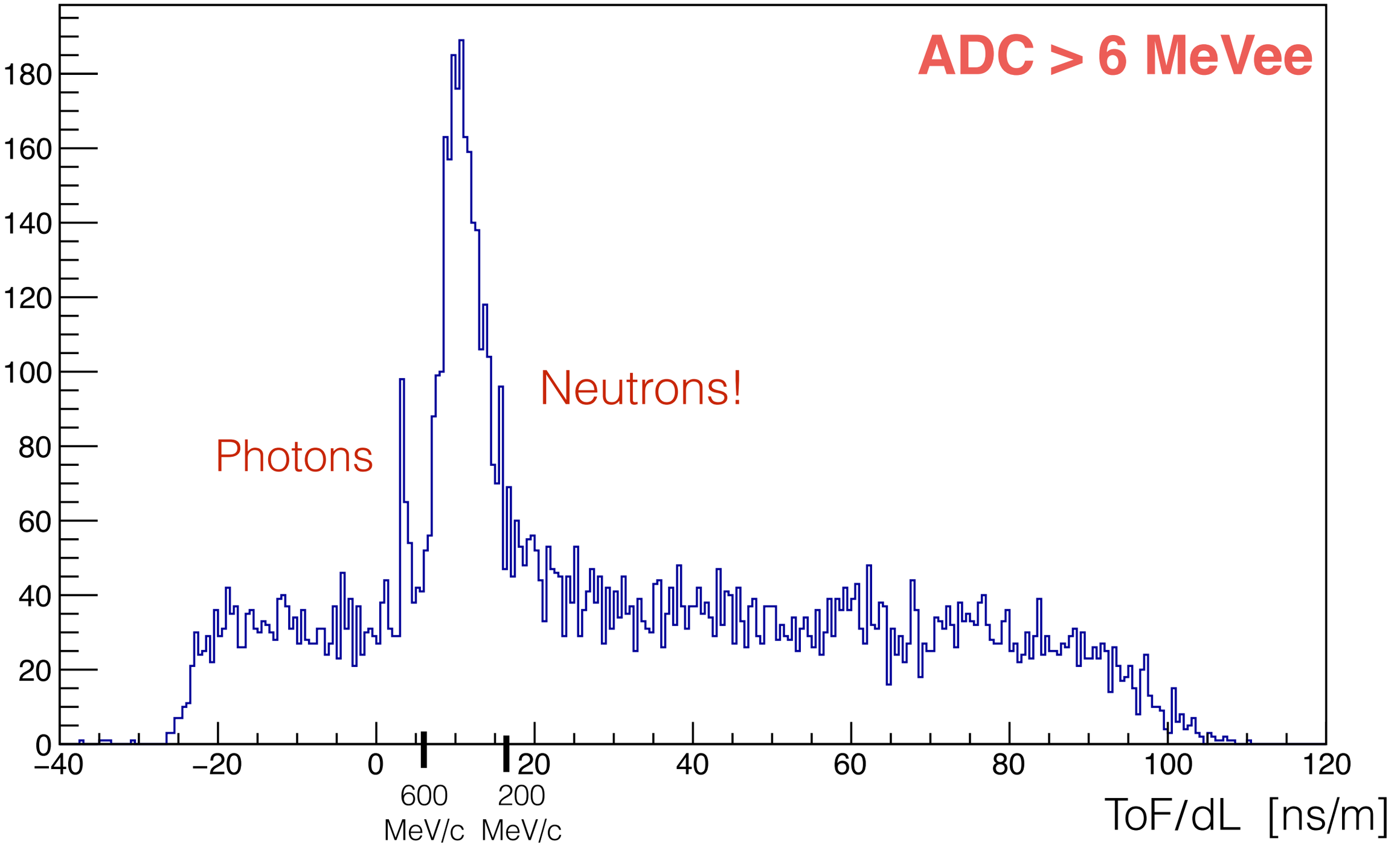
ToF/m Spectrum

One full day@50nA, DIS cuts, BAND neutral hits



ToF/m Spectrum

One full day@50nA, DIS cuts, BAND neutral hits



ToF/m Spectrum

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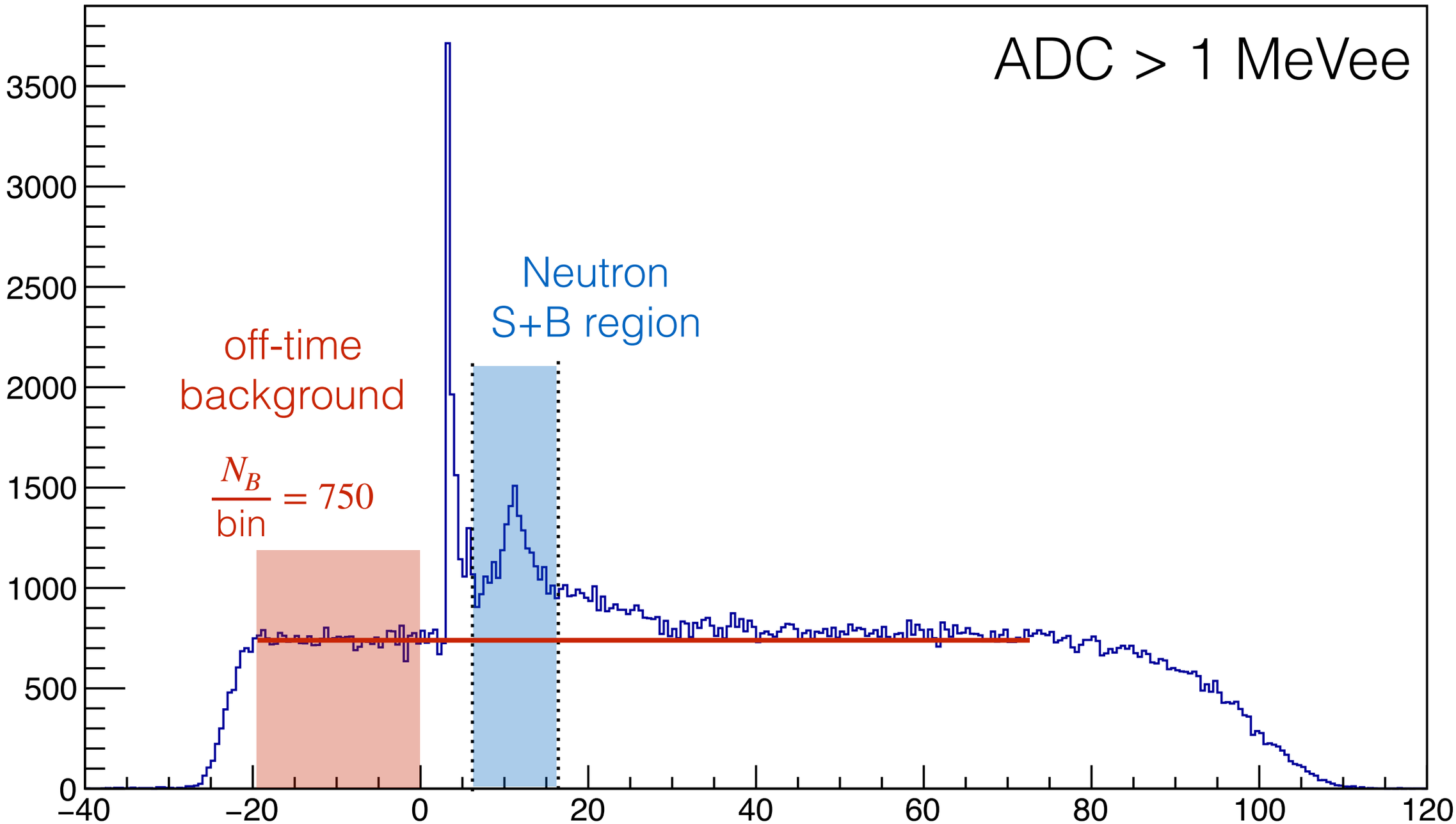
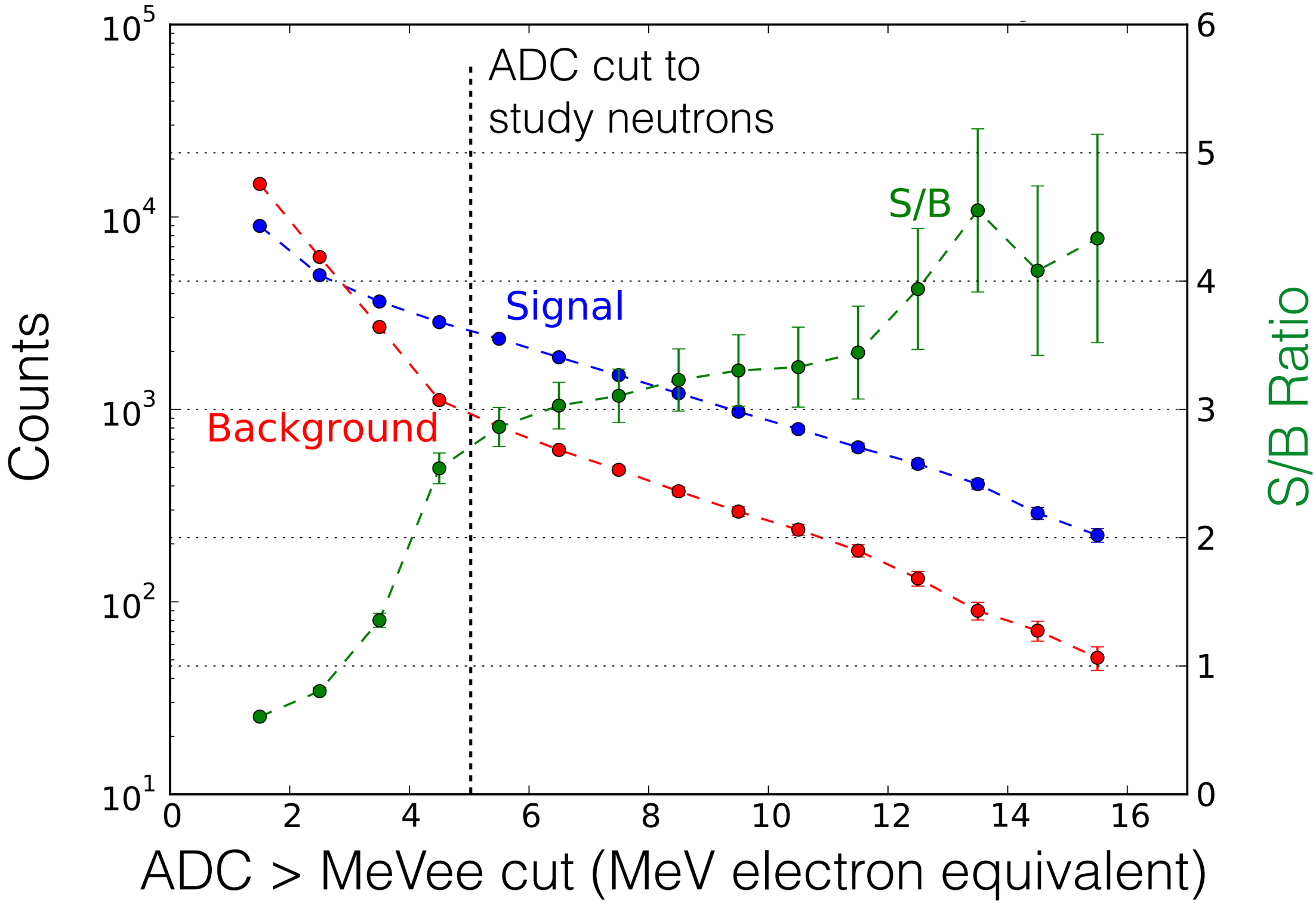
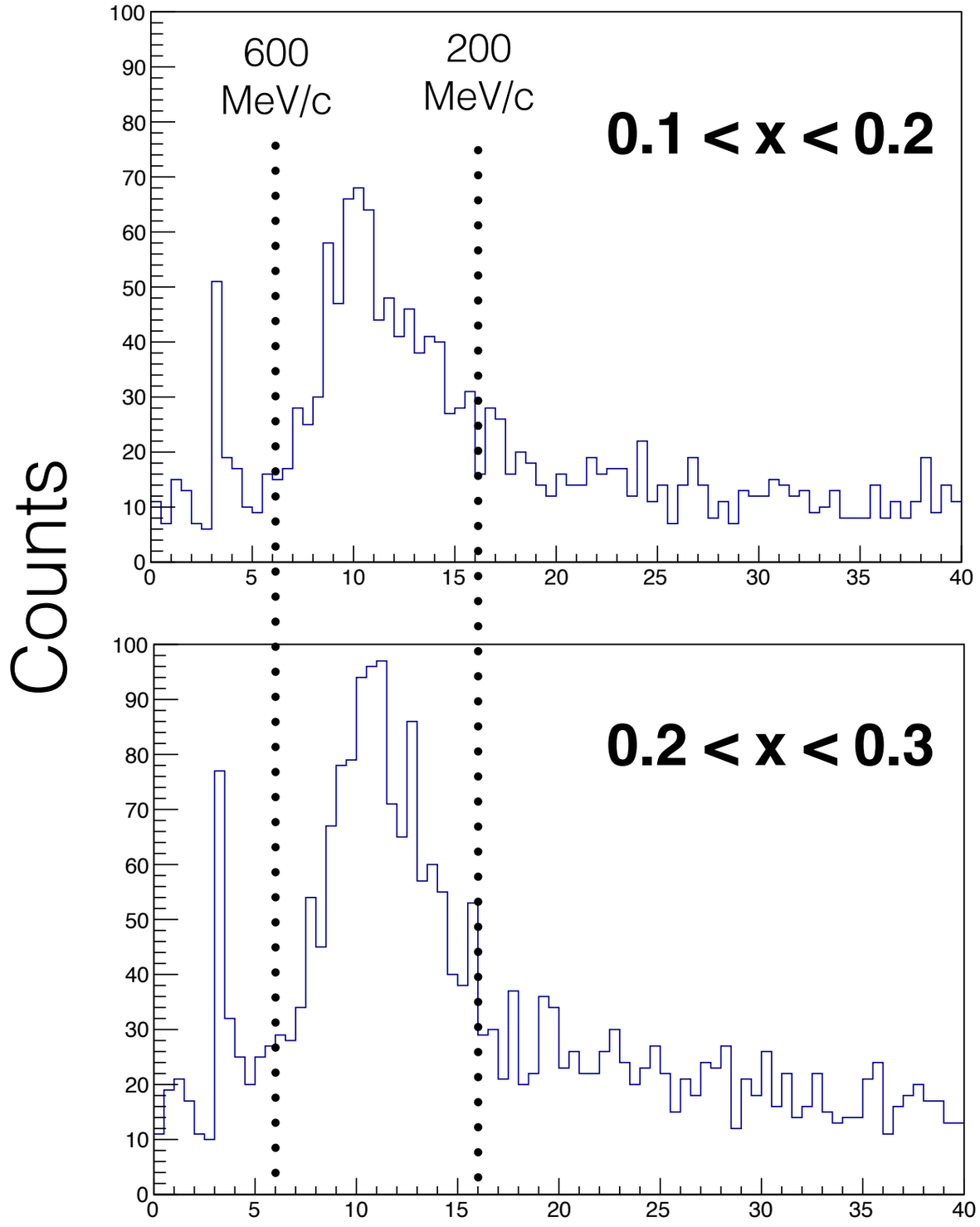


