



Exclusive ϕ electroproduction with CLAS12 and Toy MC Studies for Extraction of SDMEs

**EMMI Rapid Reaction Task Force: Impact of Vector Mesons
on the studies of the 3D structure of the nucleon**

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Wednesday, June 17, 2026

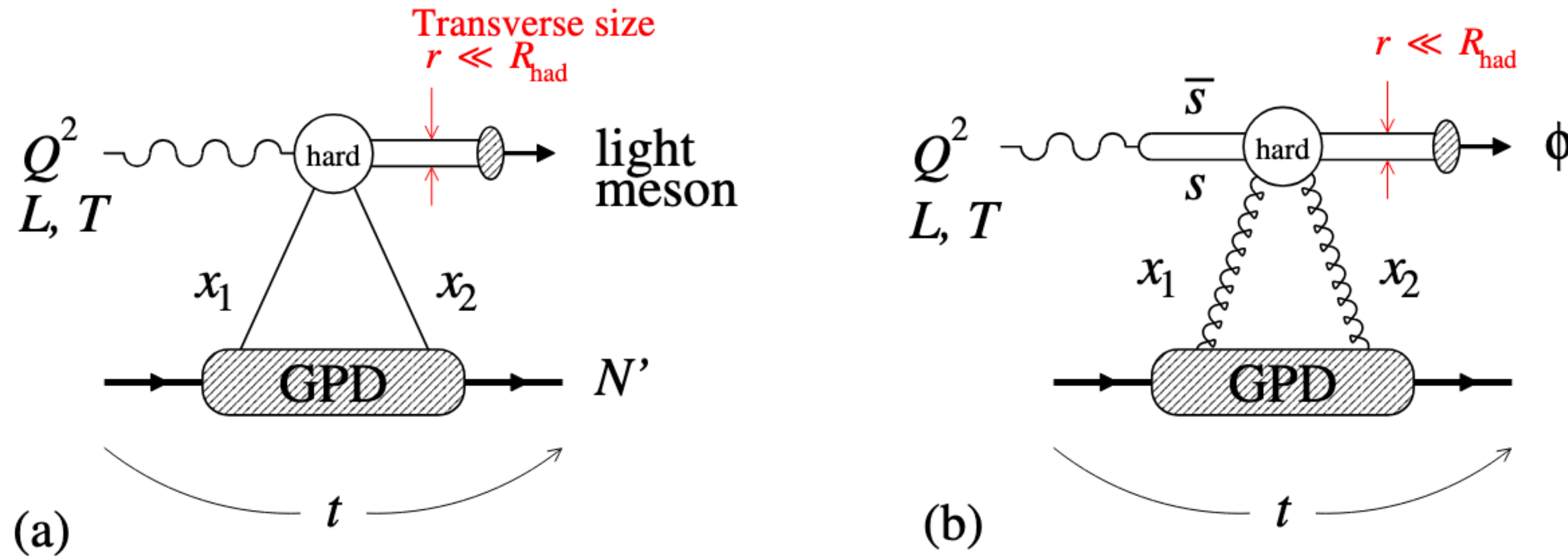
* Y. Wang, **H. Avakian**, V.D. Burkert, **L. Elouadrhiri**, **D. Glazier**, **F.X. Girod**, R. Milner, I. Korover, V. Kubarovsky, and P. Moran

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Jefferson Lab

Clean Probe For Gluonic Structure of Nucleon

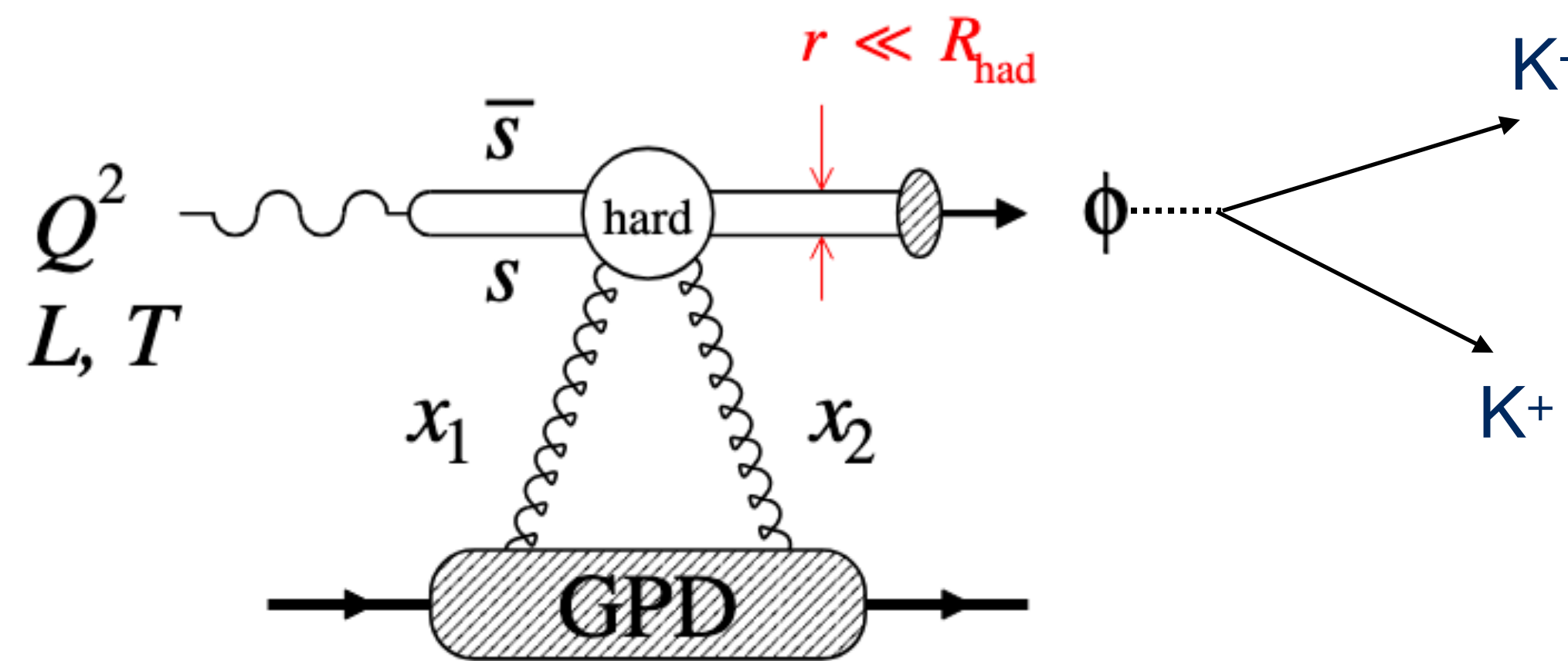
- ϕ meson a **pure $s\bar{s}$ state**, its coupling to light quarks (u,d) is suppressed (by OZI rule)
- Access to the gluon GPD even at low energy due to its flavor content $s\bar{s}$



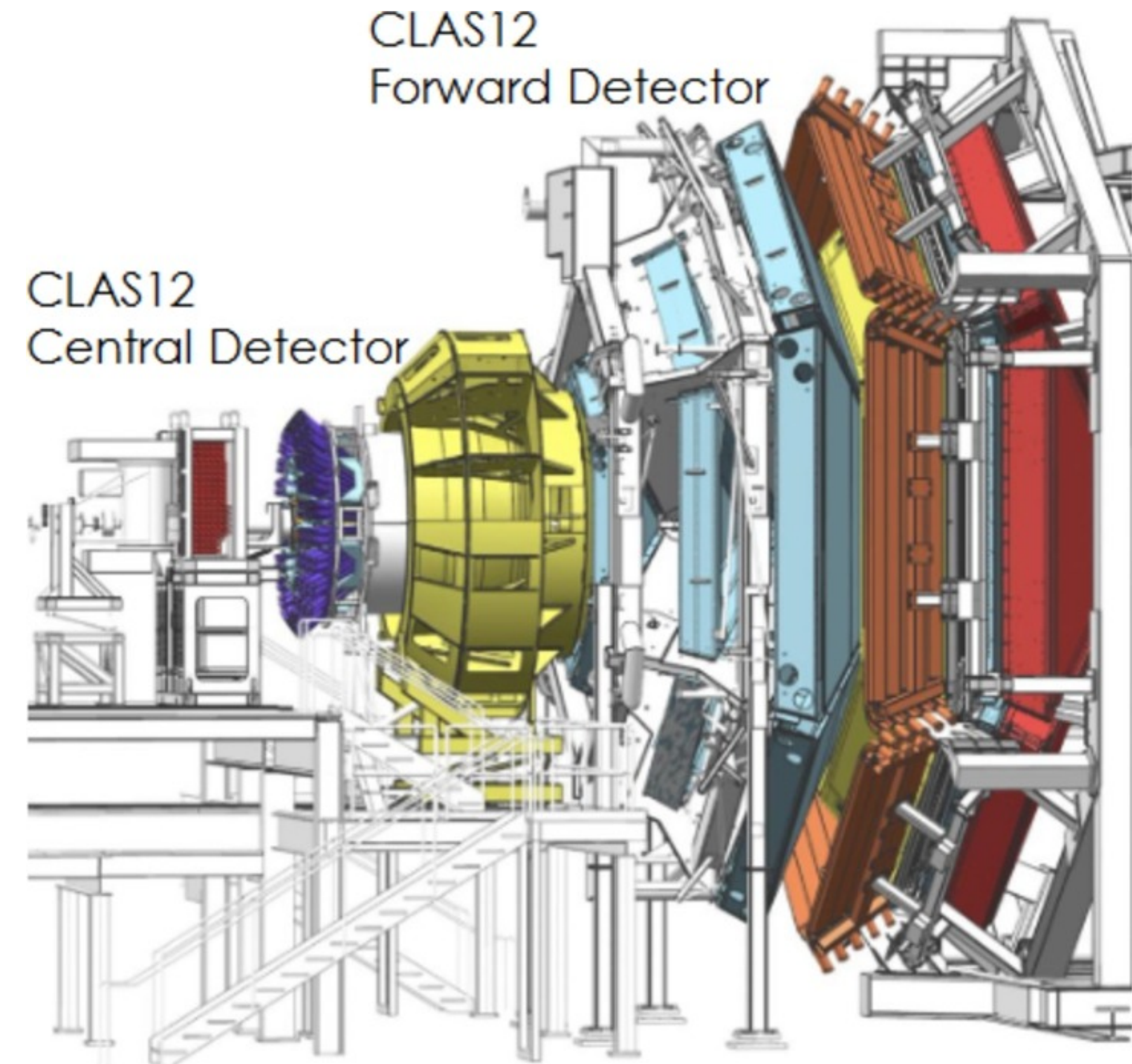
- Q^2 scaling of ϕ production cross section: opens doors to test **QCD factorization** ($\sigma_L \sim 1/Q^6$, $\sigma_L/\sigma_T \sim Q^2$)
- Change of $|t|$ -dependence with Q^2 ➔ **gluonic radius** of the proton
- Search for **near-threshold effects** linked to intrinsic $s\bar{s}$ pairs

Exclusive ϕ production with proton target

- Beam energy 10.6 GeV dependent production from data sets collection during **2018-19**
- Analysis strategy: select charge decay daughters $ep \rightarrow e'p'K^+K^-$ (branching ratio: $\sim 49.2\%$)



