GMN/NTPE Analysis Update

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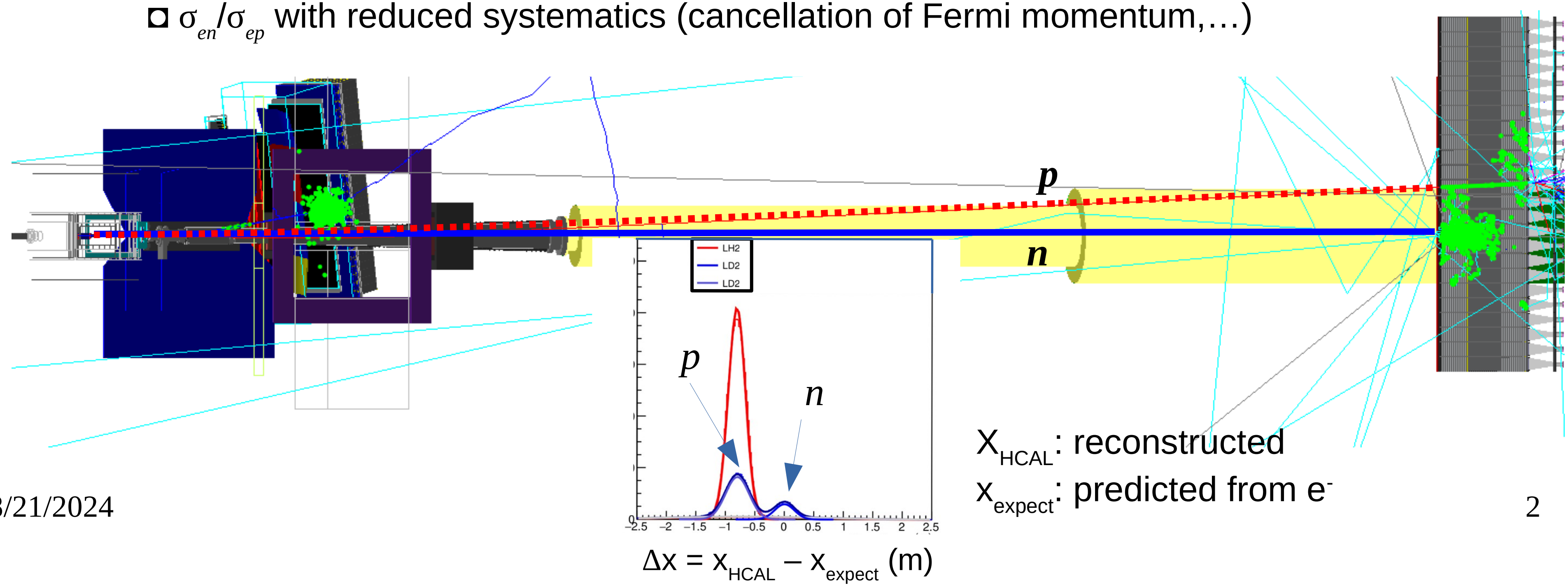
William & Mary

SBS weekly meeting, August 21st 2024

Reminder: GMN/NTPE

- GMN: E12-09-019 (A. Camsonne, B. Quinn, B. Wojteskhowski)
  - simultaneous *en*/*ep* measurement on D_2
  - Separation of *p* and *n* with SBS
  - σ_{en}/σ_{ep} with reduced systematics (cancellation of Fermi momentum,…)

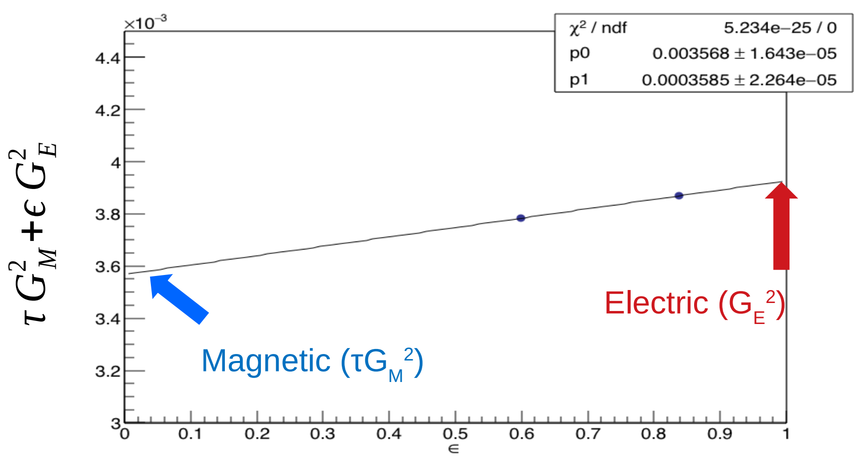


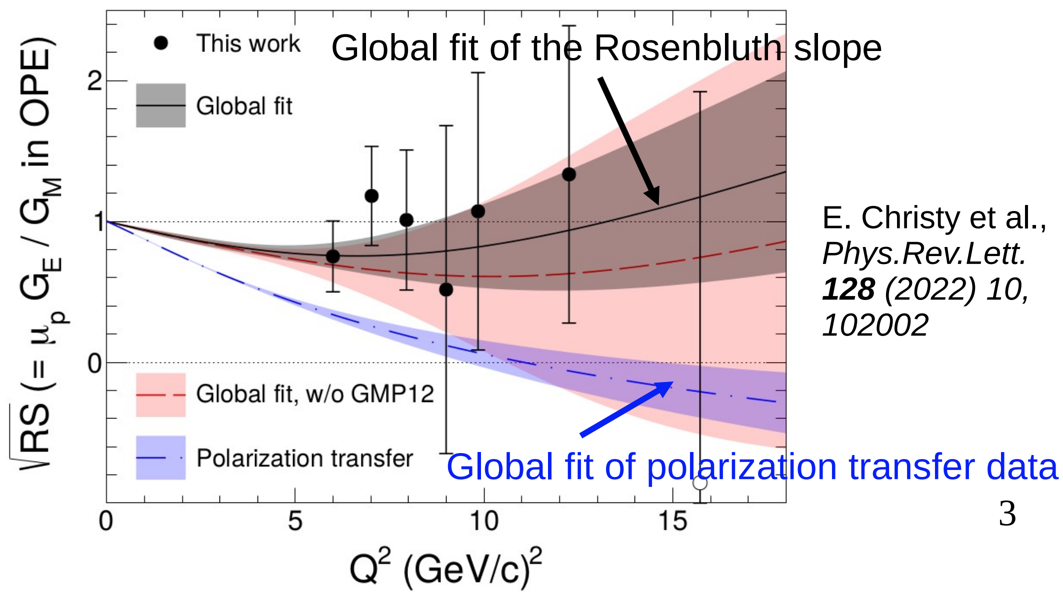
X_{HCAL}: reconstructed

x_{expect}: predicted from e^-

Reminder: GMN/NTPE

- NTPE: E12-20-010 (E.F., S. Alsalmi, B. Wojteskhowski)
  - measurement of σ_{en}/σ_{ep} at two beam energies, Q^2 = 4.5 GeV^2
  - neutron Rosenbluth slope;
  - NTPE = Discrepancy between neutron Rosenbluth slope and polarization data