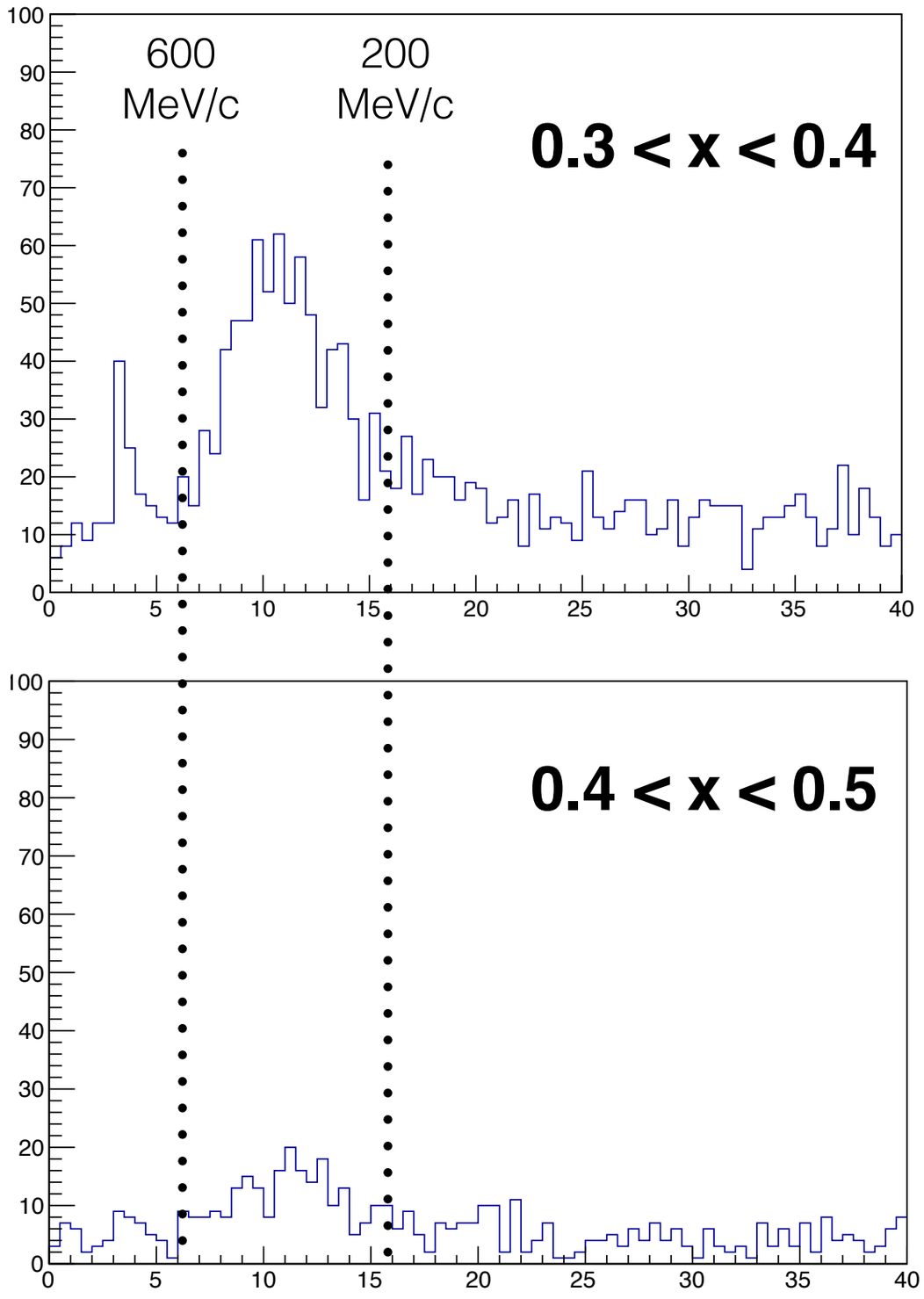
Determine dependence on ADC cut

Signal and Background at 50nA, DIS cuts



ToF/m: ADC > 5MeVee, x ranges





Counts

ToF/dL [ns/m]