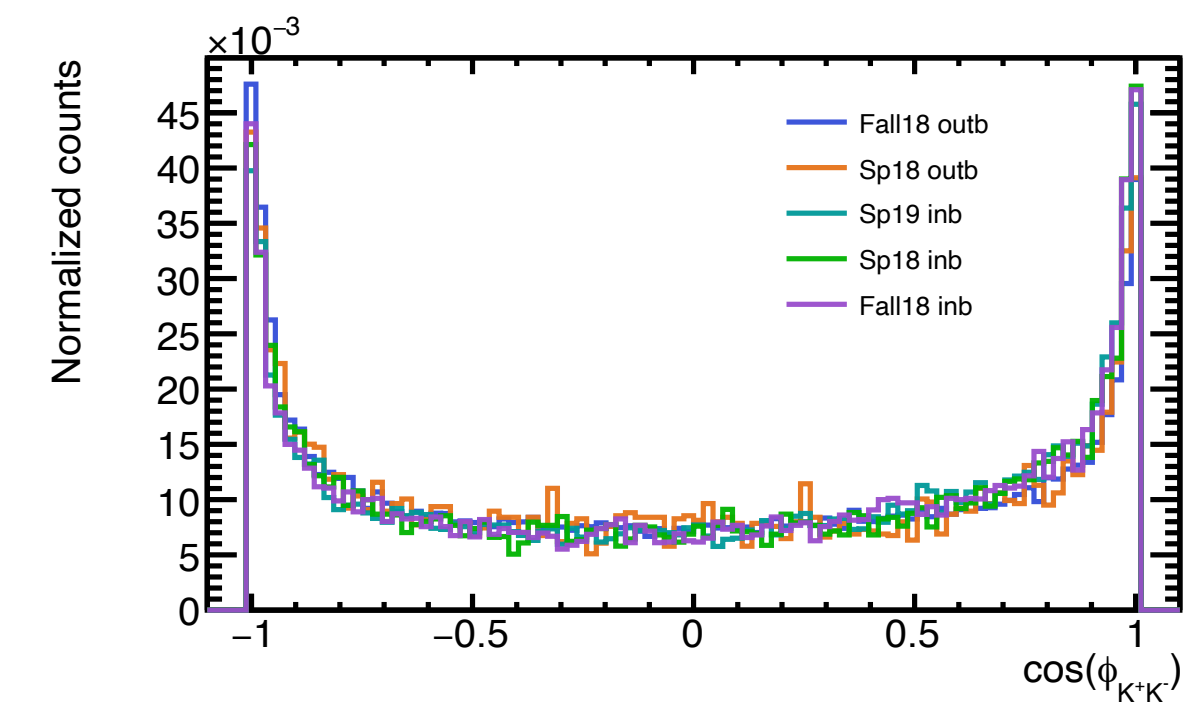
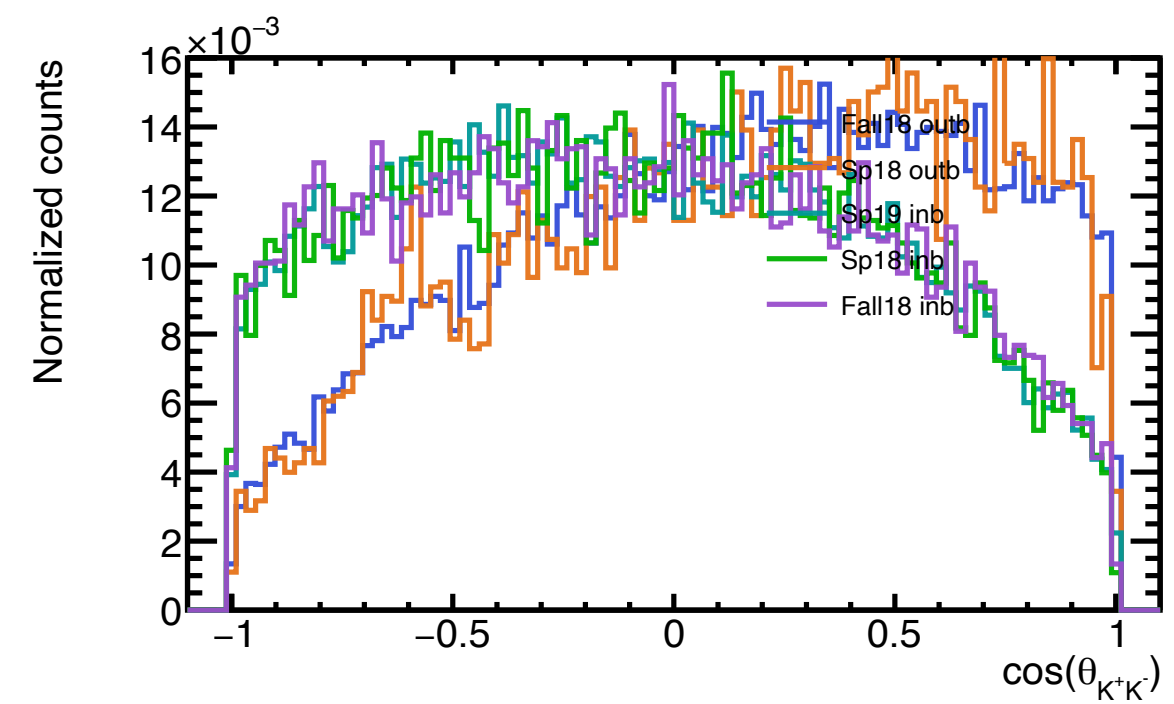
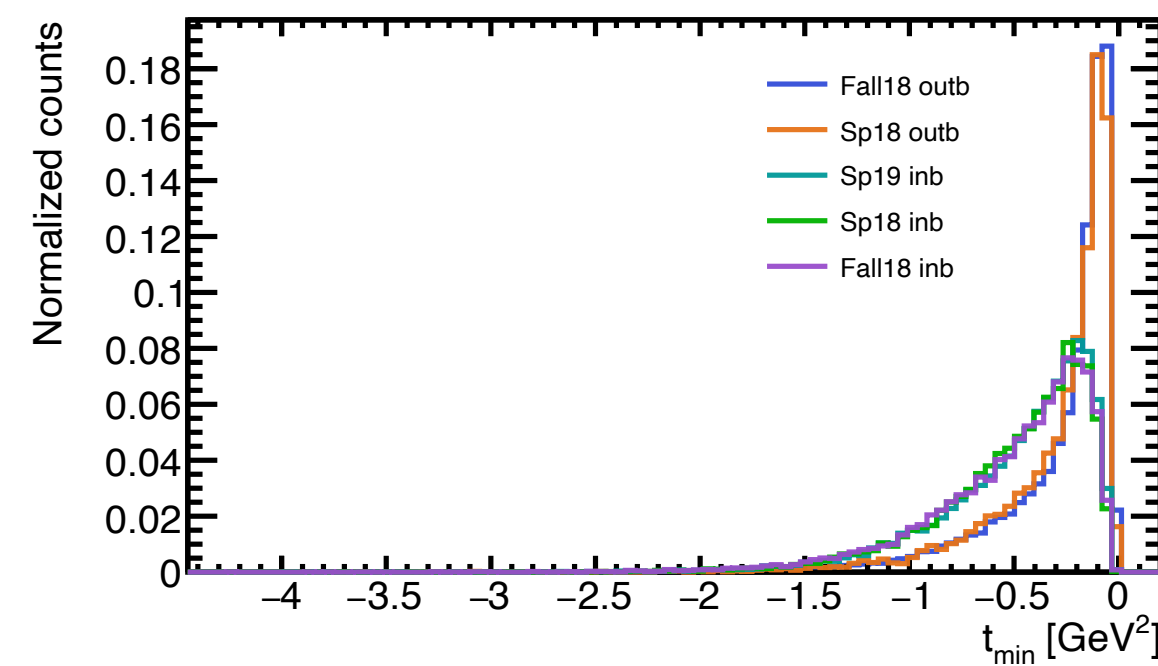
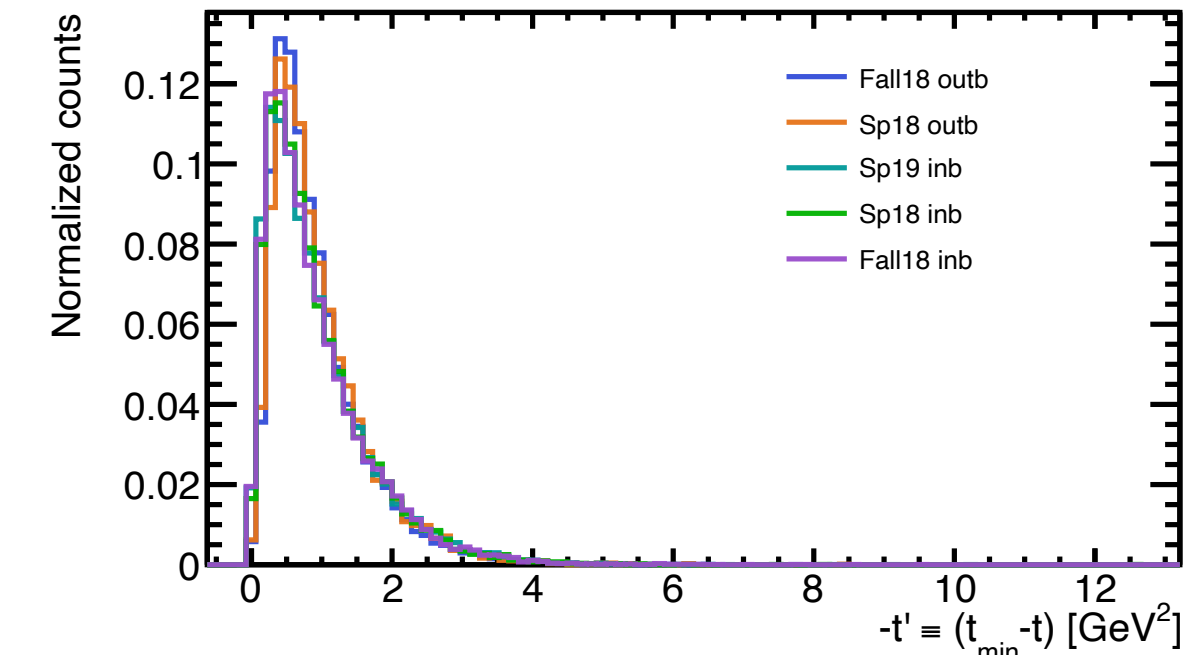
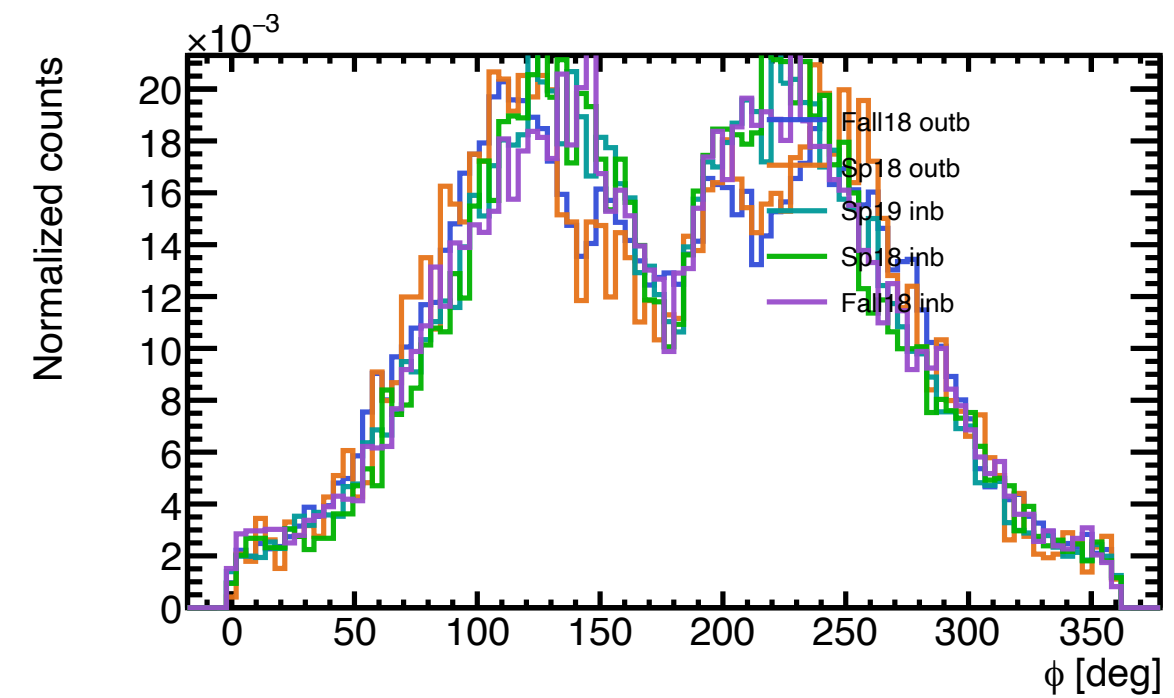
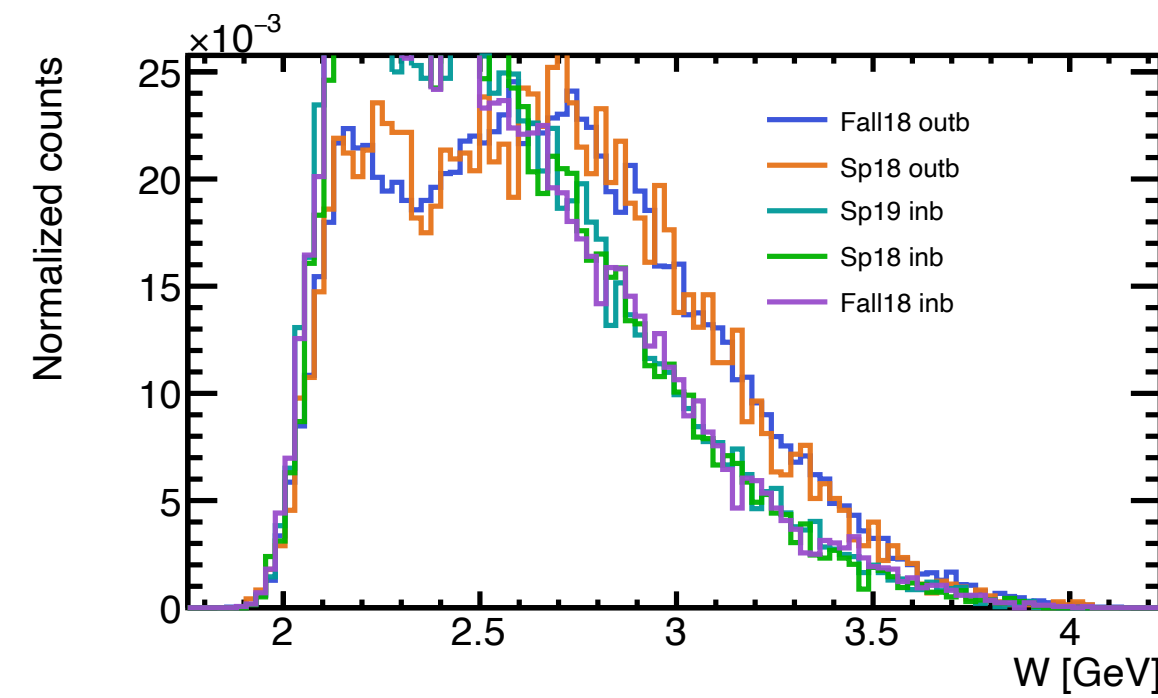
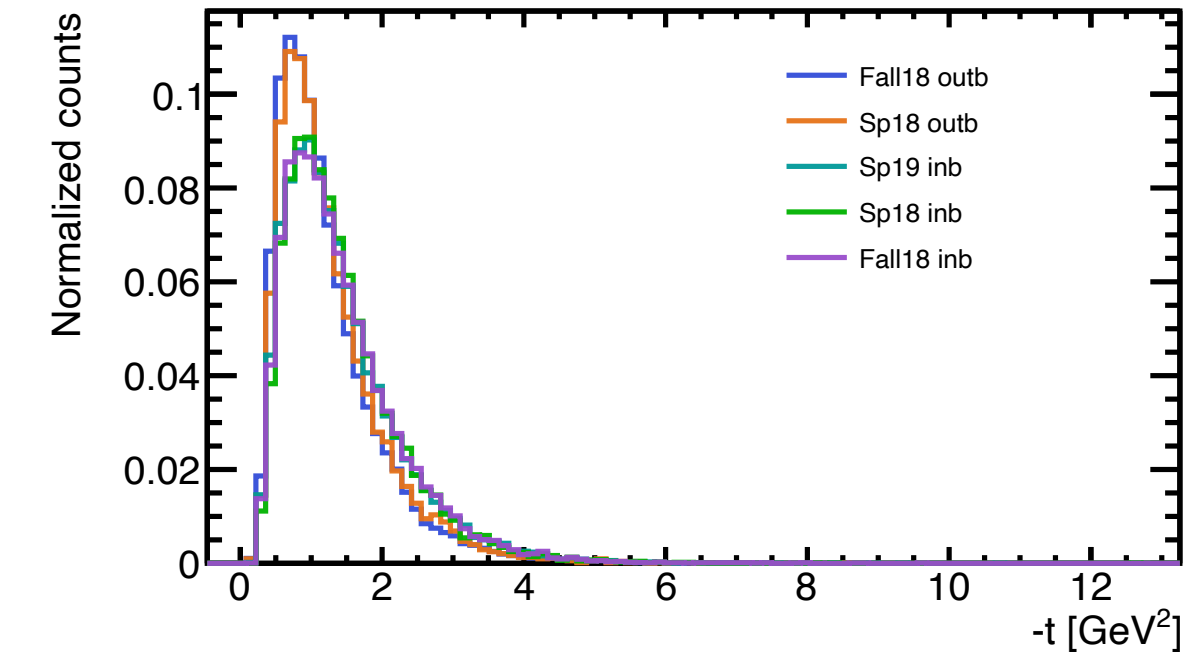
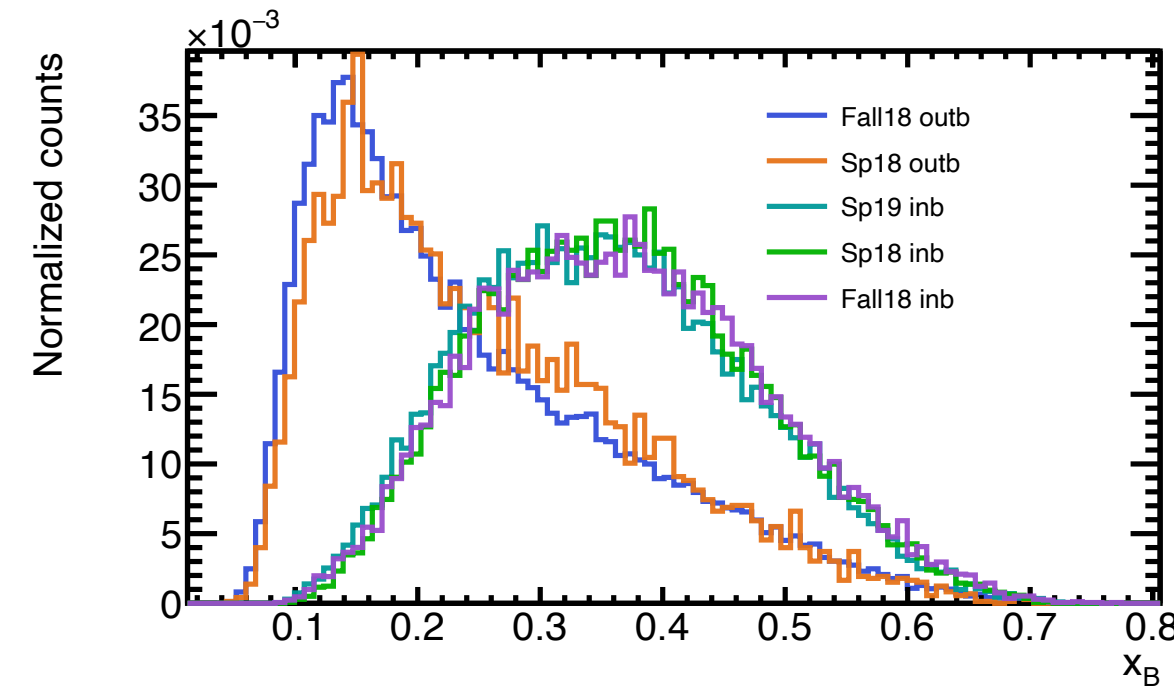