E. Christy et al., *Phys.Rev.Lett.* ***128*** *(2022) 10, 102002*

Status as of February 21st

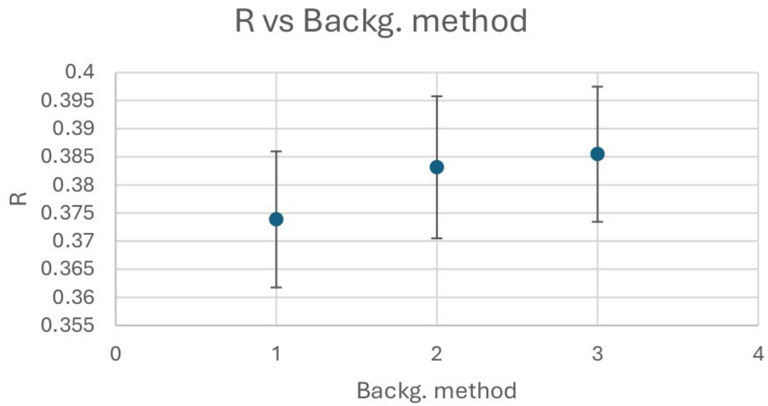
Since *last update*:

- Method of evaluation of n/p ratio established;
- Method of extraction of physics from n/p provided;
- Pass 2 data ready;
- Pending items as of February 21st;
  - estimation of systematics from inelastic background;
  - estimation of n/p stability over selection cuts;
  - account for HCAL non-uniformity; estimation of systematics;
  - extraction of observables with all systematic uncertainties;

Subtraction of inelastic background

- Three methods for inelastic background estimation/subtraction:
  - 1) Combined fit quasi-elastic(gauss) + inelastic (pol2) of the Δx distribution;
  - 2) Estimation of background with anti-selection of nucleon (out-of-time)
  - 3) Inelastic MC generation with Christy-Bosted model;

SBS7, analysis credit *A. Rathnayake*:
Induced systematic uncertainty ~0.9%



SBS14, analysis credit *P. Datta*:
Induced systematic uncertainty ~1.2%
SBS11: 3.5% (not shown here)

p Cross-section from: Ye et all, 2017
GEn from: Ye et all, 2017

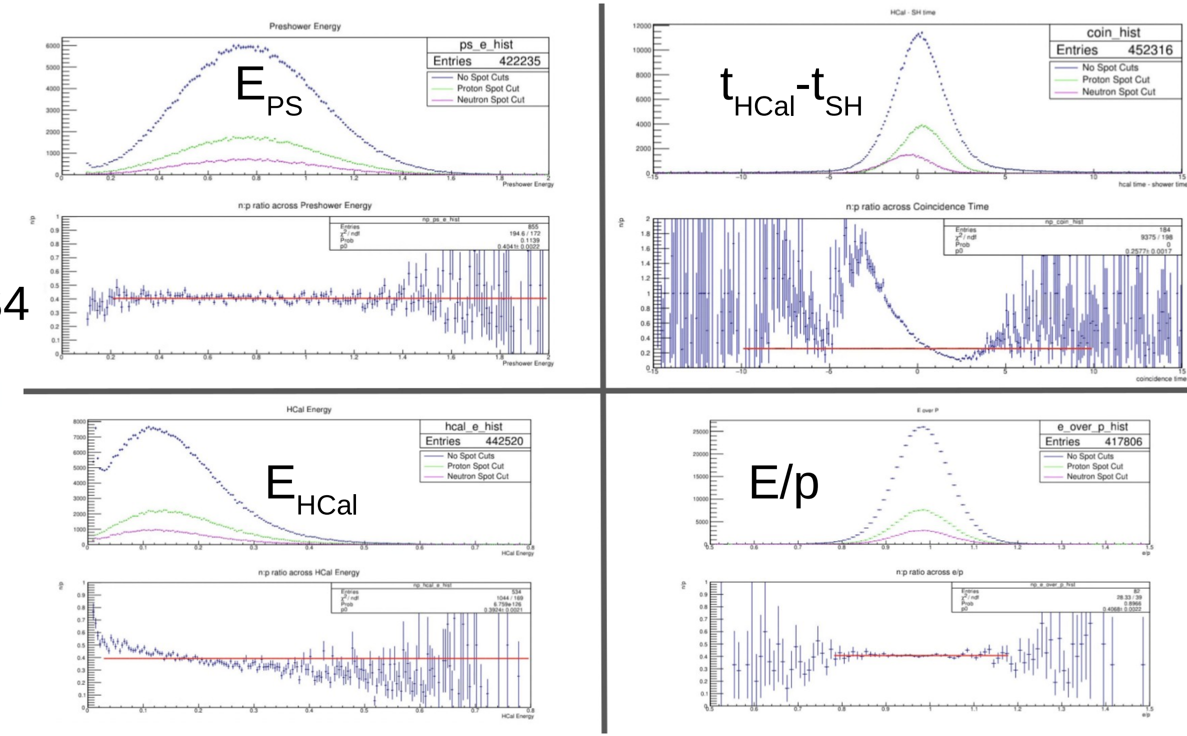
1. R w/ MC bg. : 1.095 +/- 0.010 -> GMn/muGD : **0.8968**
2. R w/ data bg : 1.108 +/- 0.010 -> GMn/muGD : **0.9022**
3. R w/ poly. bg. : 1.112 +/- 0.010 -> GMn/muGD : **0.9039**

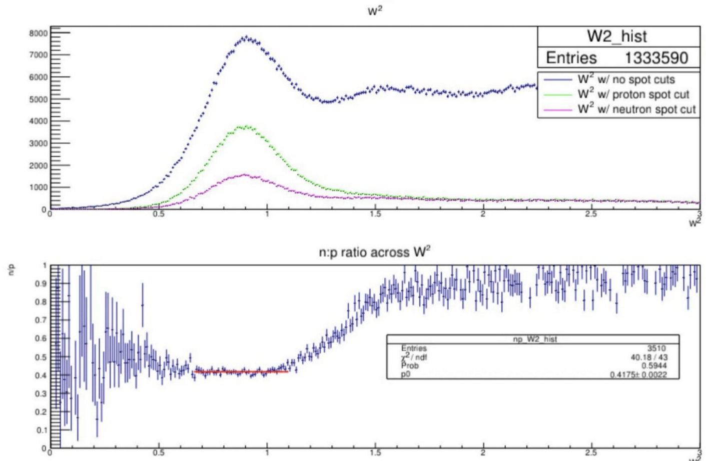
Preliminary

n/p ratio stability over selection cuts

- n/p ratio stability over several cuts:
  - W^2;
  - E_{PS}, E_{SH}, E_{HCAL};
  - t_{HCAL}-t_{Shower};
  - Δx, Δy;
  - fiducial cuts;