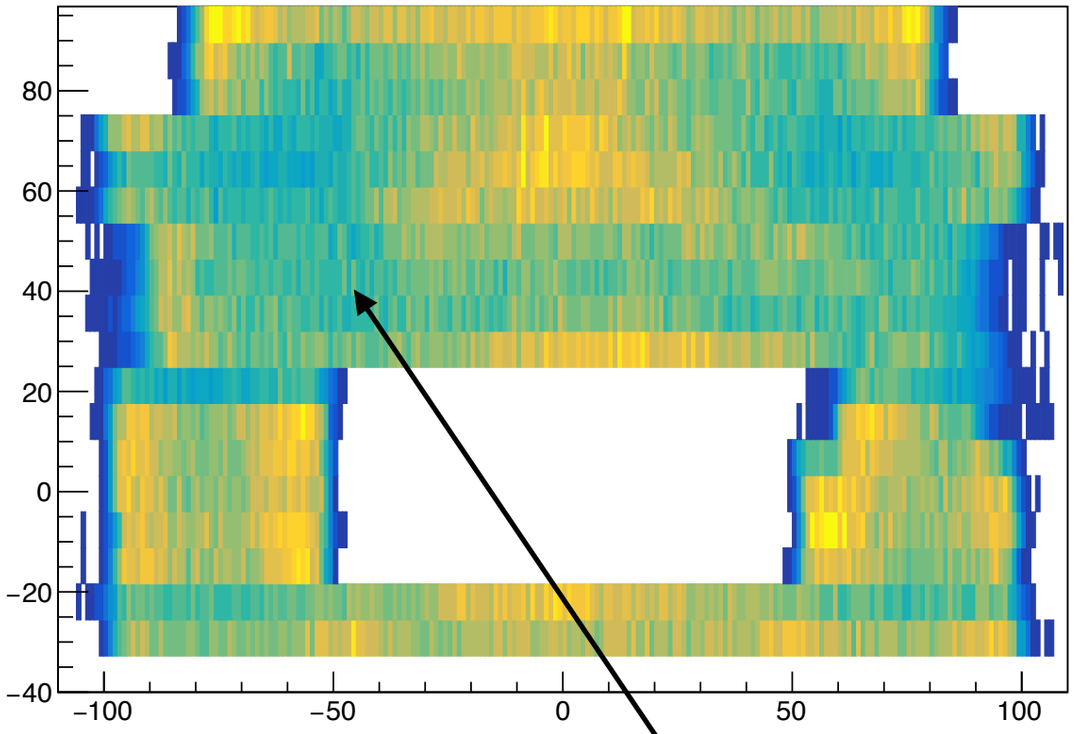
BAND Simulations

- Stand-alone Geant4 simulation
  - CLAS12 via acceptance map (no detailed detector simulation)
  - Simple CLAS12 momentum resolution
  - Tagged DIS neutrons and accidental background neutrons
  - Check of analysis methods and routines

- Implementation work for GEMC
  - BAND
  - Upstream Beam pipe ✓
  - Micromegas electronic boxes
  - CTOF PMTs and shielding
  - CND PMTs and shielding

BAND Hit Distribution

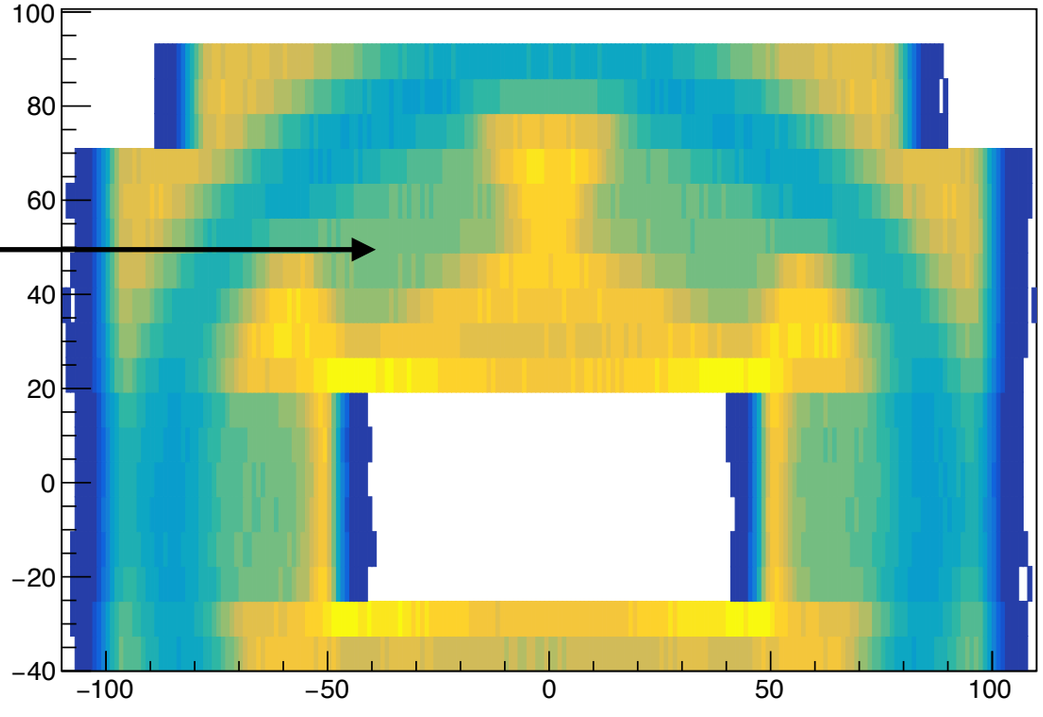
Data



Micromegas electronic boxes

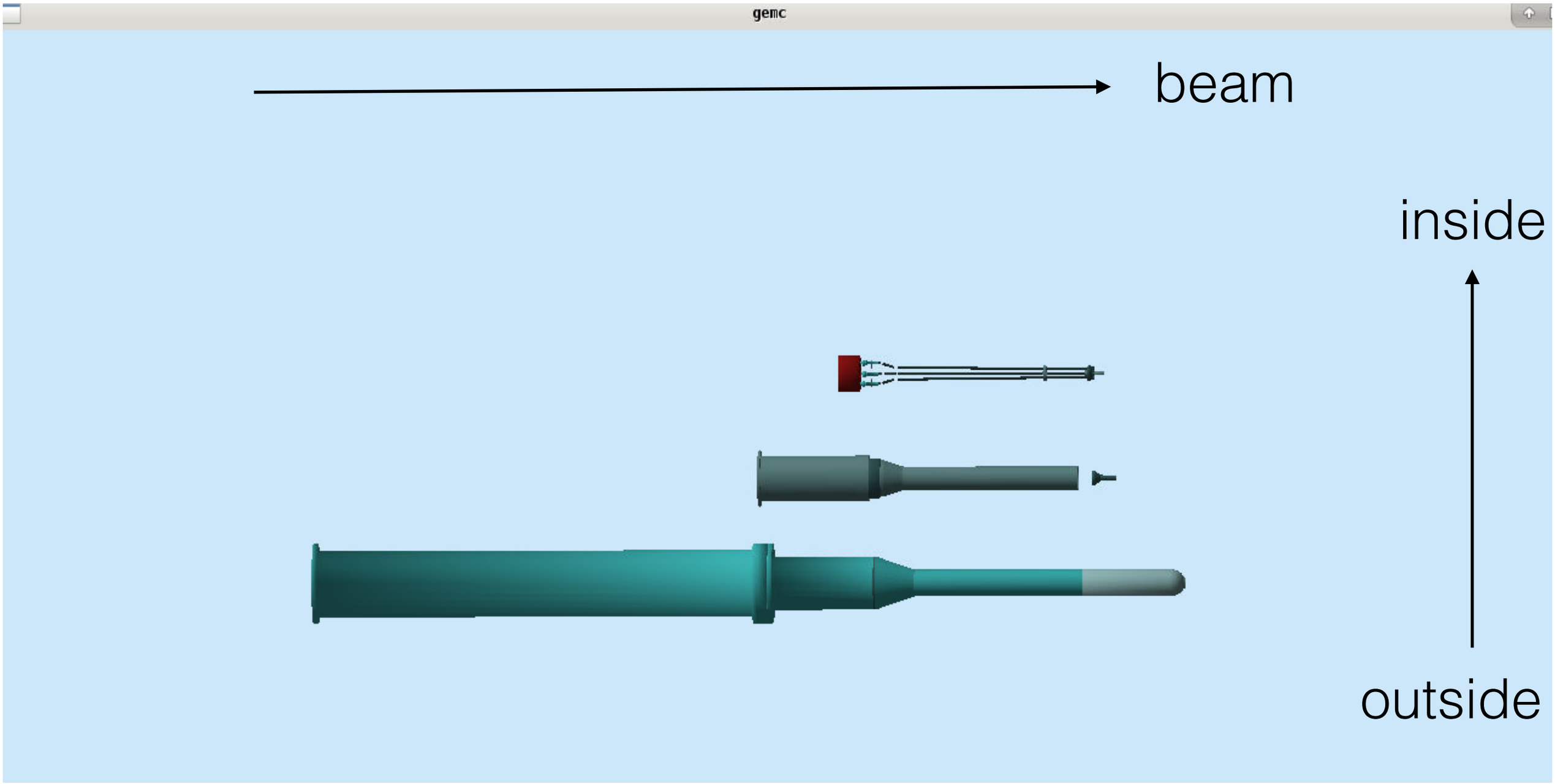
Similarities of hit distribution in data and simple Geant4 simulations