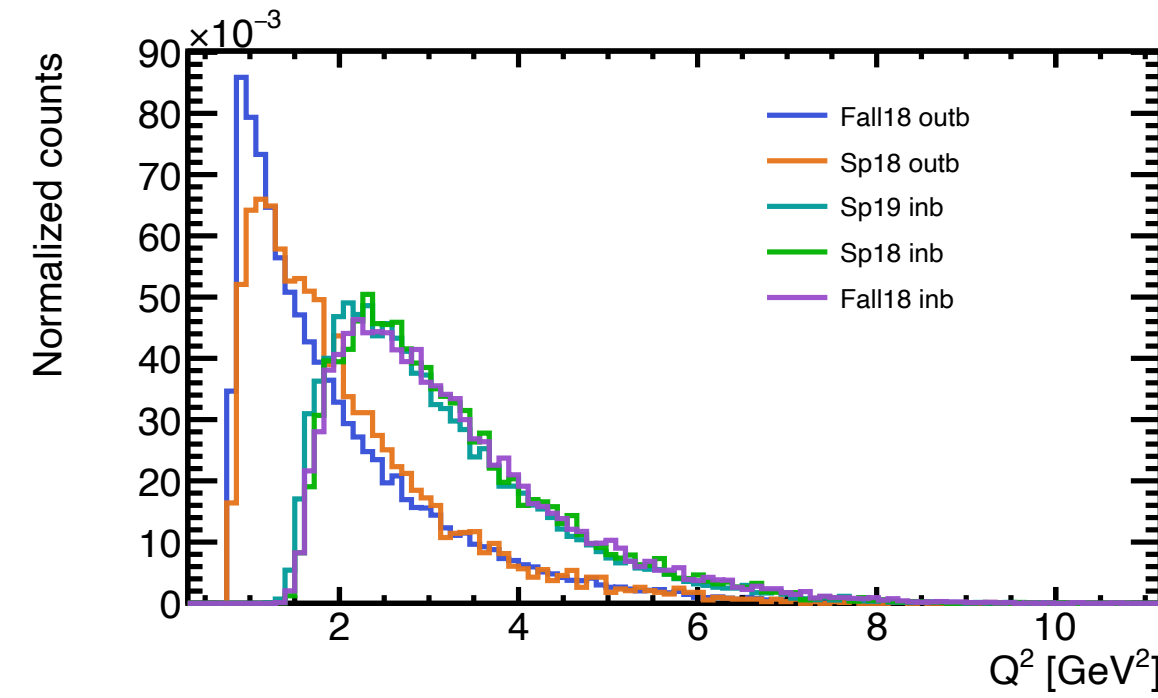
- **Forward Detector (FD)** covers the range of polar angles from 5 to 35 degrees segmented into 6 sectors in azimuthal angle
- **Central Detector (CD)** covers the range of polar angles from 35 to 125 degrees
- Electron selected in only FD while protons and Kaons are selected in both CD and FD