- Analysis credit: *M. Satnik* SBS4





W^2

n/p ratio stability over selection cuts

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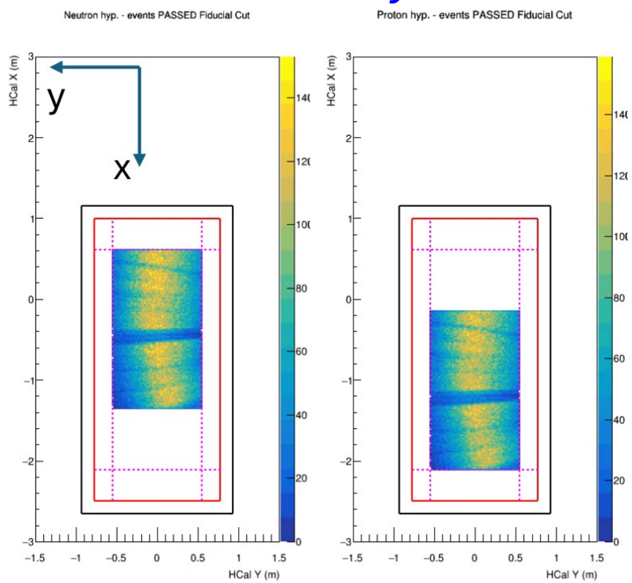
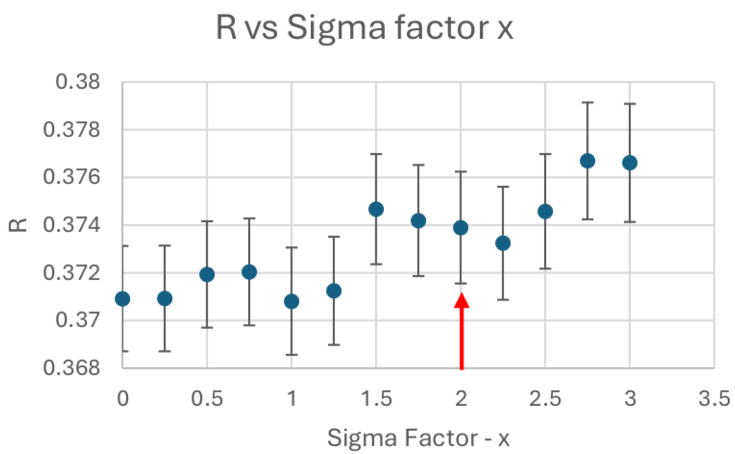
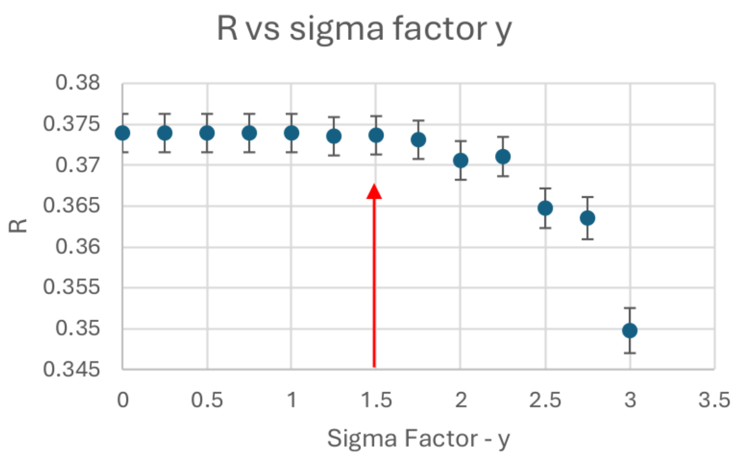
  - W^2;
  - E_{PS}, E_{SH}, E_{HCAL};
  - t_{HCAL}-t_{Shower};
  - Δx, Δy;
  - fiducial cuts;
- Analysis credit: *A. Rathnayake* SBS7