Simple Simulation



Upstream Beam Pipe in GEMC

parts are separated for better visibility



courtesy of Caleb Fogler, ODU

Upstream Beam Pipe in GEMC

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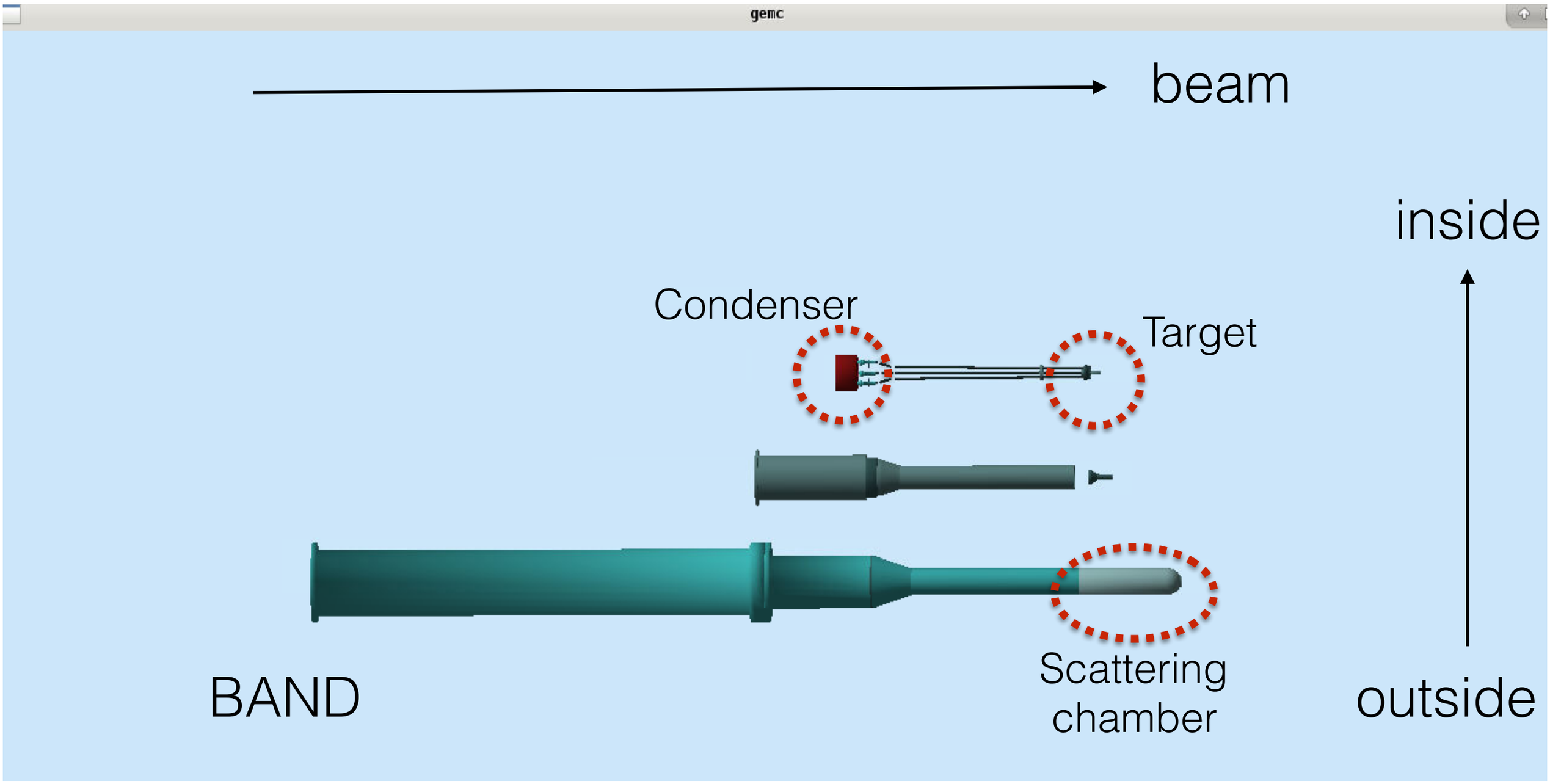


courtesy of Caleb Fogler, ODU

Summary and Outlook

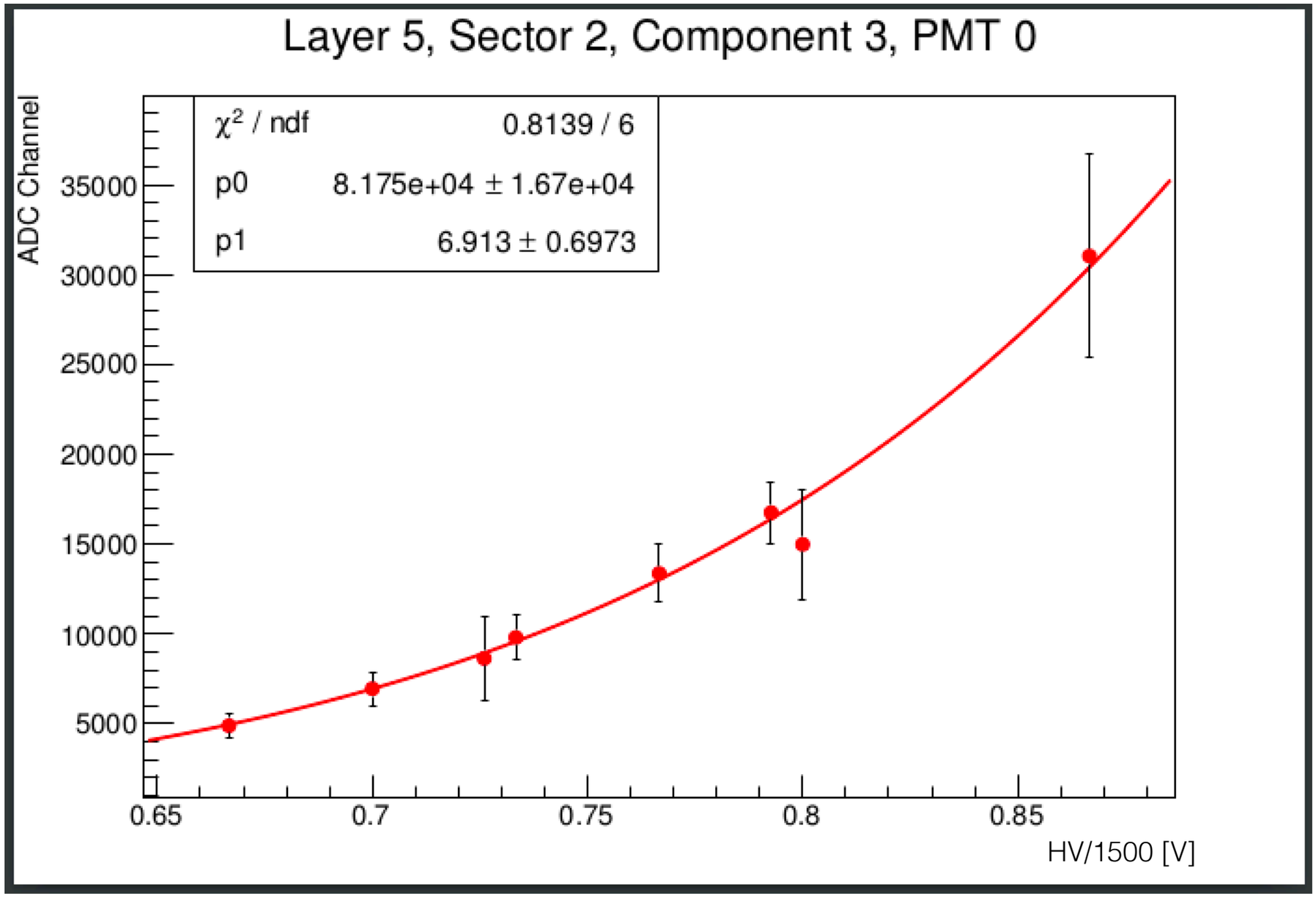
- Tagged DIS measurements to explain EMC effect
- Finished first set of BAND calibrations
- Clear neutron signal in DIS kinematics
- S/B study to determine ADC cut
- Start implementing BAND and upstream components to GEMC

- Finishing of implementing BAND and other components to GEMC
- Developing analysis chain for physics channel with simulations
- **NEED** Fall 2019 low energy data for neutron efficiency and momentum resolution with

We didn't

Back up slides

Gain Curves: Optimizing HV

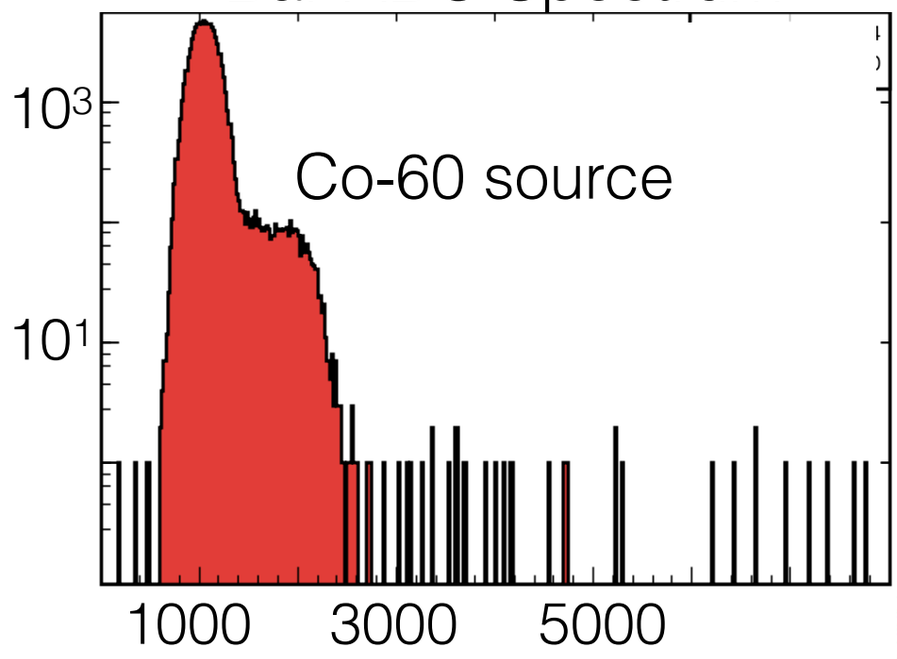


$$\text{ADC} = p_o \left(\frac{\text{HV}}{1500} \right)^{p_1}$$

Have most ADC channels possible for neutrons while not driving PMTs into non-linearity