R. Tyson et al, Comp. Phys. Com., 290, 108783, (2023)

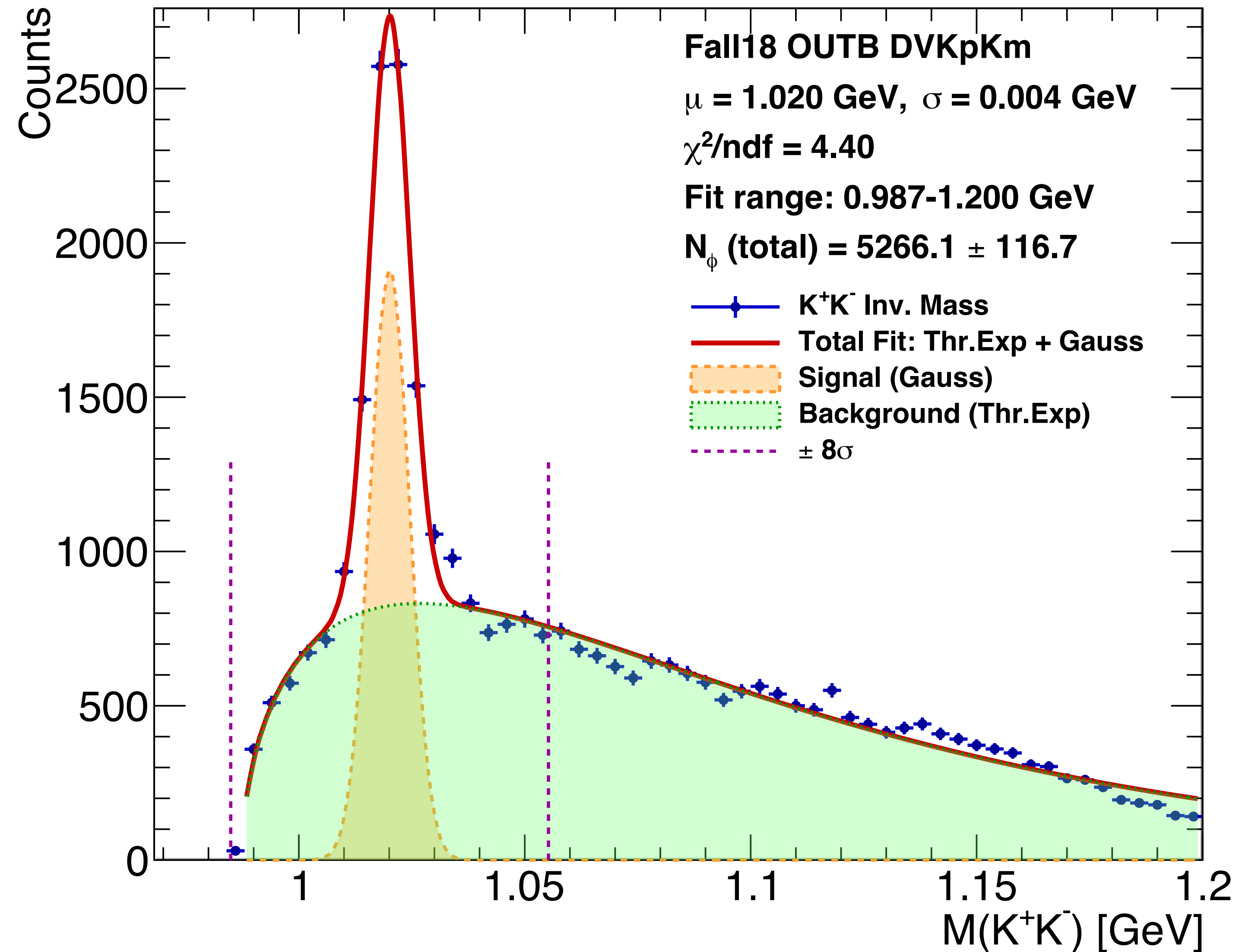
DVEP Kinematic variables

- Energy loss correction for proton and $W > 1.8$ GeV and $Q^2 > 0.2$ GeV²



K⁺K⁻ Invariant Mass Distributions

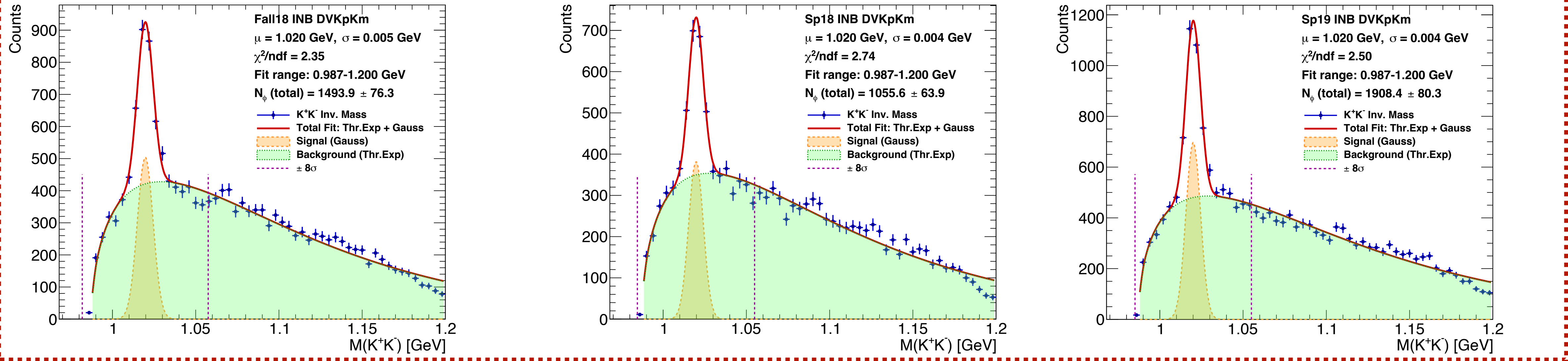
- ϕ candidate counts from the invariant mass peak at ~ 1.019 GeV of K^+K^- in $ep \rightarrow epK^+K^-$
- Signal: Gaussian distribution
- Background: Exponential+polynomial 3rd order
- Extracted yield as integral of the Gaussian function
- Exclusive selection: **~ 5200** candidates from fall 2018 outb alone



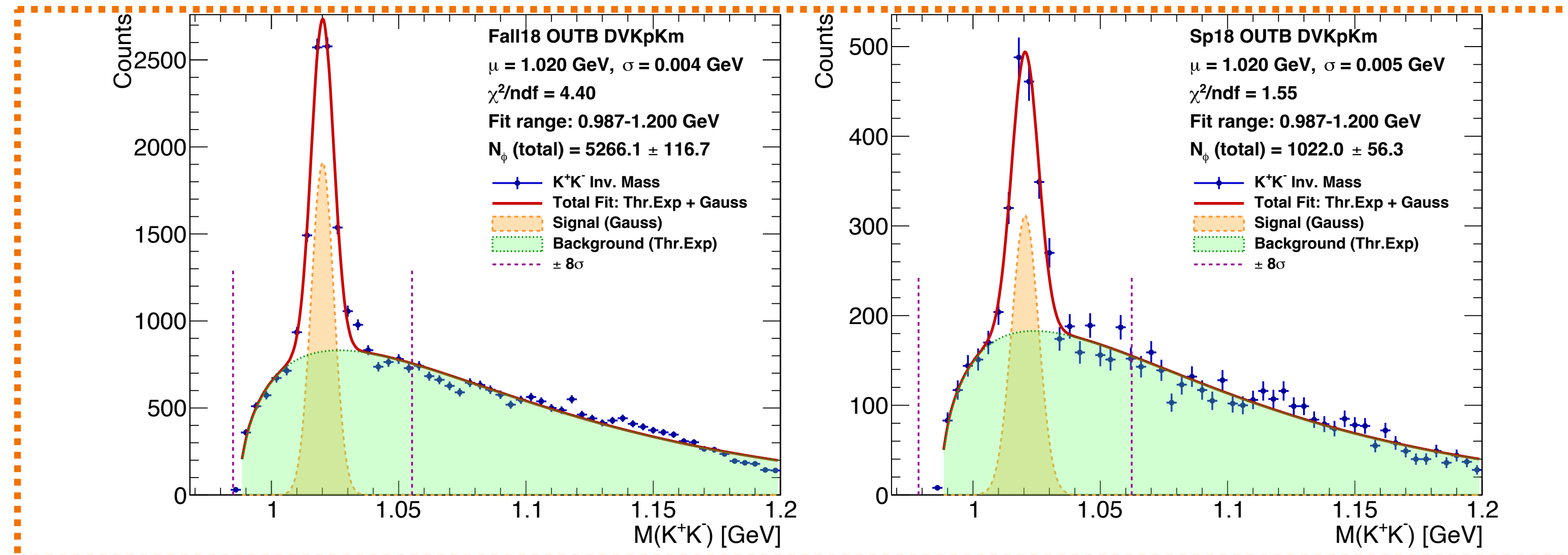
All phi K⁺K⁻ Invariant Mass all periods of 2018-19 run

- ϕ peak at ~ 1020 MeV, total ~ 10000 candidates from 2018-19 Run group A datasets