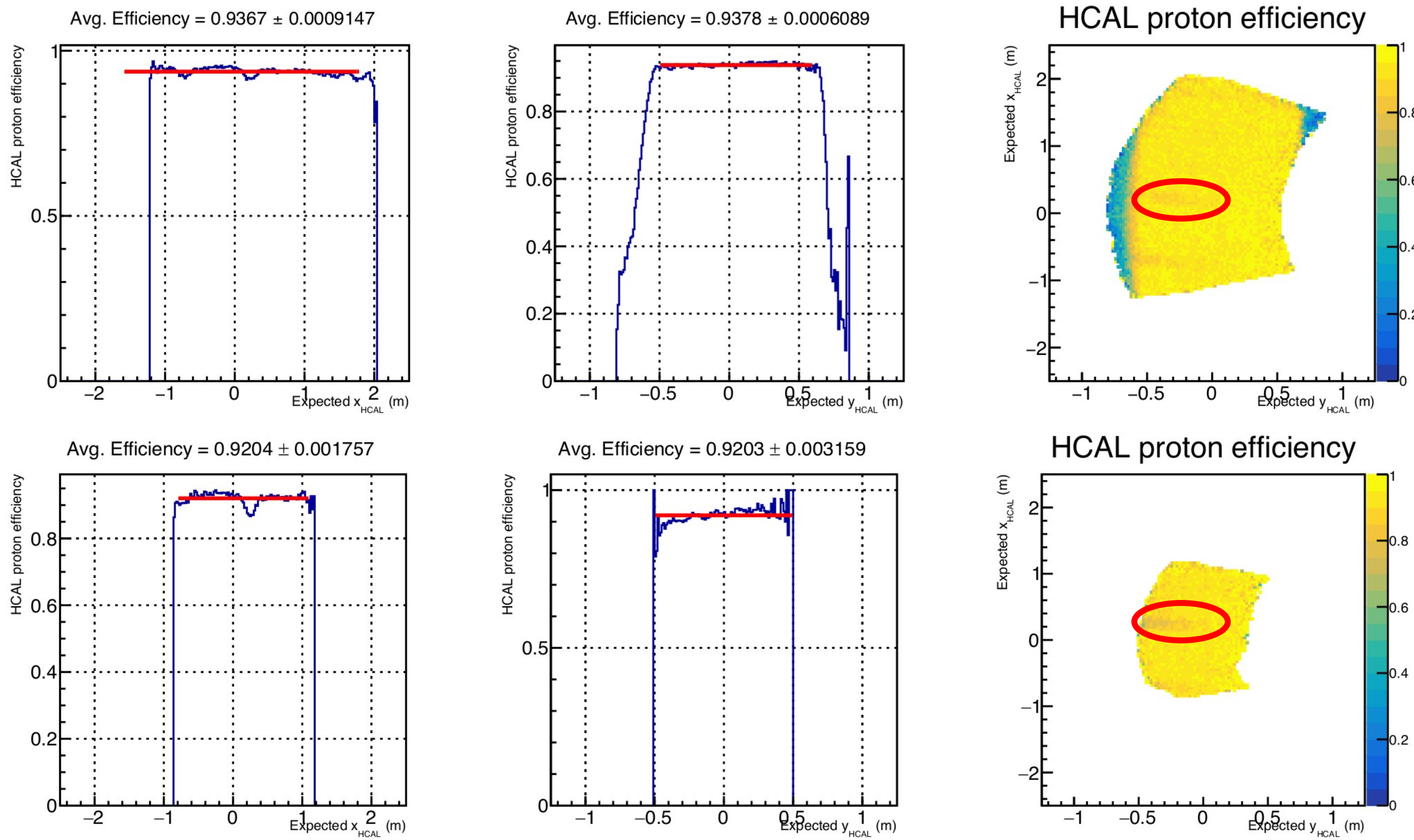


HCAL efficiency non-uniformity

- Efficiency uniformity estimated with data (plots/analysis credit: *A. Puckett*)

SBS8

SBS9

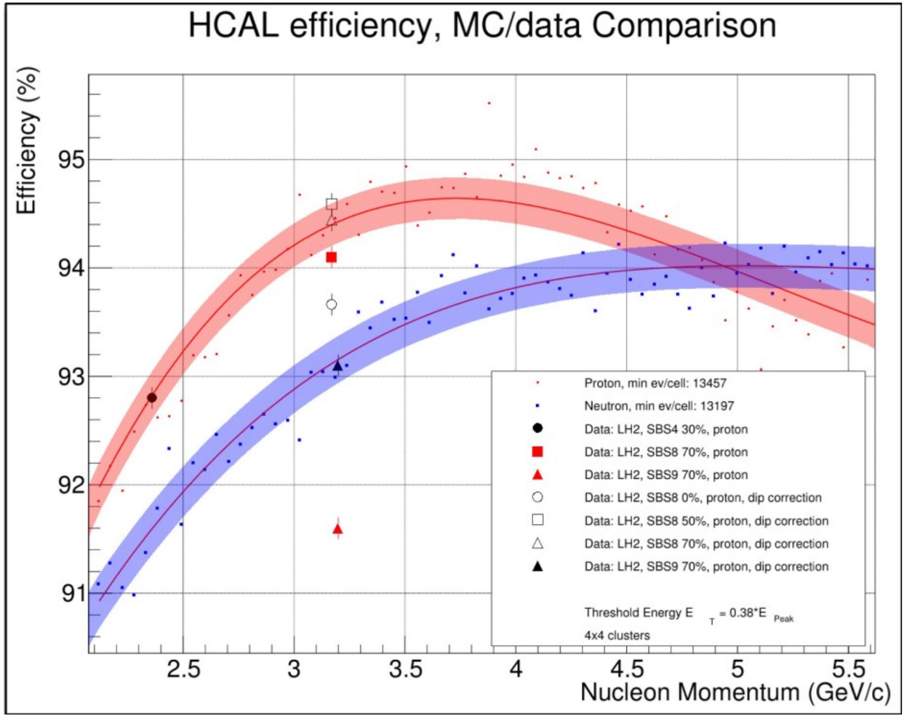


Dip in efficiency: more impact on SBS9 than SBS8

HCAL efficiency non-uniformity

- Impact on HCal global detection efficiency:

Analysis credit: *S. Seeds*



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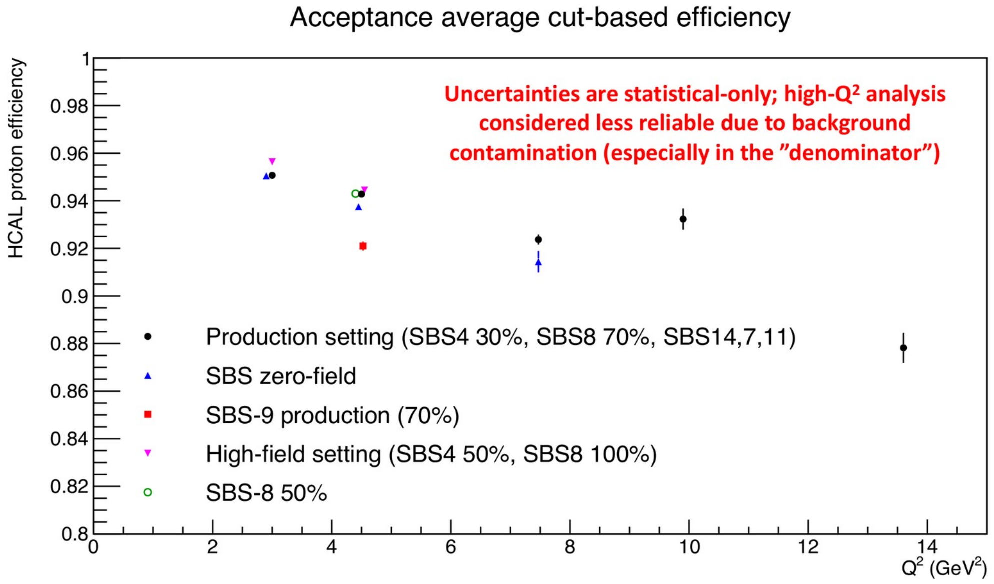
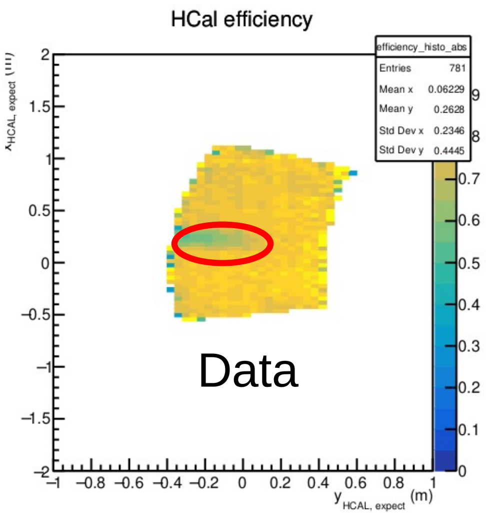
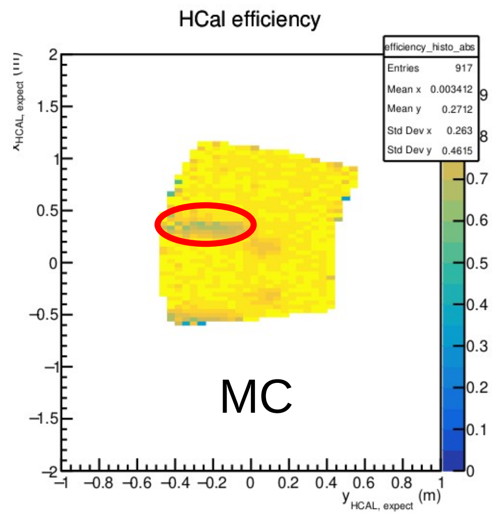
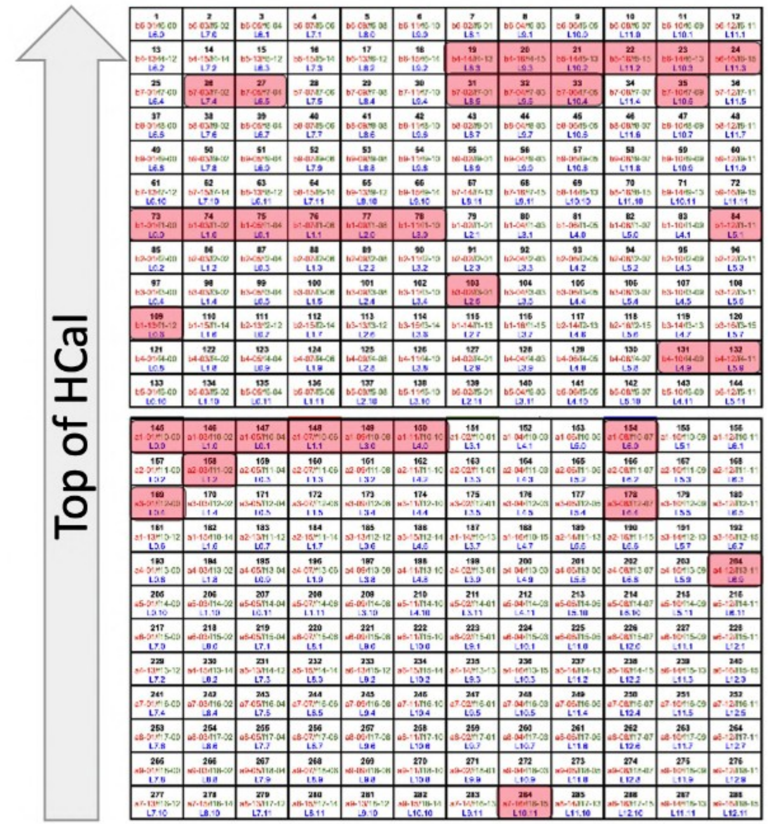


HCAL efficiency non-uniformity

- Attempt to reproduce non-uniformity with MC [1]:
  - HCal gain in MC digitization: 10^6;
  - Setting gains for red blocks on map: 10^3;
  - Efficiency on LH_2, SBS9 (independent analysis):