Calibrating ADC to MeVee

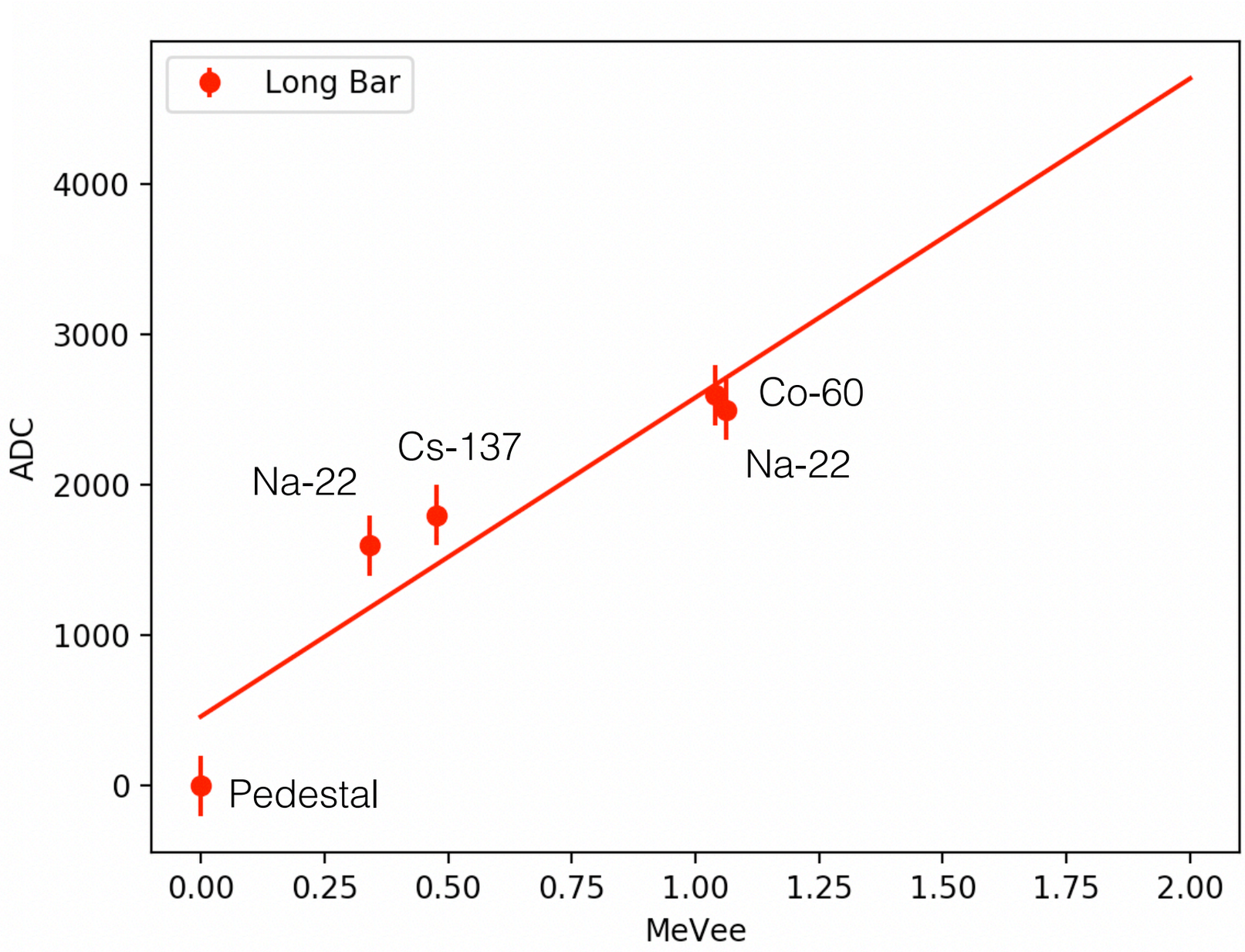
Bar ADC Spectrum



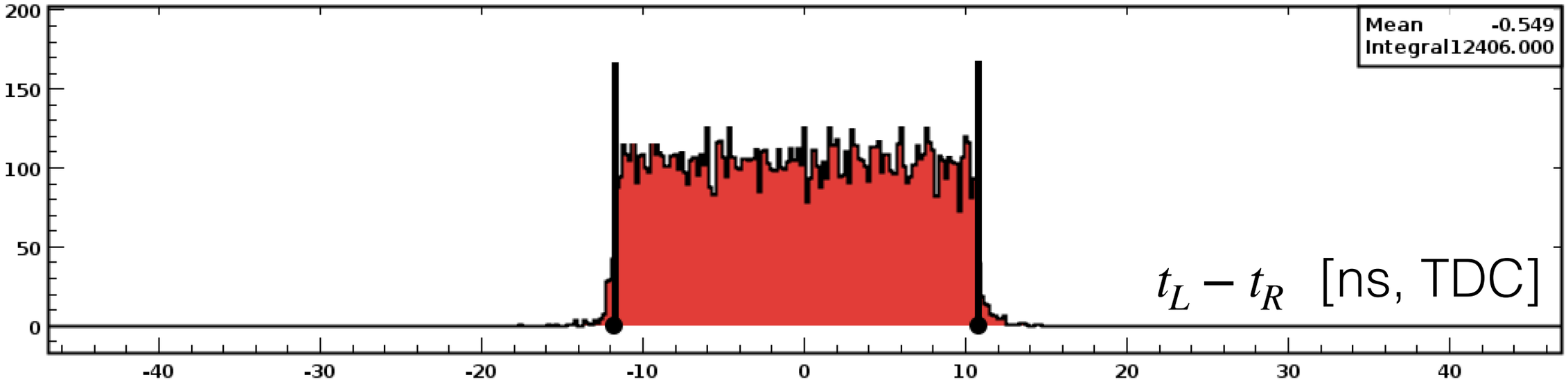
$$\sqrt{\mathrm{ADC}_L \cdot \mathrm{ADC}_R}$$

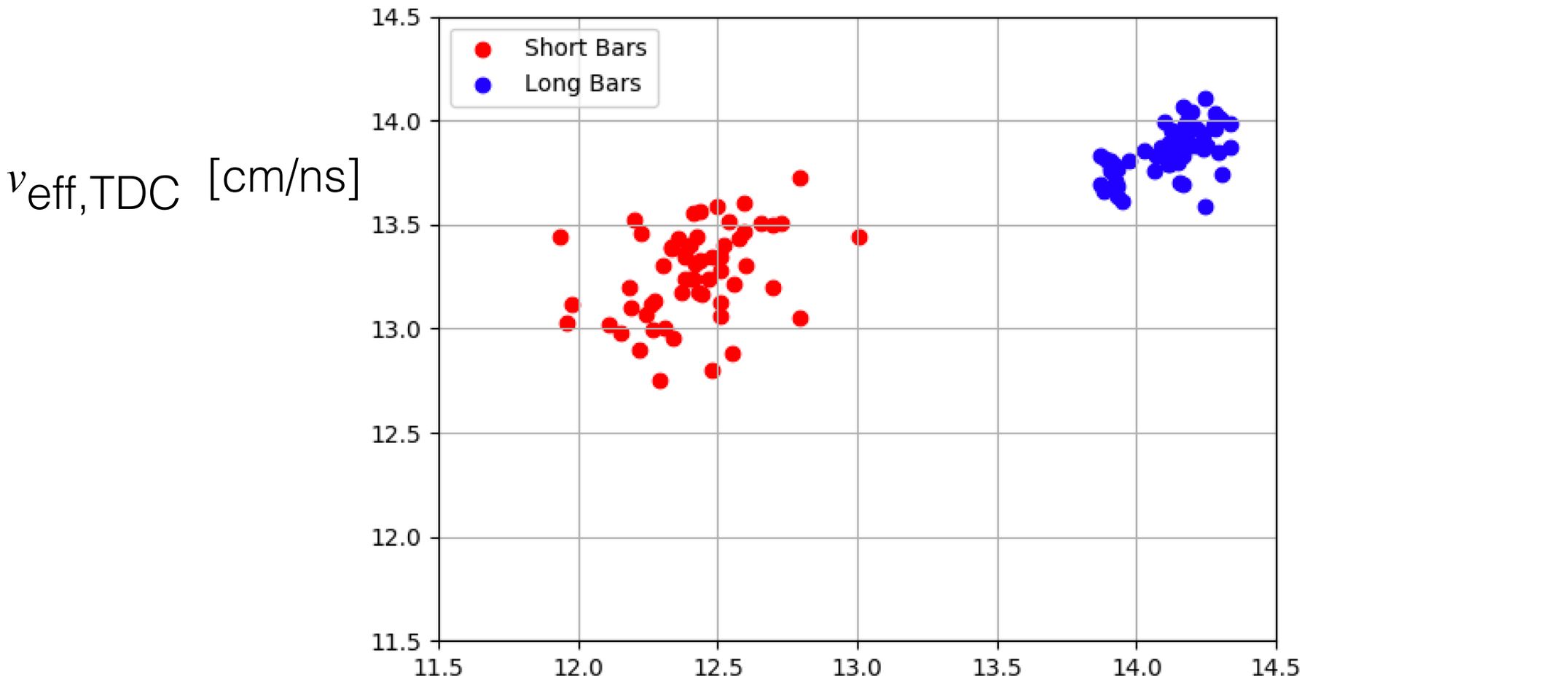
(MeVee =MeV Electron-Equivalent)