Inb

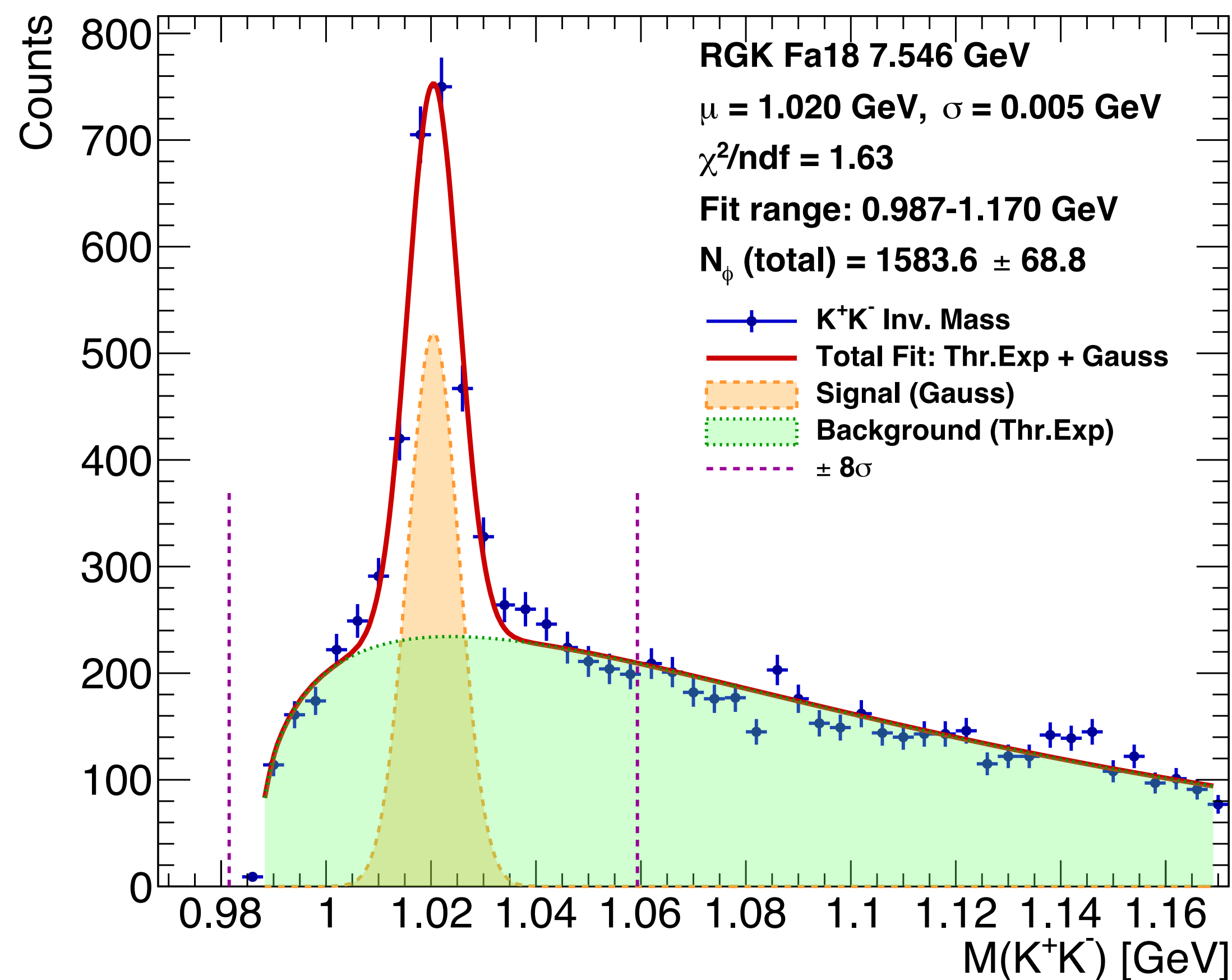
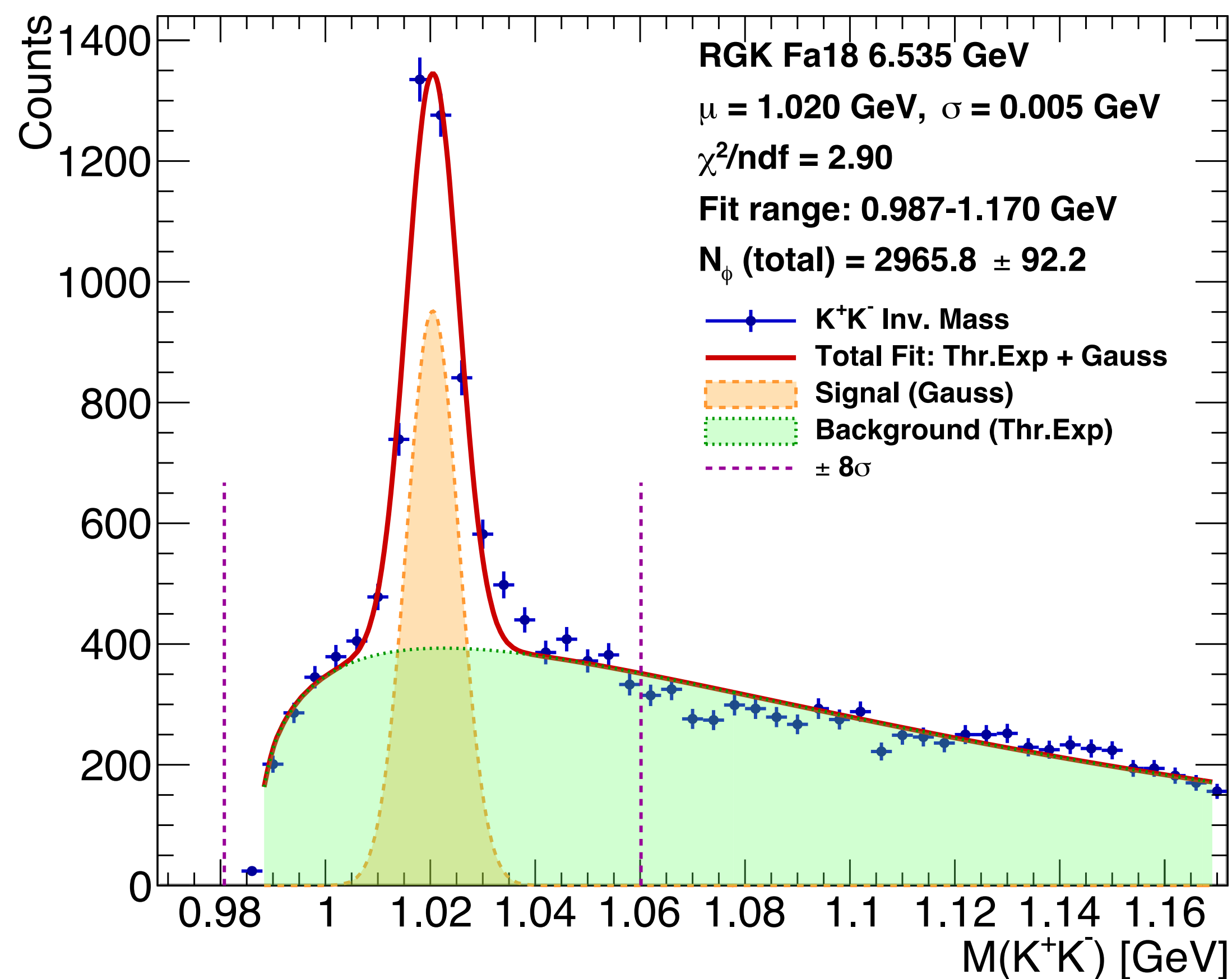


Outb



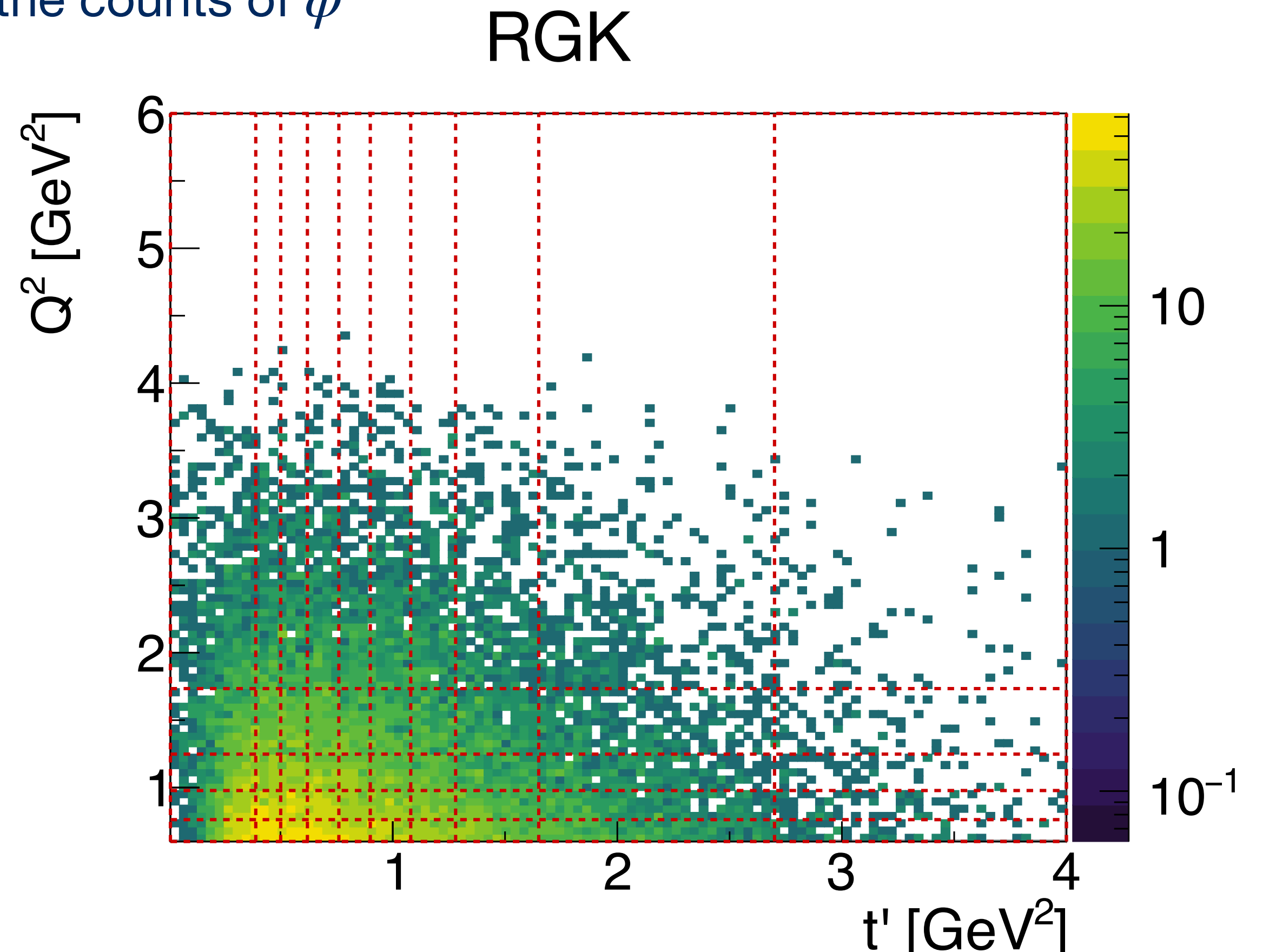
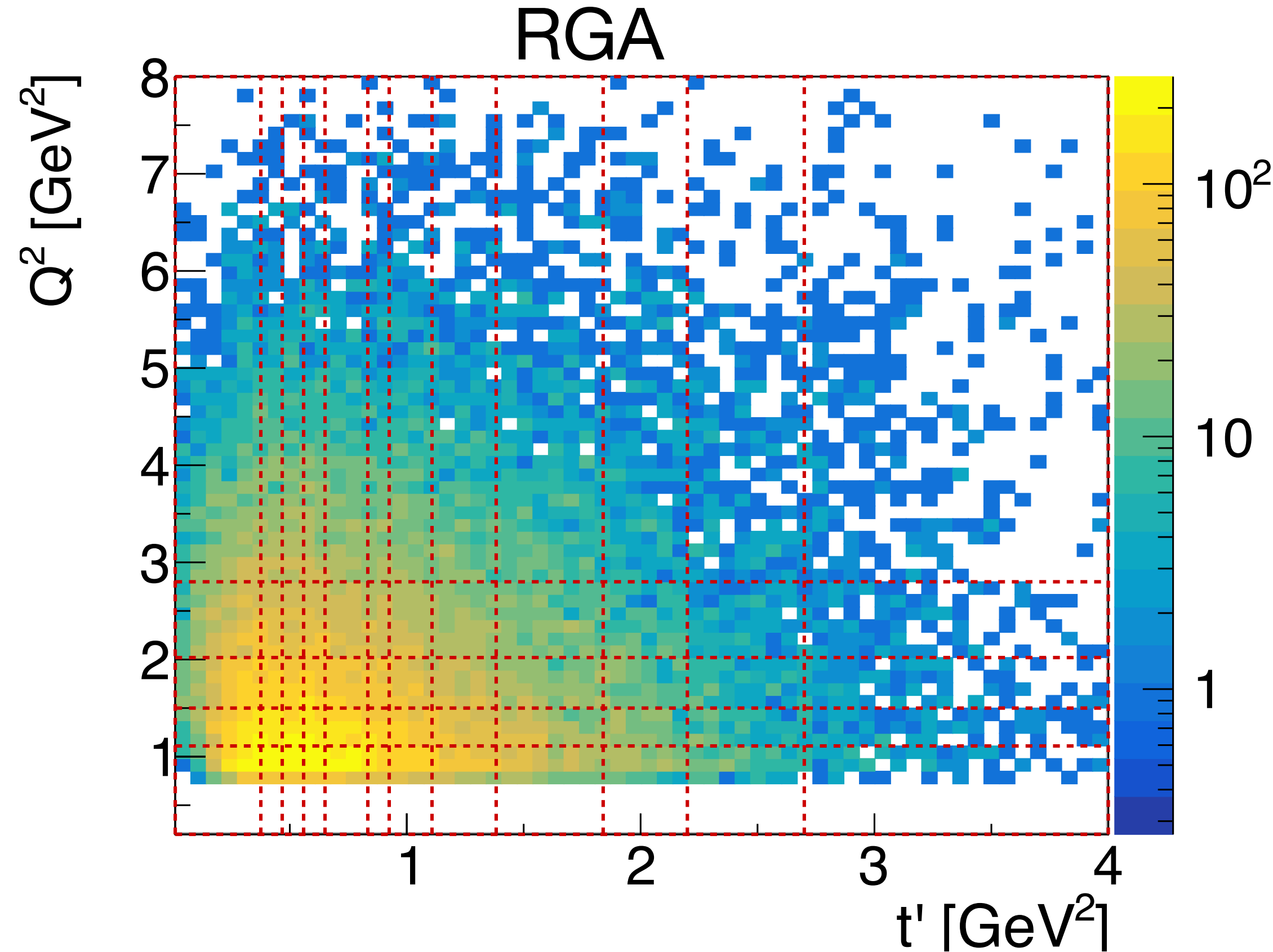
Run Group K: 6.5 and 7.5 GeV Beam Energies