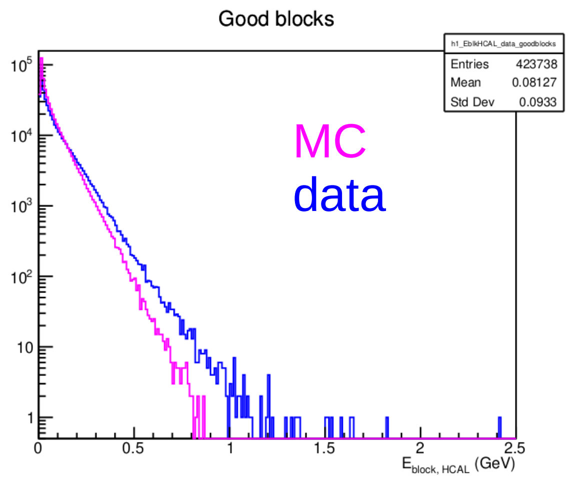


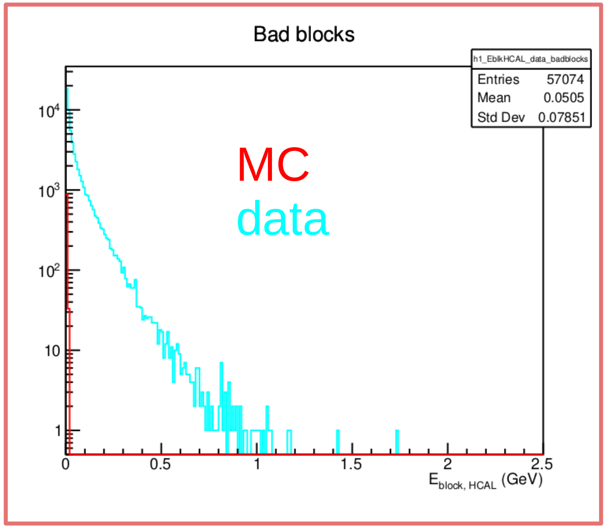


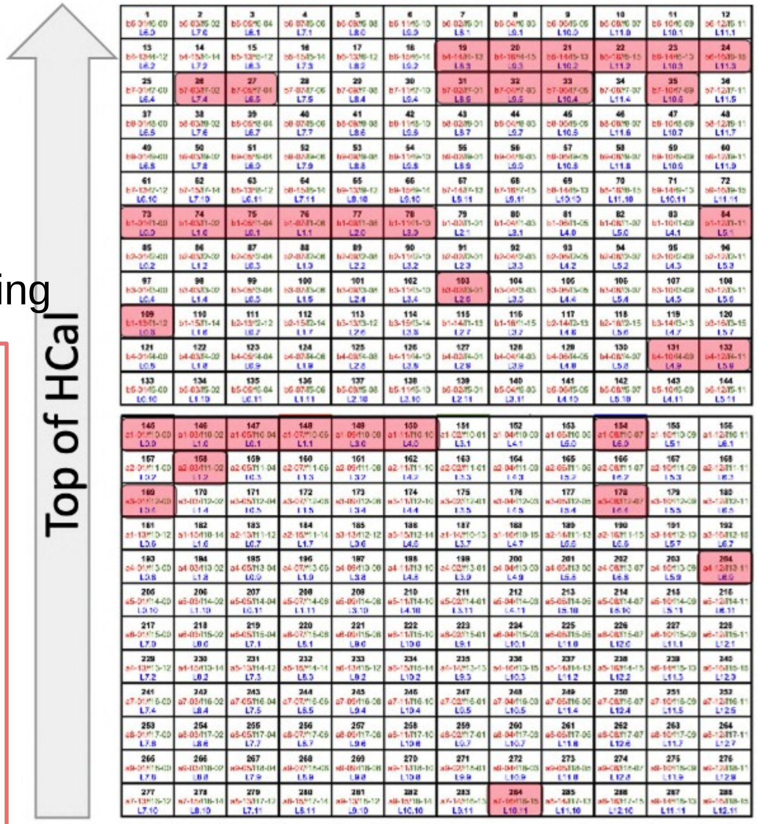


HCAL efficiency non-uniformity

- Attempt to reproduce non-uniformity with MC [1]:
  - HCal gain in MC digitization: 10^6;
  - Setting gains for red blocks on map: 10^3;
  - Energy deposit in blocks data Vs MC => needs tuning

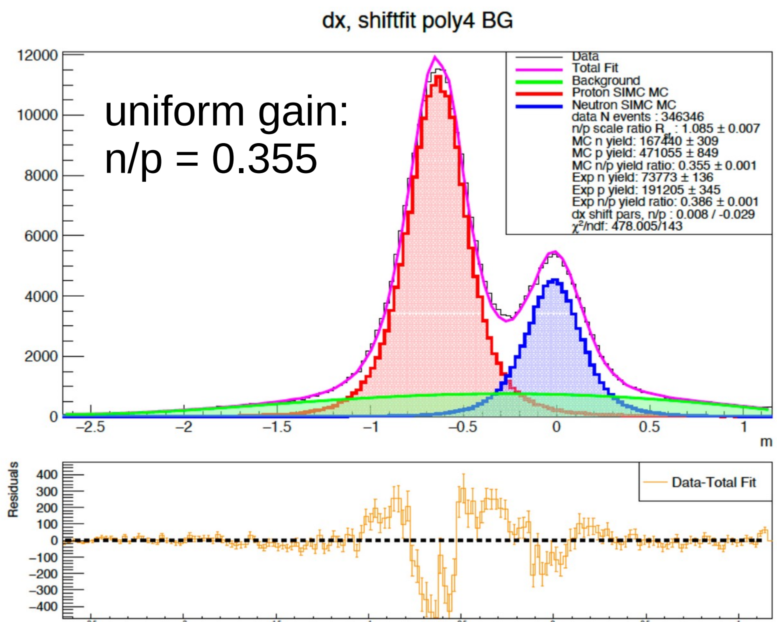


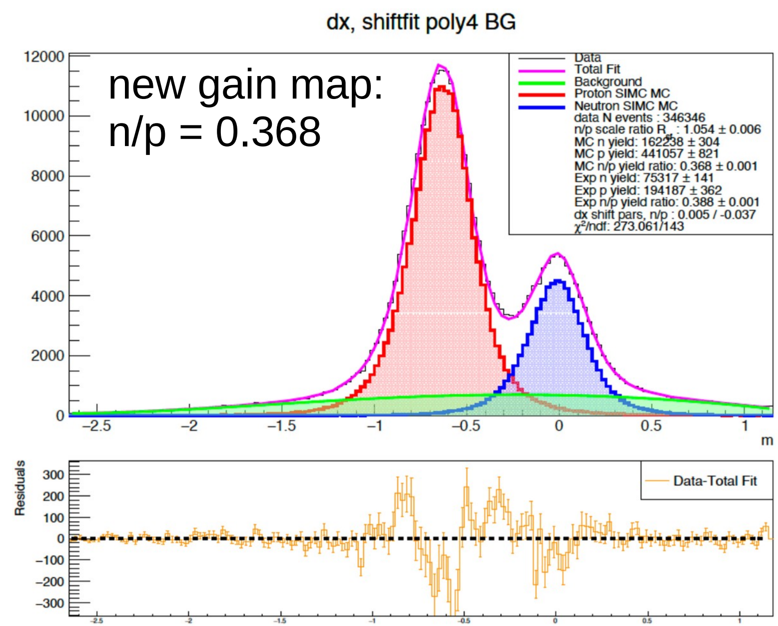




HCAL efficiency non-uniformity

- Attempt to reproduce non-uniformity with MC:
  - Comparison between n/p ratios with new gain map vs uniform gain;
  - Analysis credit *Z. Wertz*: 3% increase in n/p ratio for SBS8, 50% SBS field;
  - **In progress** (other setting give results that remain to be understood);

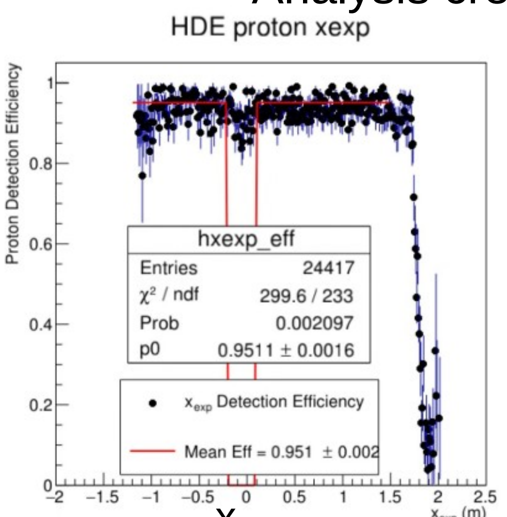




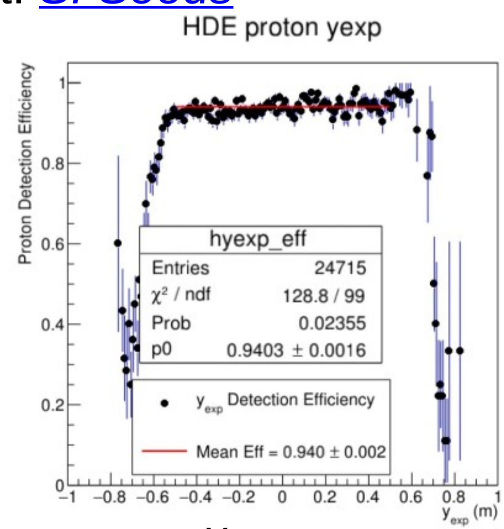
HCAL efficiency non-uniformity

- Alternate method to work around HCal efficiency non-uniformity:
  Reweight MC events with HCal non-uniformity map;
  - Map efficiency along x_{expect}, y_{expect};
  - weight MC with relative variation efficiency according to x_{expect}, y_{expect} map;
    - used by John for his analysis