Planned software threshold of 2-3 MeVee

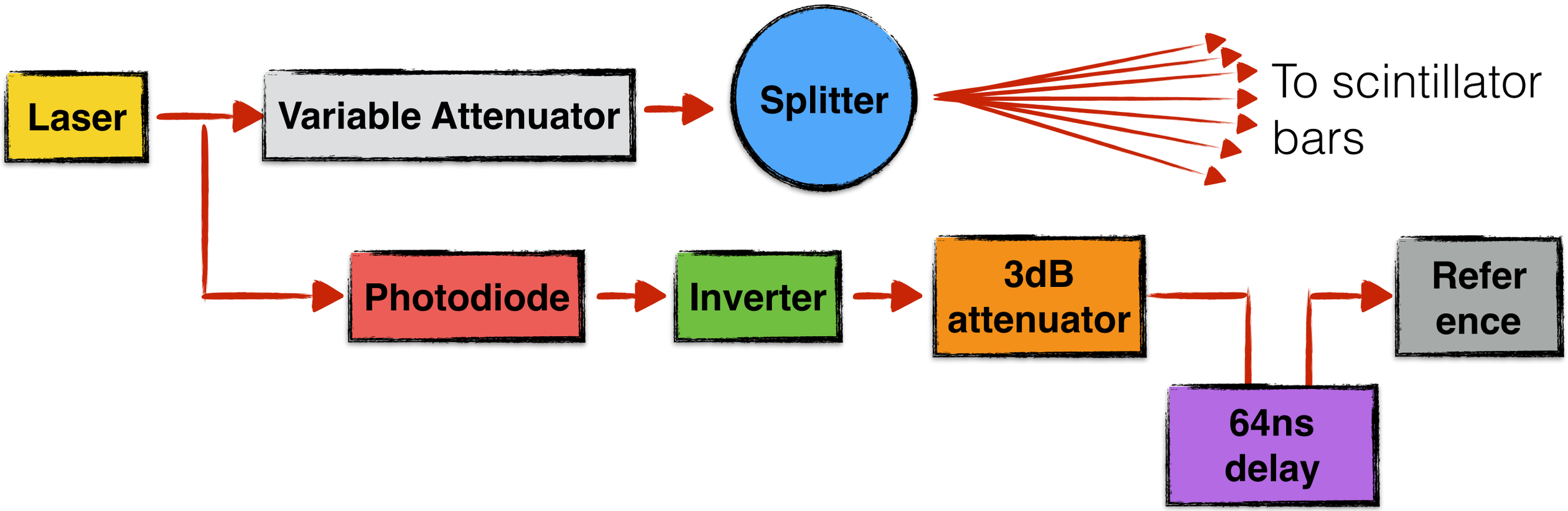


L-R Offsets and Effective Velocity (old)





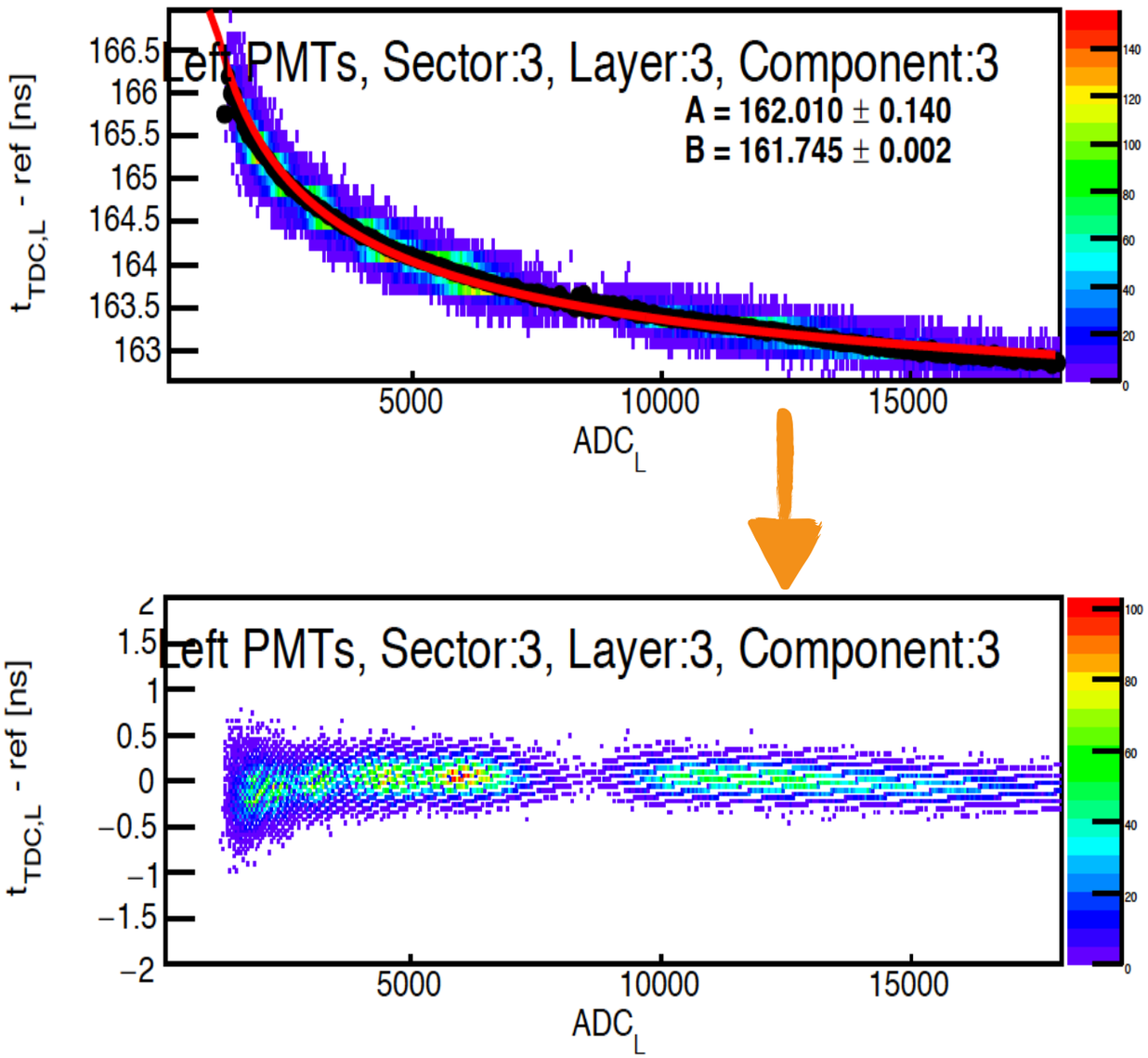
Taking Laser Data



- Photodiode output passes same electronics path as signals from bars
- Varying variable attenuator to scan over ADC range

Time Walk Correction

$$t_{TDC,L}^{R} - \text{ref} = A/\sqrt{ADC_{L}^{R}} + B$$



Typical fit ‘quality’

(parameters extracted with run 261, see presentation from last week for details)

same curve after correction

What will be measured

- Measuring cross section ratios to minimize uncertainties
- Choose kinematics with minimal FSI $\theta_{rq} > 107°$

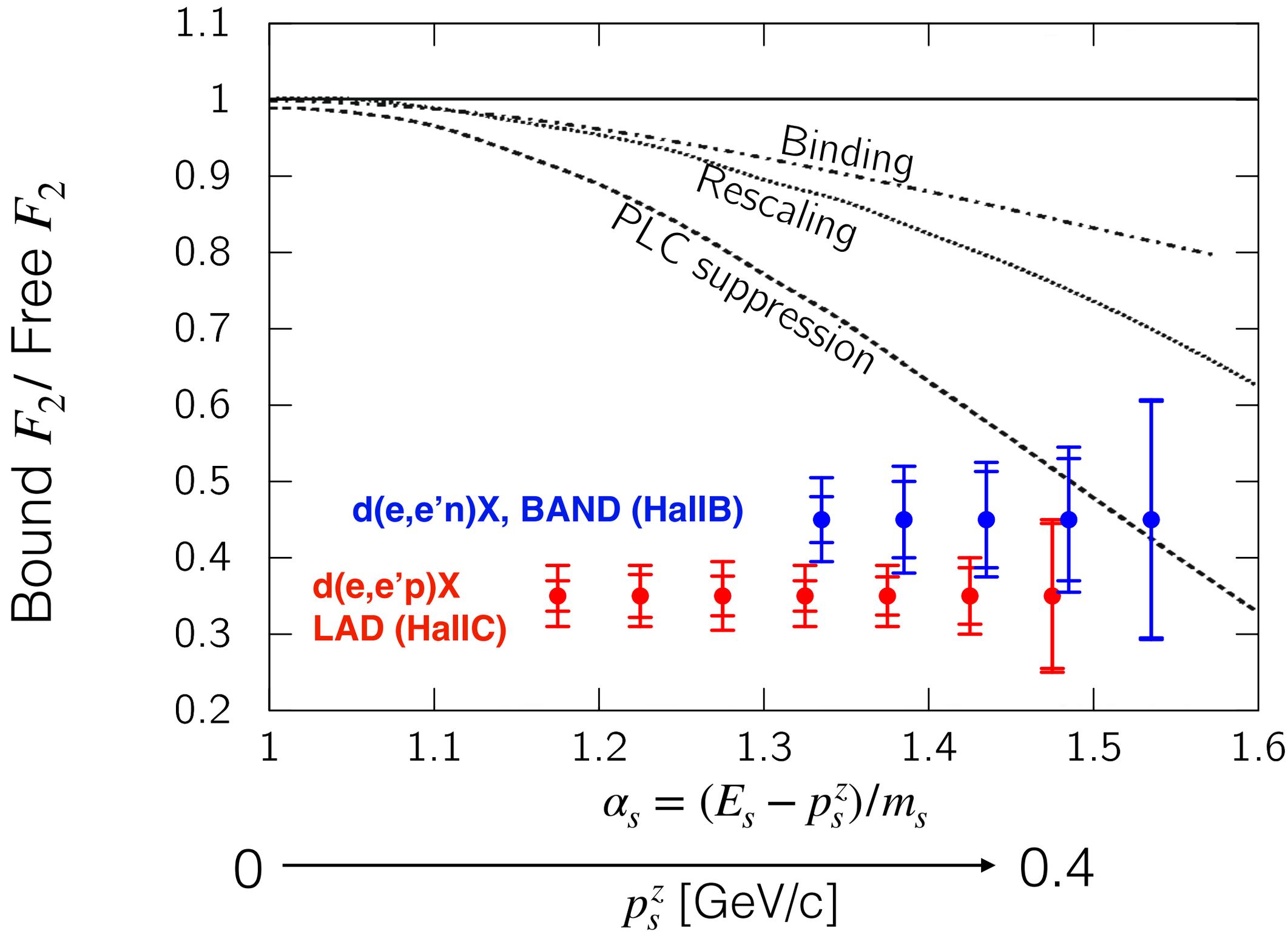
$$\frac{\sigma_{DIS}(x'_{\text{high}}, Q_1^2, \alpha_s)}{\sigma_{DIS}(x'_{\text{low}}, Q_2^2, \alpha_s)} \cdot \frac{\sigma_{DIS}^{\text{free}}(x_{\text{low}}, Q_2^2)}{\sigma_{DIS}^{\text{free}}(x_{\text{high}}, Q_1^2)} \cdot R_{FSI} = \frac{F_2^{\text{bound}}(x'_{\text{high}}, Q_1^2, \alpha_s)}{F_2^{\text{free}}(x_{\text{high}}, Q_1^2)}$$