- 6.5 and 7.5 GeV fall 2018 data, $Q^2 > 0.6 \text{ GeV}^2$, after all fiducial cuts and sampling fraction cuts for electron, energy loss correction for proton, 3 sigma exclusivity cuts
- Statistics is too small



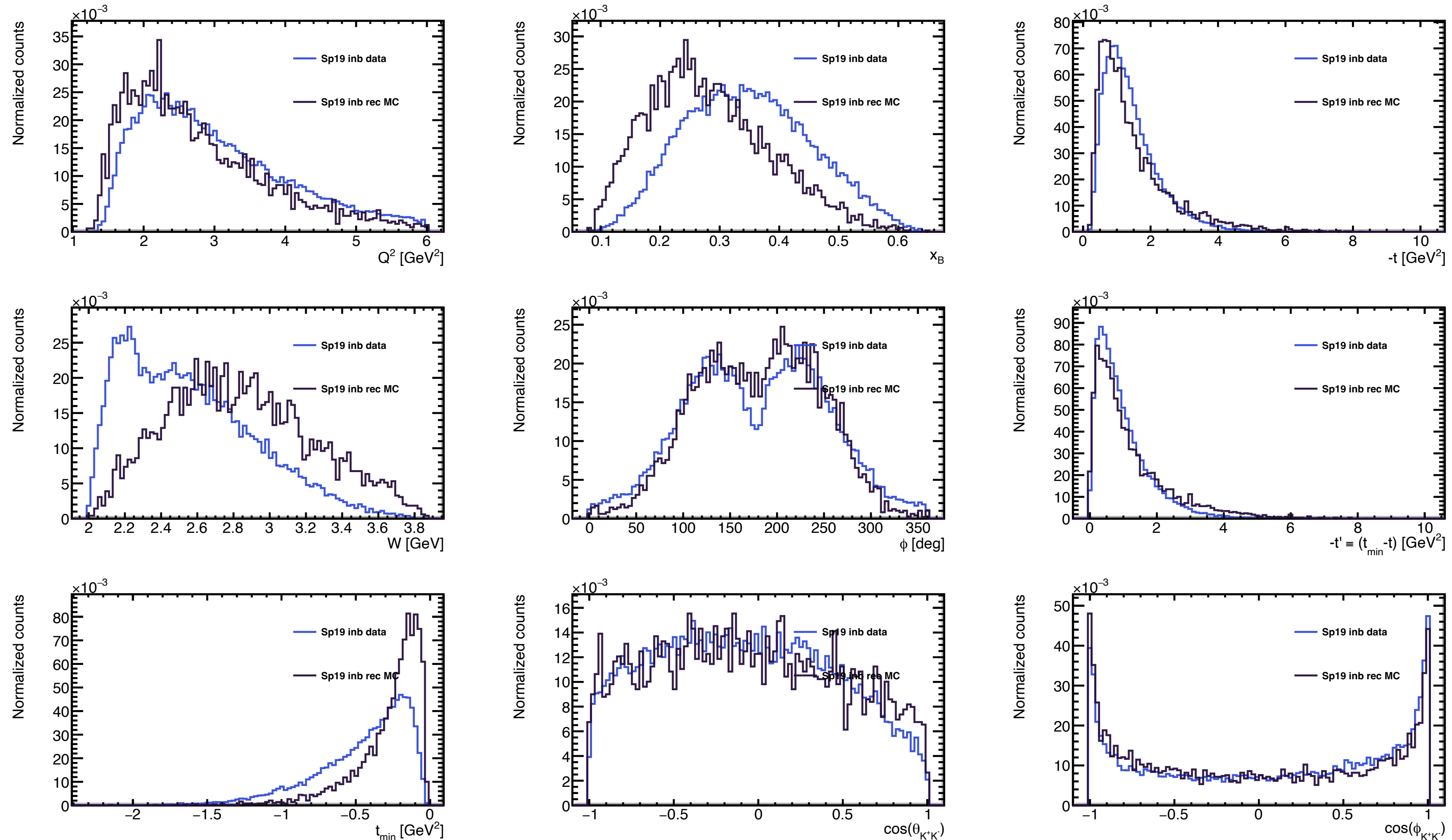
Extraction of cross-section: RGA and RGK binning

- Divide the total sample with equal statistics in each Q^2 and t' bin
- Currently **5** Q^2 and **12** t' bins
- In each $-t'$ bin used a $InvM_{K+K^-}$ distribution to extract the counts of ϕ



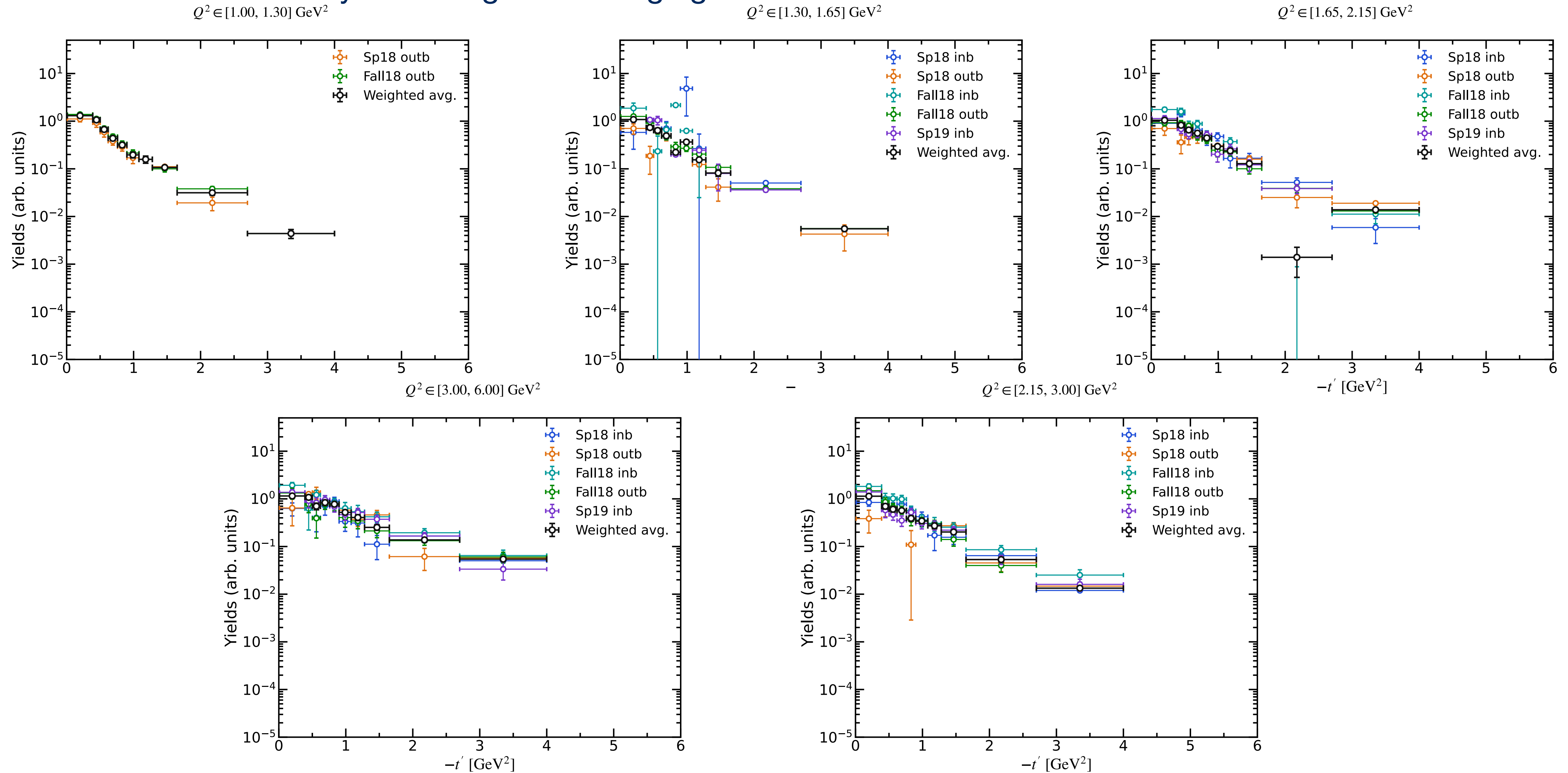
Simulation vs Data

- Simulations based on the Argonne ϕ Event Generator tuned to Clas 6 data and **ϕ event decay in rest mass is considered as isotropic (flat distribution)**