Analysis credit: S. Seeds

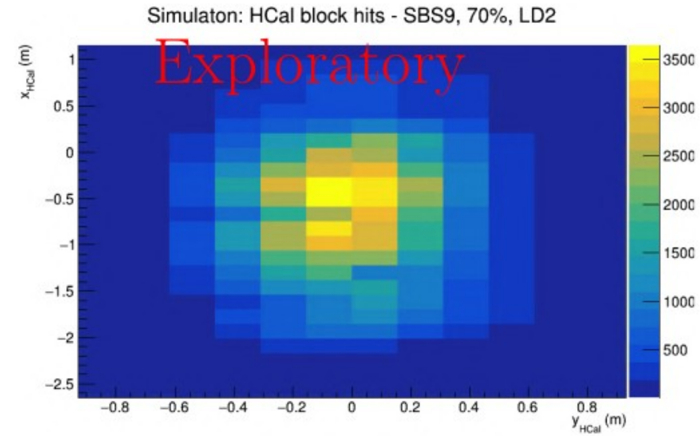


x_{expect}



y_{expect}

Analysis credit: J. Boyd

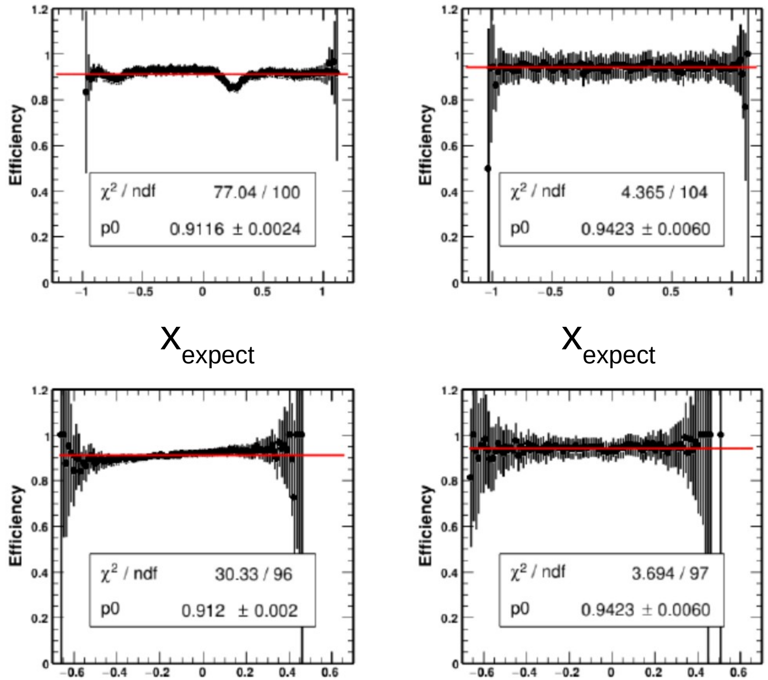


HCAL efficiency non-uniformity

- Alternate method to work around HCal efficiency non-uniformity:
  Reweight MC events with HCal non-uniformity map;
  - Map efficiency along x_{expect}, y_{expect};
  - weight MC with relative efficiency variation
  - Improvement:
    - Apply same efficiency analysis for data, MC;
    - use ratio of η_{data}/η_{MC};
    - has yet to be deployed in analysis;

Analysis credit: P. Datta

Data SBS9 LH2 MC SBS9 LH2



x_{expect} x_{expect}

y_{expect} y_{expect}

GMN/NTPE results

- GMN (all students):
  - most advanced analysis include statistics and systematics *except HCAL detection efficiency*
  - GMN will still benefit from a refined correction of HCal non-uniformity
- NTPE: (John, Sebastian, Zeke)
  - Existing analyses very preliminary and need independent cross checks
  - use very coarse corrections for HCal non-uniformity map
  - Result featured in John’s thesis may change with a more refined correction of HCal non-uniformity;

Summary

- Progress:
  - Inelastic background subtraction nailed down (~1%-3% systematic induced);
  - Systematic studies of n/p stability;
- Getting to integrate the HCal non-uniformity in the analysis (in progress):
  - using MC including non-uniformity effects;
  - reweighting MC events with HCal non-uniformity map;
- Next steps:
  - Converge on HCal non-uniformity corrected analysis
  - Evaluate and propagate systematic;
  - Prepare publication;

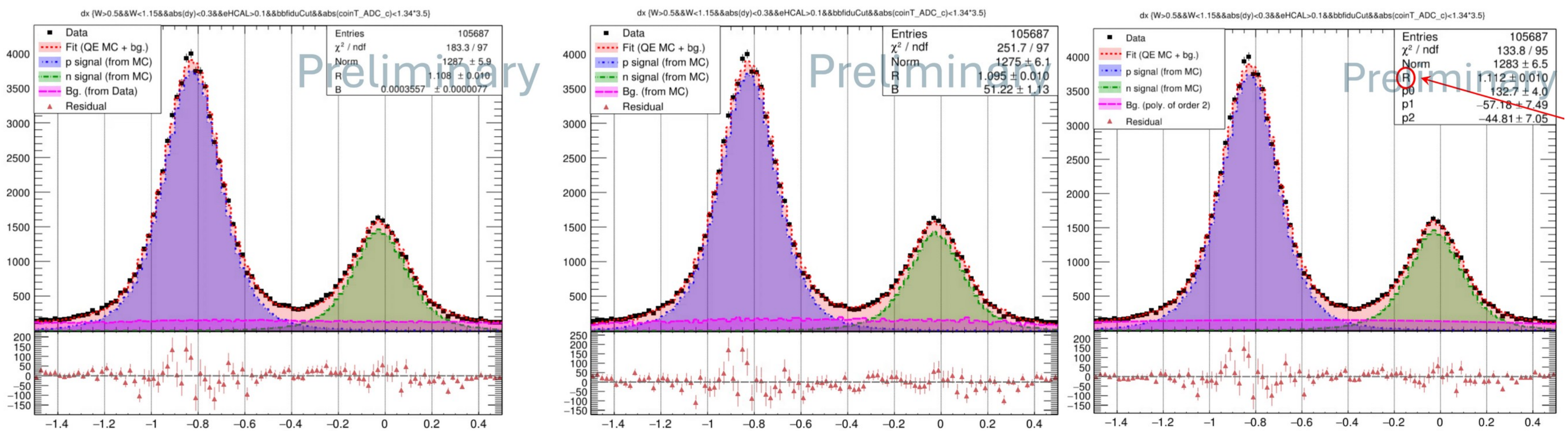
Students status

- John, Sebastian, Nathaniel, recently graduated (Congrats!);
- Anu, Provakar to graduate within 2-4 weeks;
- Maria, Zeke to graduate within the next 3-6 months;
- A few students may continue the analysis as post-docs;