measurement theory

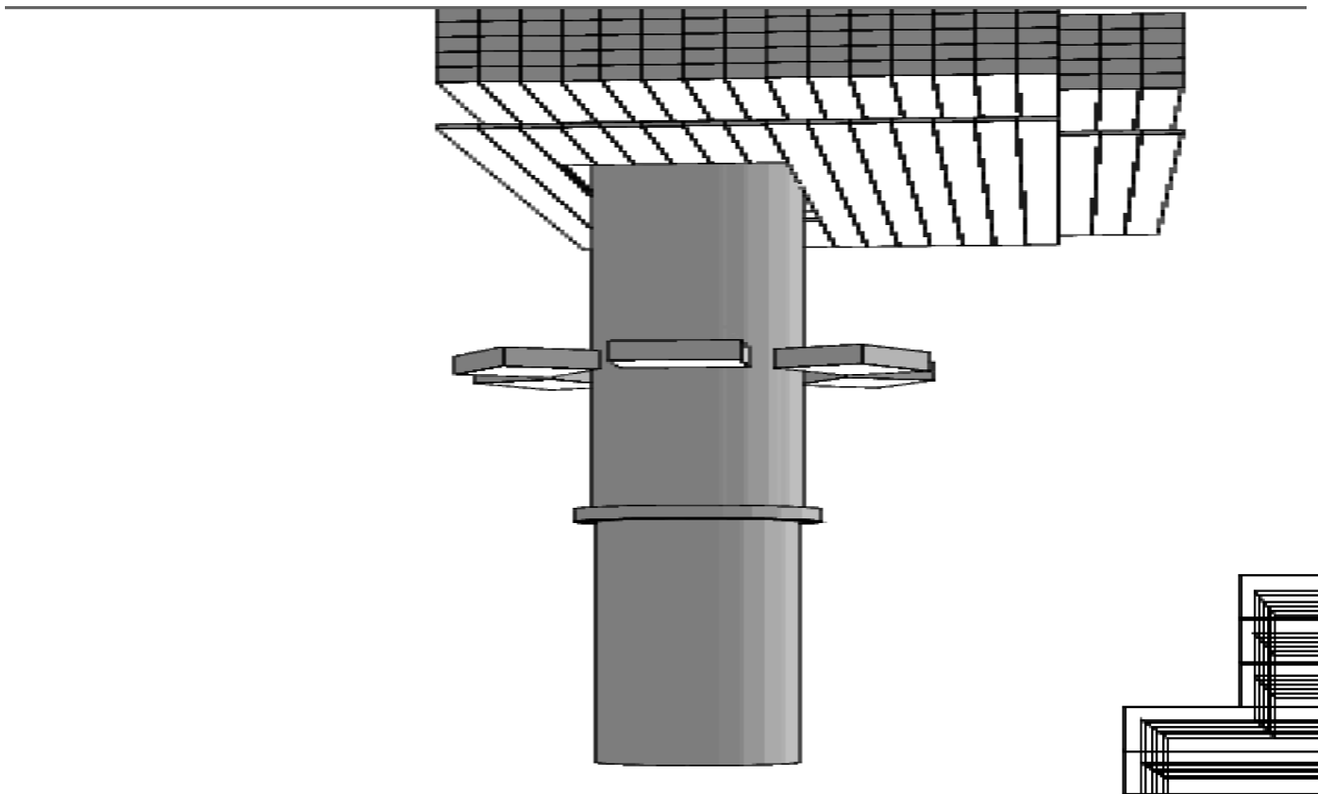
- $x'_{\text{high}} > 0.45$
- Expect no EMC effect at low x': $0.25 \leq x'_{\text{low}} \leq 0.35$

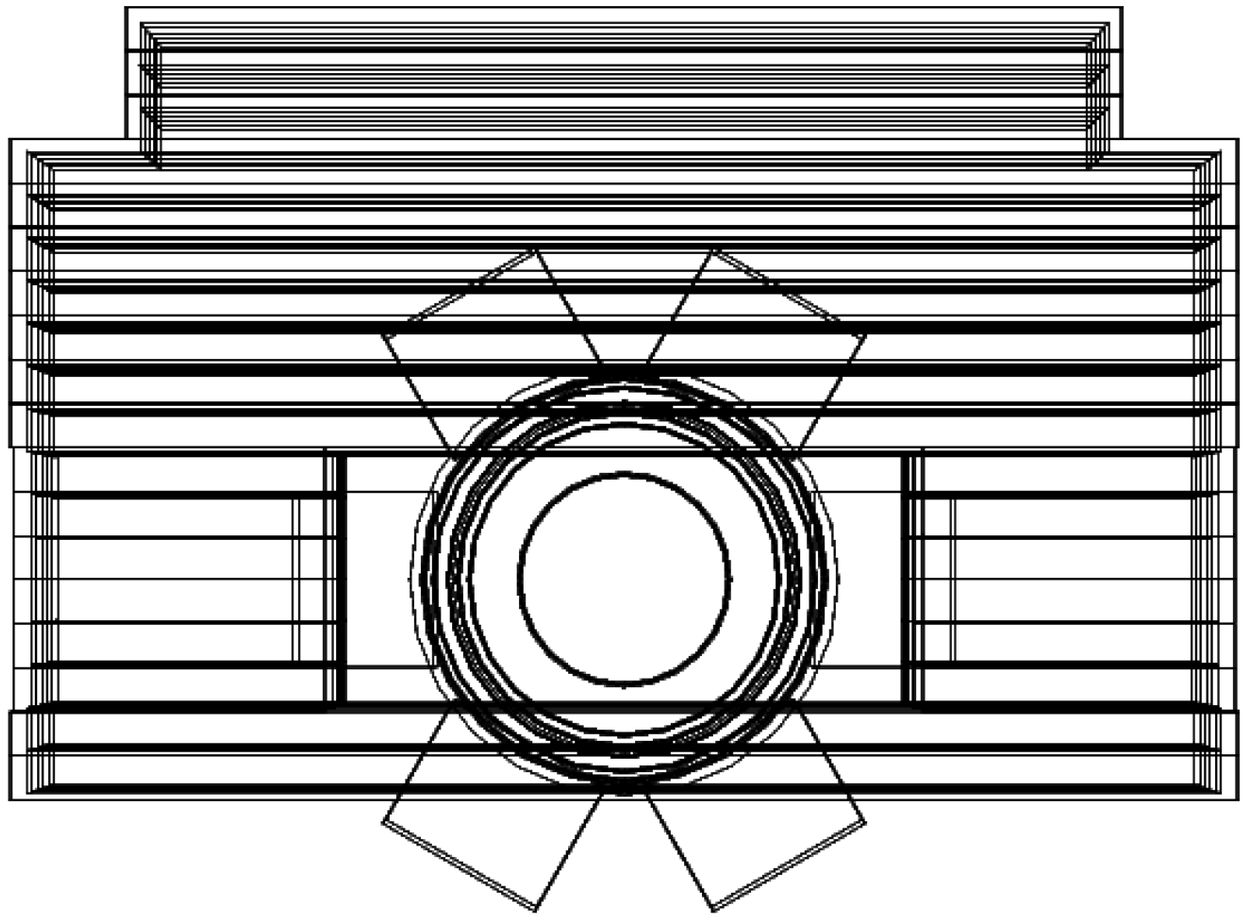
$$x'_B = \frac{Q^2}{2[(M_d - E_s)\omega + \vec{p_s} \cdot \vec{q}]} \qquad x_B = \frac{Q^2}{2m_N\omega} \qquad \alpha_s = (E_s - p_s^z)/m_s$$