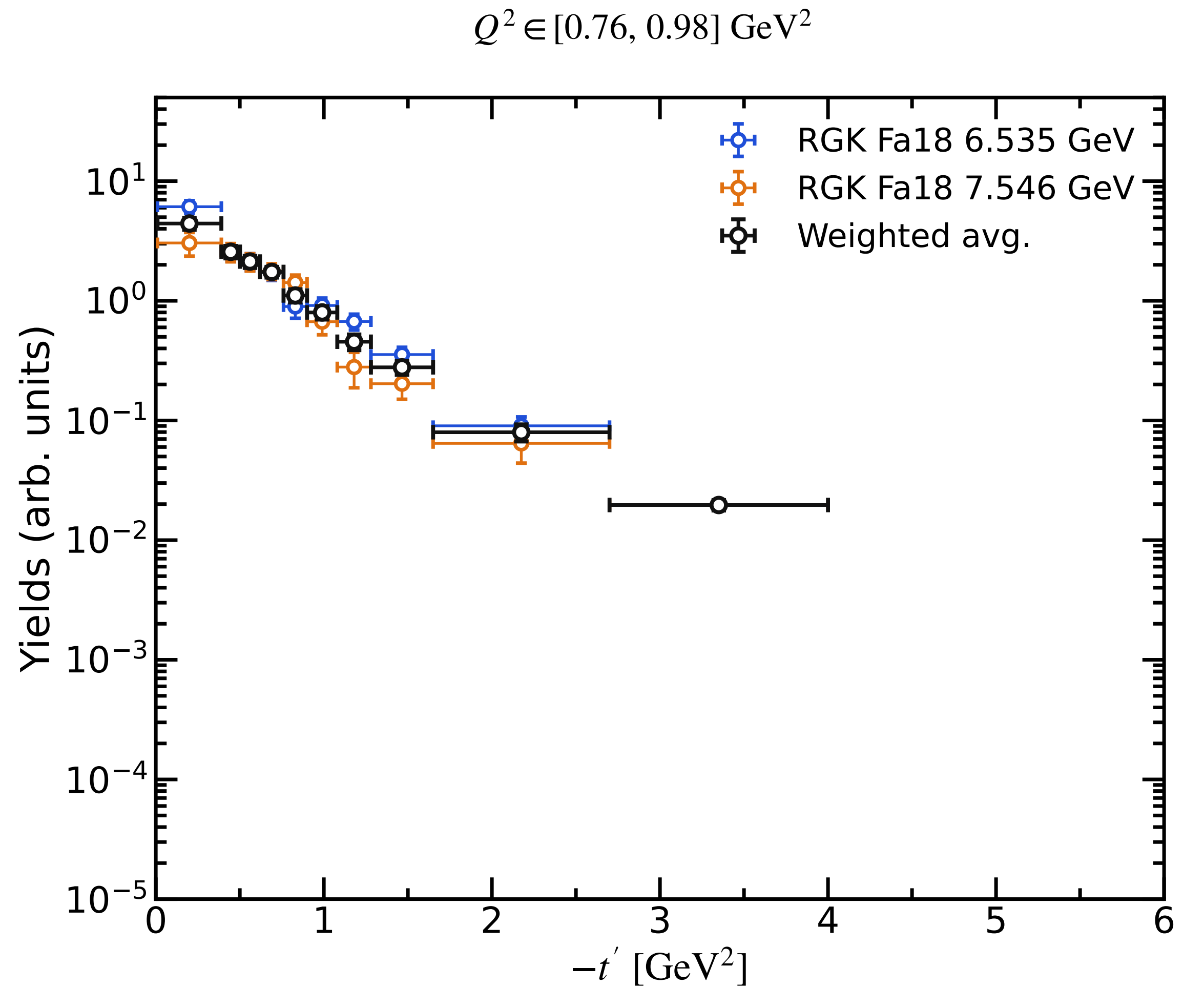
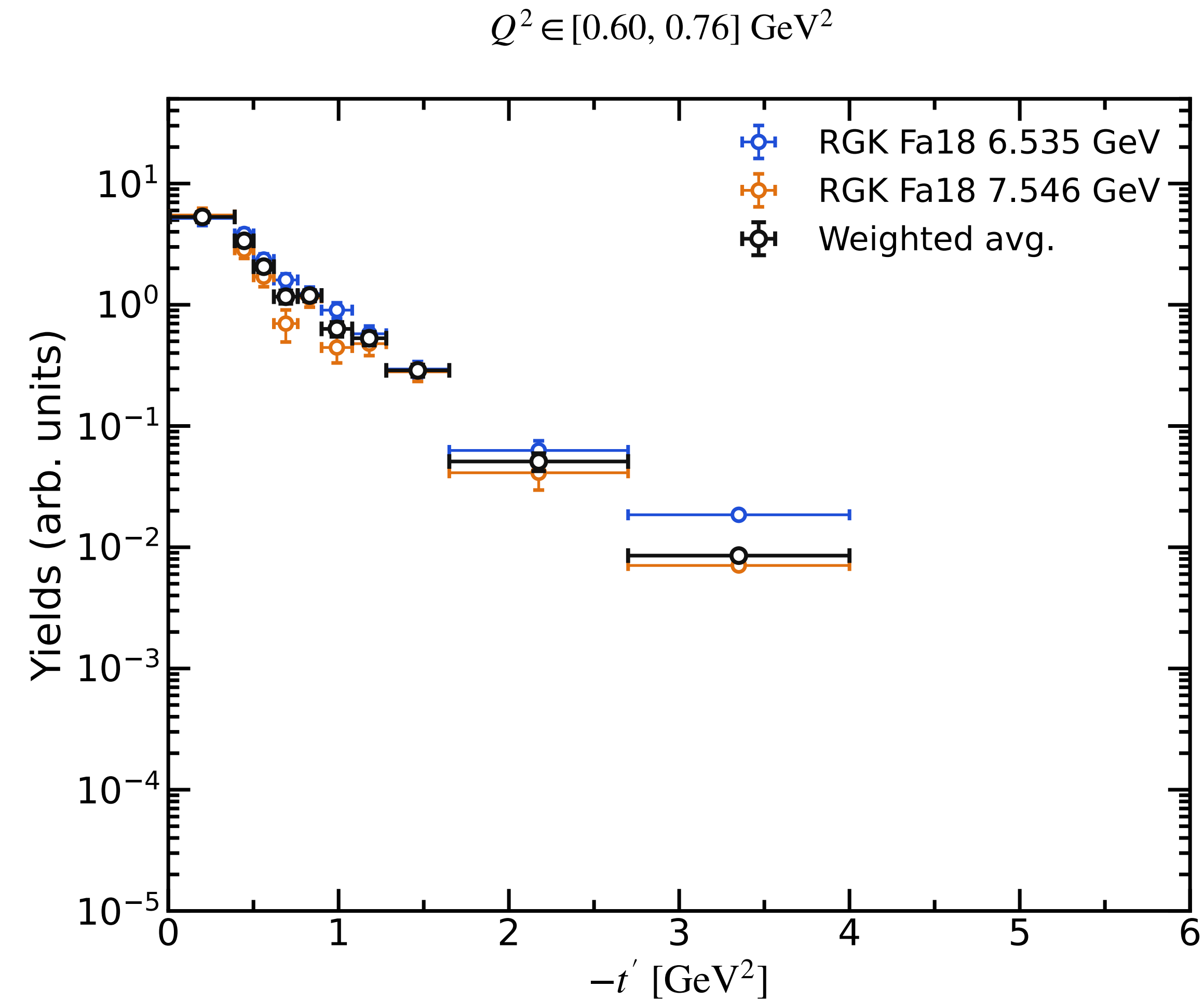


Final reduced cross-sections RGA

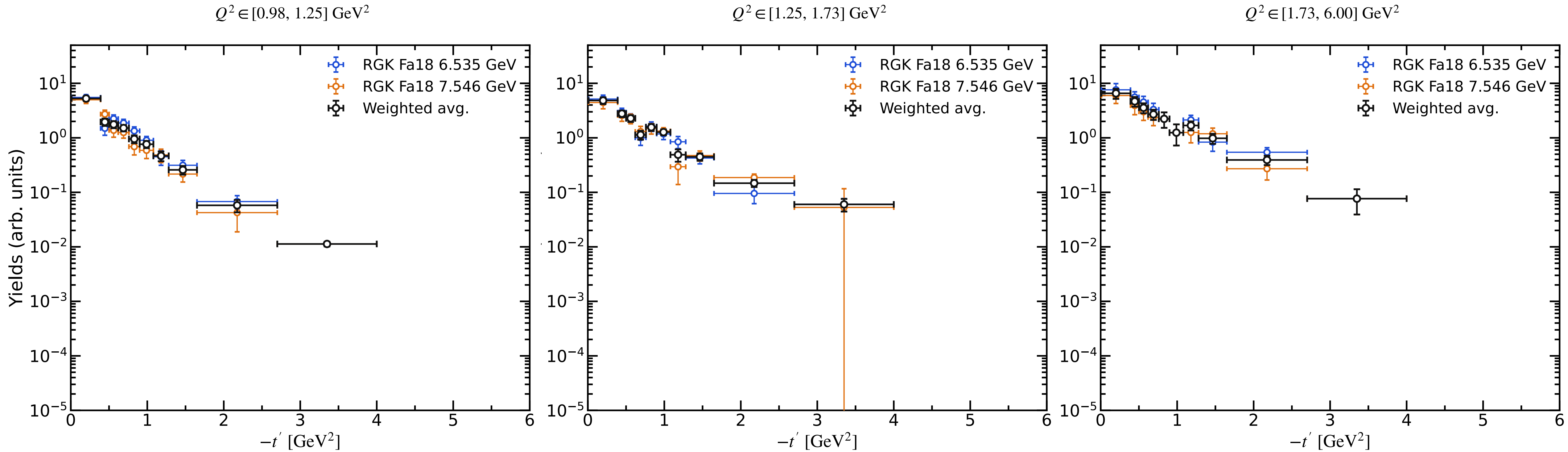
- **Without** the efficiency for background merging corrections!