Back up

Subtraction of inelastic background

- Three methods for inelastic background estimation/subtraction:
  - SBS14, analysis credit *P. Datta* => induced systematic uncertainty ~1.2%



(SBS7 ~1.5%)
(SBS11 ~ 3.5%)

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Std. Dev.: 0.0037

Subtraction of inelastic background

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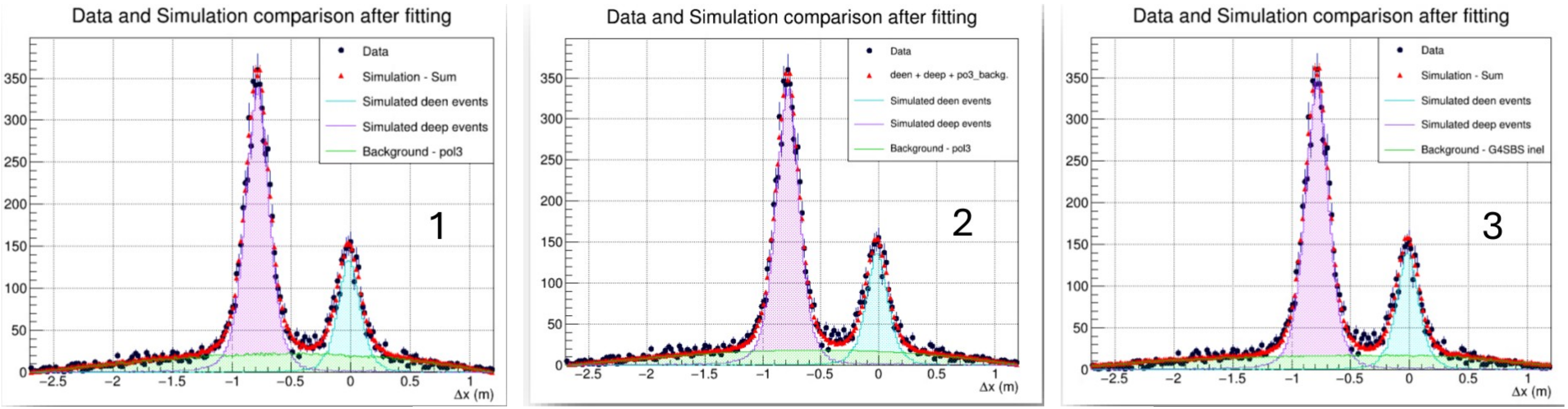
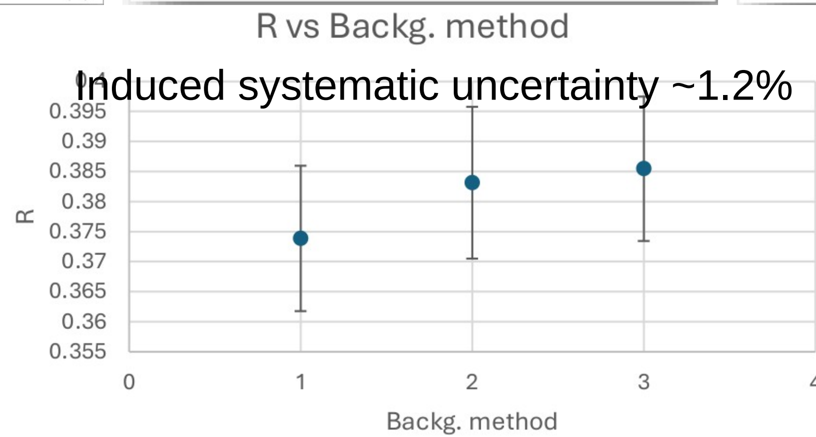


(SBS4 <0.5%)

Induced systematic uncertainty ~1.2%



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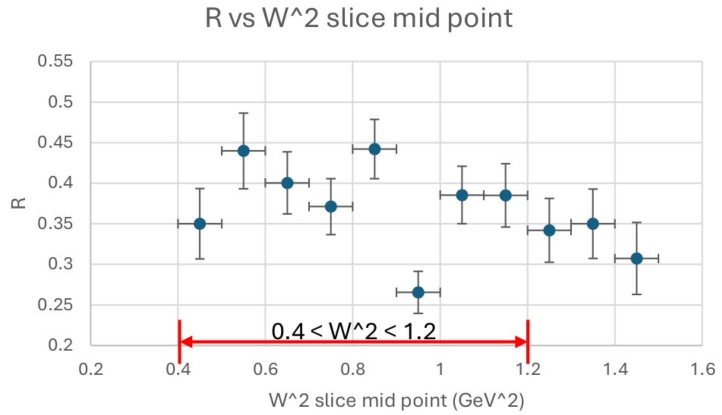

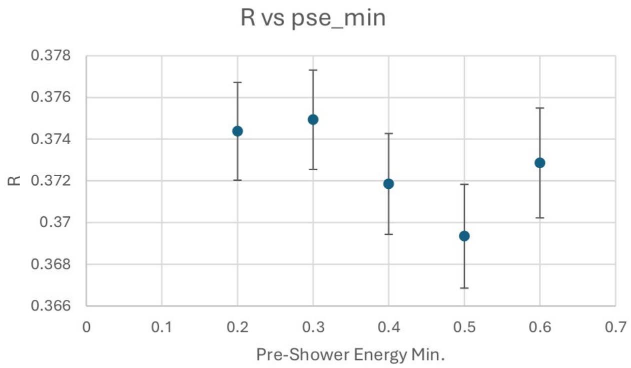

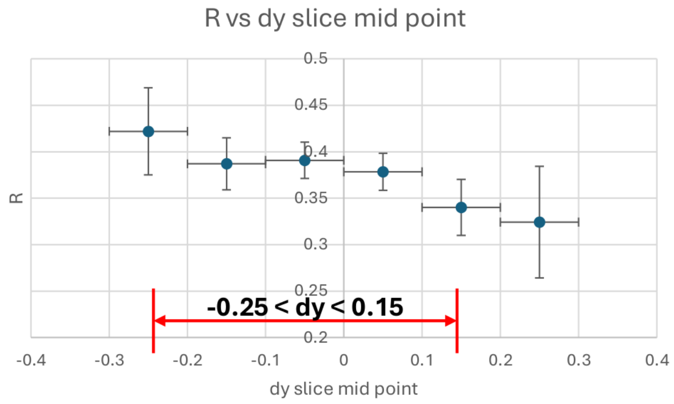

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  - For SBS9: 10% increase in n/p ratio (analysis credit *Z. Wertz*);