DIS Recoil Tagging d(e,e'N)X - Expected Results

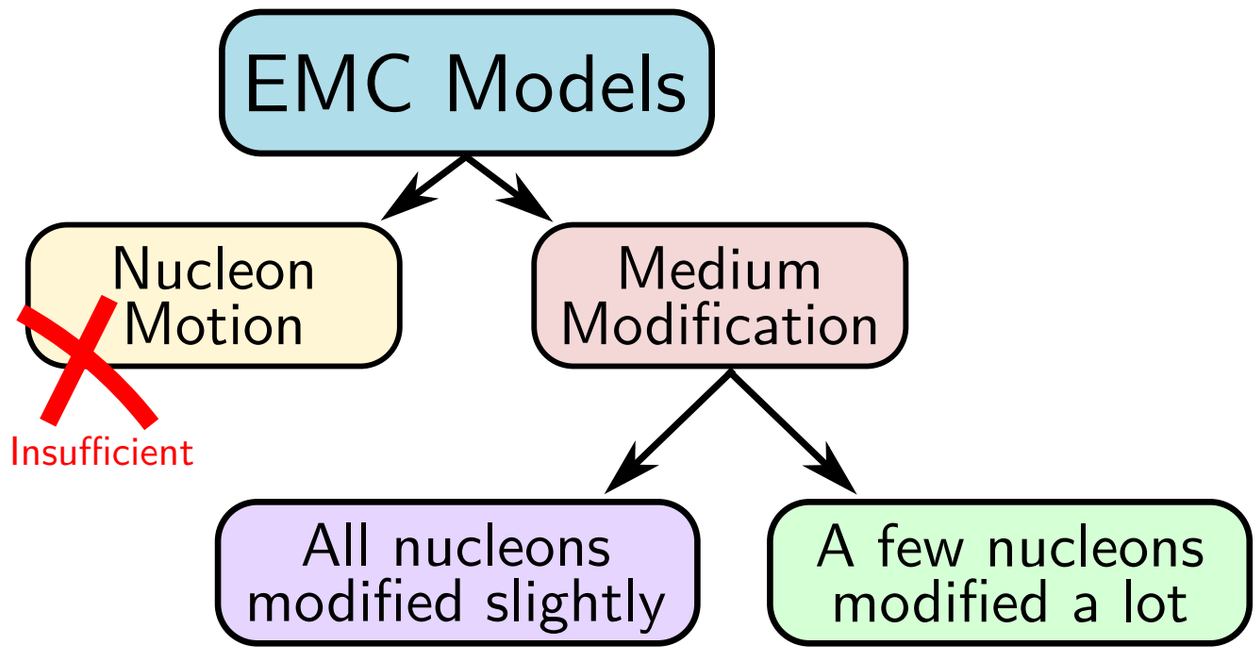


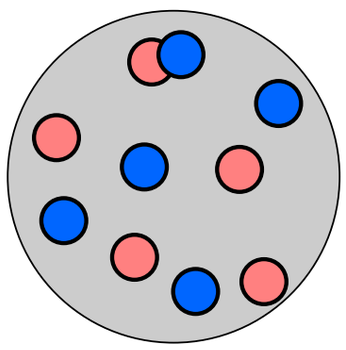
BAND and beam pipe in standalone Geant simulation



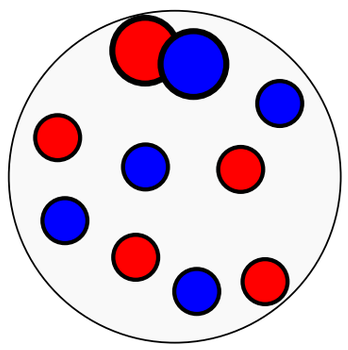


EMC Models



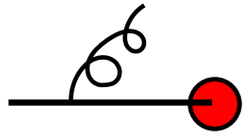
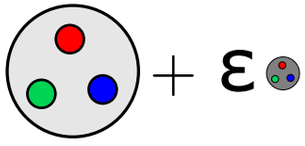
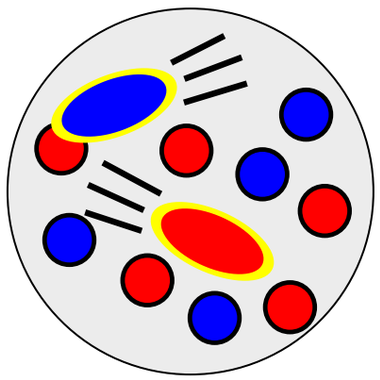
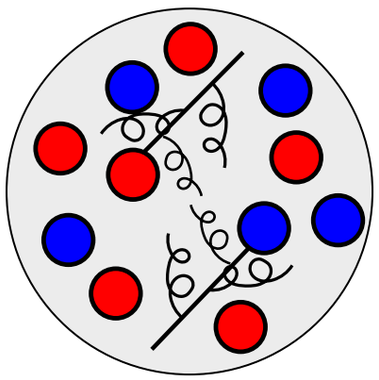
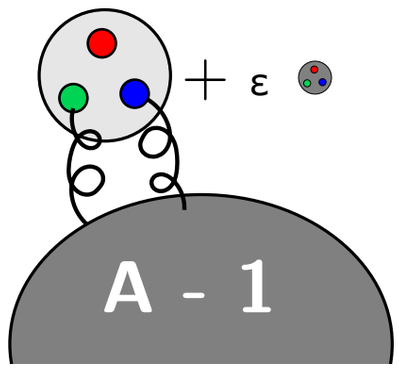


Mean Field Modifications



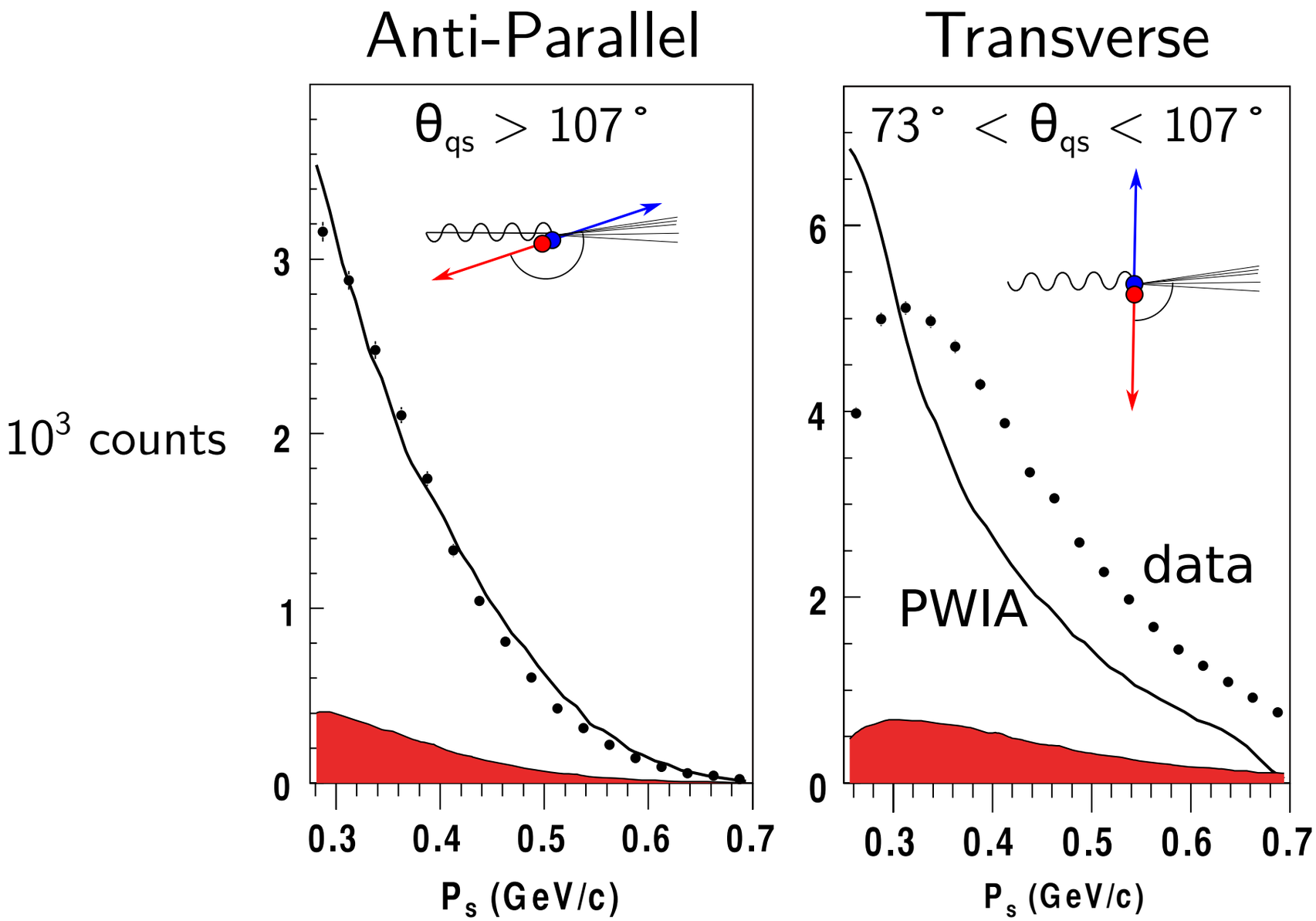
Short Range Correlations (SRC)

Theories

	Binding	Rescaling	Point-like Configuration Suppression
Free			
Bound			

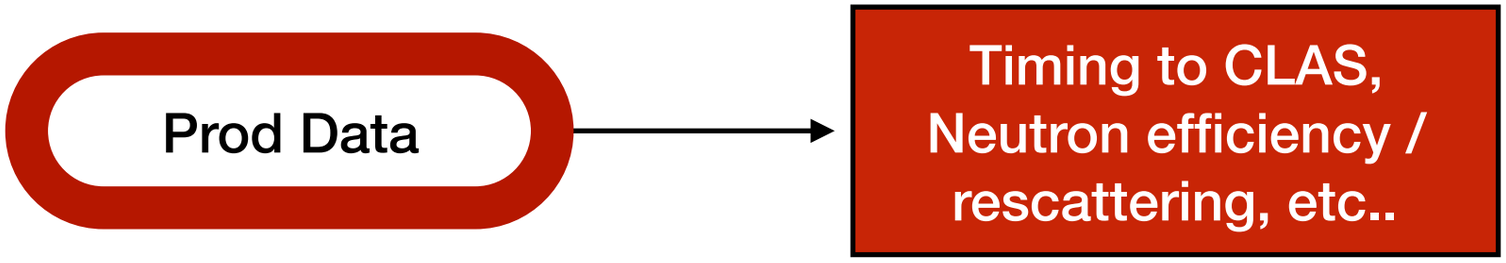
FSI in Tagged DIS

DEEPS showed little FSI at back angles.



Klimenko et al., PRC 73 035212 (2006)

BAND + CLAS



Calibrating with exclusive processes

$d(e, e'p)n$ (measure n efficiency)

$d(e, e'p\pi^+\pi^-)n$ (measure n efficiency)

$d(e, e'pp\pi^-)$ (study resolution in CLAS)

Note 1: low energy run in fall to study neutron efficiency due to currently limited statistics
Note 2: Calibrations are too preliminary to study achievable resolution

Tagged DIS at JLab

Hall B:
CLAS 12 + Backward Angle Neutron Detector (BAND)

Hall C:
SHMS/HMS + Large Angle Detector (LAD)