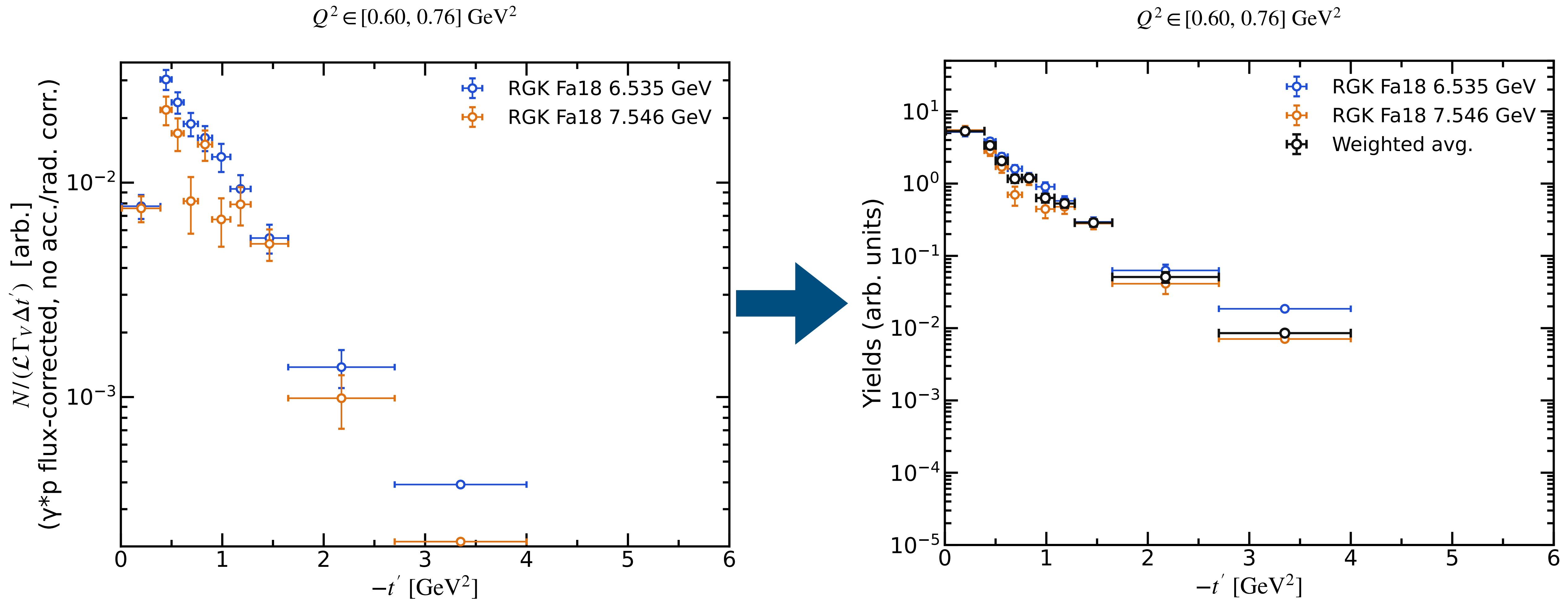
RGK Efficiency corrected cross-sections



RGK Acceptance corrections

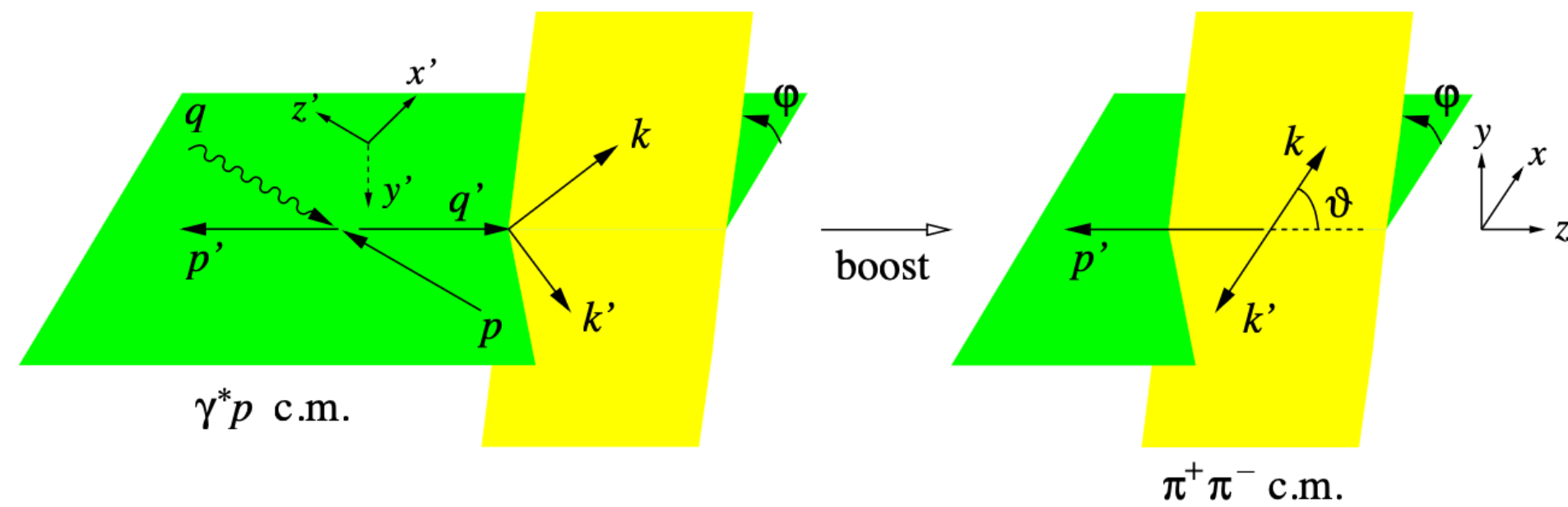


Impact of acceptance correction

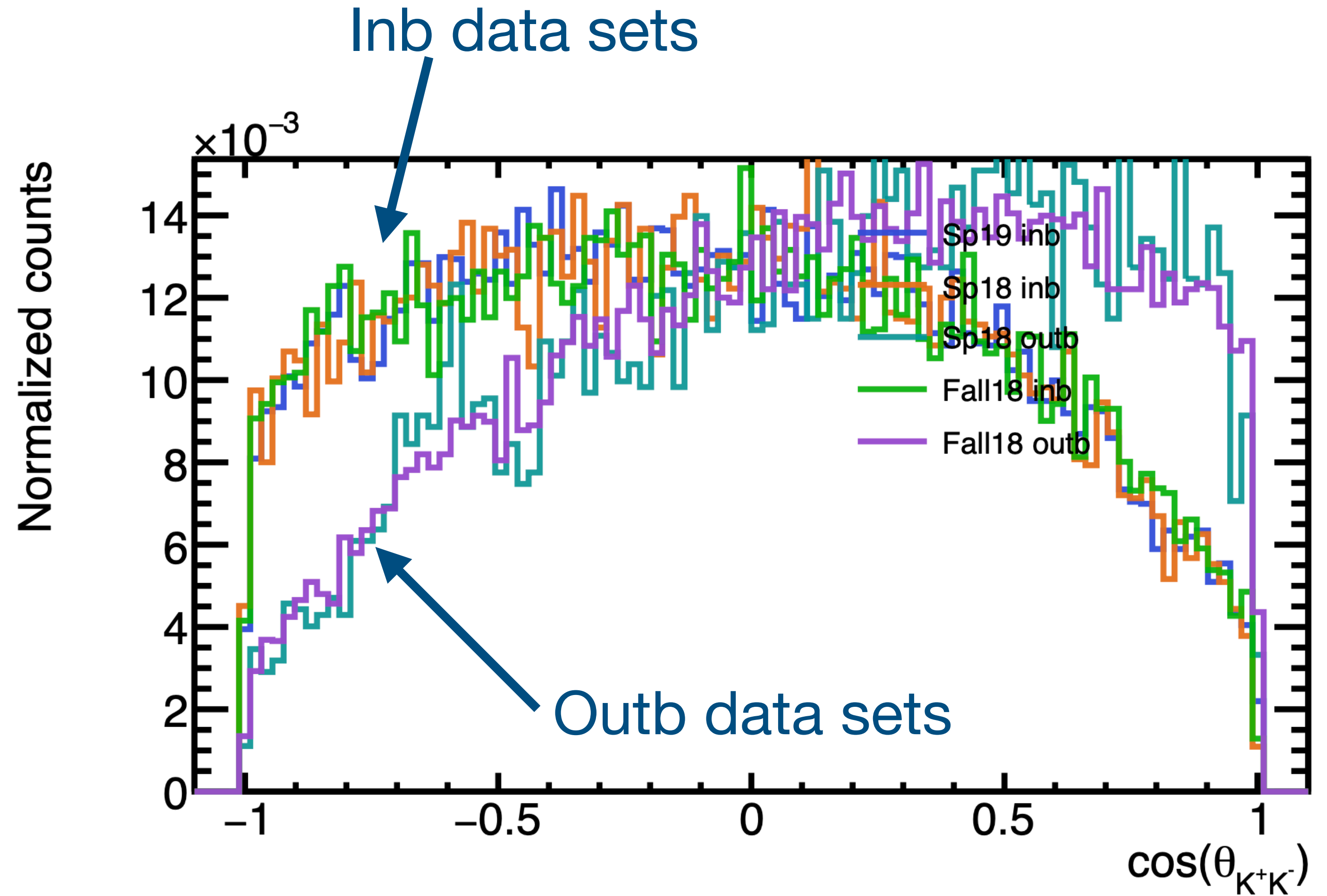


ϕ -decay and acceptance within CLAS 12

- Vector meson with spin 1 possible decay is expected to be a non-flat distribution



Markus Diehl JHEP09(2007)064



Total Cross-section, normalized SDMEs

- A generic cross-section depends on both SDMEs and the σ_L and σ_T

$$\left[\sigma_T(Q^2, x_B, t) + \epsilon \sigma_L(Q^2, x_B, t) \right] W(SDME(Q^2, x_B, t), \cos \theta, \Phi, \phi)$$

- Schilling-Wolf form

$$W(\cos \theta, \phi, \Phi; \epsilon, P_\ell; \{r_{ij}^\alpha\}) = W_{UU} + P_\ell W_{LU}$$

with 23 SDMEs as free parameters:

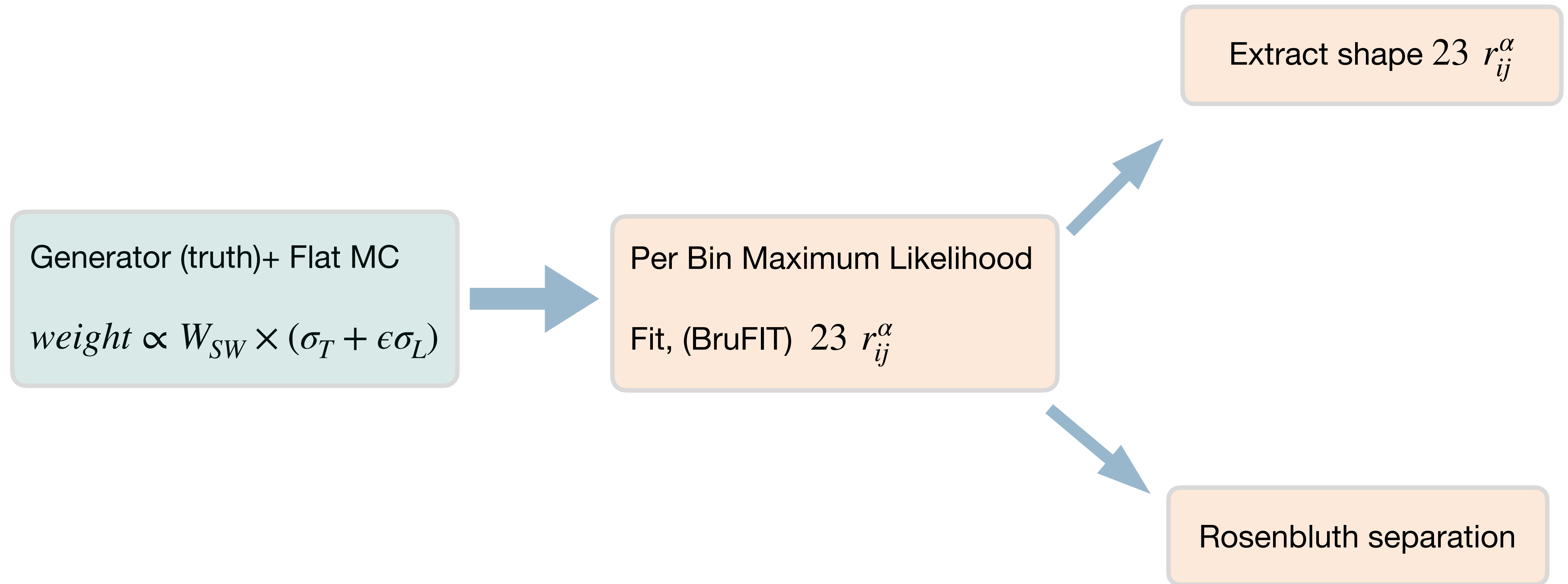
- W_{UU} (15 unpolarised-beam SDMEs): $r_{00}^{04}, \text{Rer}_{10}^{04}, r_{1,-1}^{04}$ ($\alpha = 0 + 4$); $r_{11}^1, r_{00}^1, \text{Rer}_{10}^1, r_{1,-1}^1$ ($\alpha = 1$); $\text{Im}r_{10}^2, \text{Im}r_{1,-1}^2$ ($\alpha = 2$); $r_{11}^5, r_{00}^5, \text{Rer}_{10}^5, r_{1,-1}^5$ ($\alpha = 5$); $\text{Im}r_{10}^6, \text{Im}r_{1,-1}^6$ ($\alpha = 6$).
- W_{LU} (8 polarised-beam SDMEs): $\text{Im}r_{10}^3, \text{Im}r_{1,-1}^3$ ($\alpha = 3$); $\text{Im}r_{10}^7, \text{Im}r_{1,-1}^7$ ($\alpha = 7$); $r_{11}^8, r_{00}^8, \text{Rer}_{10}^8, r_{1,-1}^8$ ($\alpha = 8$).
- M. Diehl (JHEP 09 (2007) 064)

$$2\pi \frac{d\sigma}{dt d\Phi} = \frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt} + \epsilon \cos 2\Phi \frac{d\sigma_{TT}}{dt} + \sqrt{2\epsilon(1+\epsilon)} \cos \Phi \frac{d\sigma_{LT}}{dt} + h_\ell \sqrt{2\epsilon(1-\epsilon)} \sin \Phi \frac{d\sigma_{LT'}}{dt},$$

$$\rho_{\mu\mu', \lambda\lambda'}^{\nu\nu'} = \frac{1}{N_T + \epsilon N_L} \sum_{\sigma} T_{\mu\lambda}^{\nu\sigma} (T_{\mu'\lambda'}^{\nu'\sigma})^*,$$

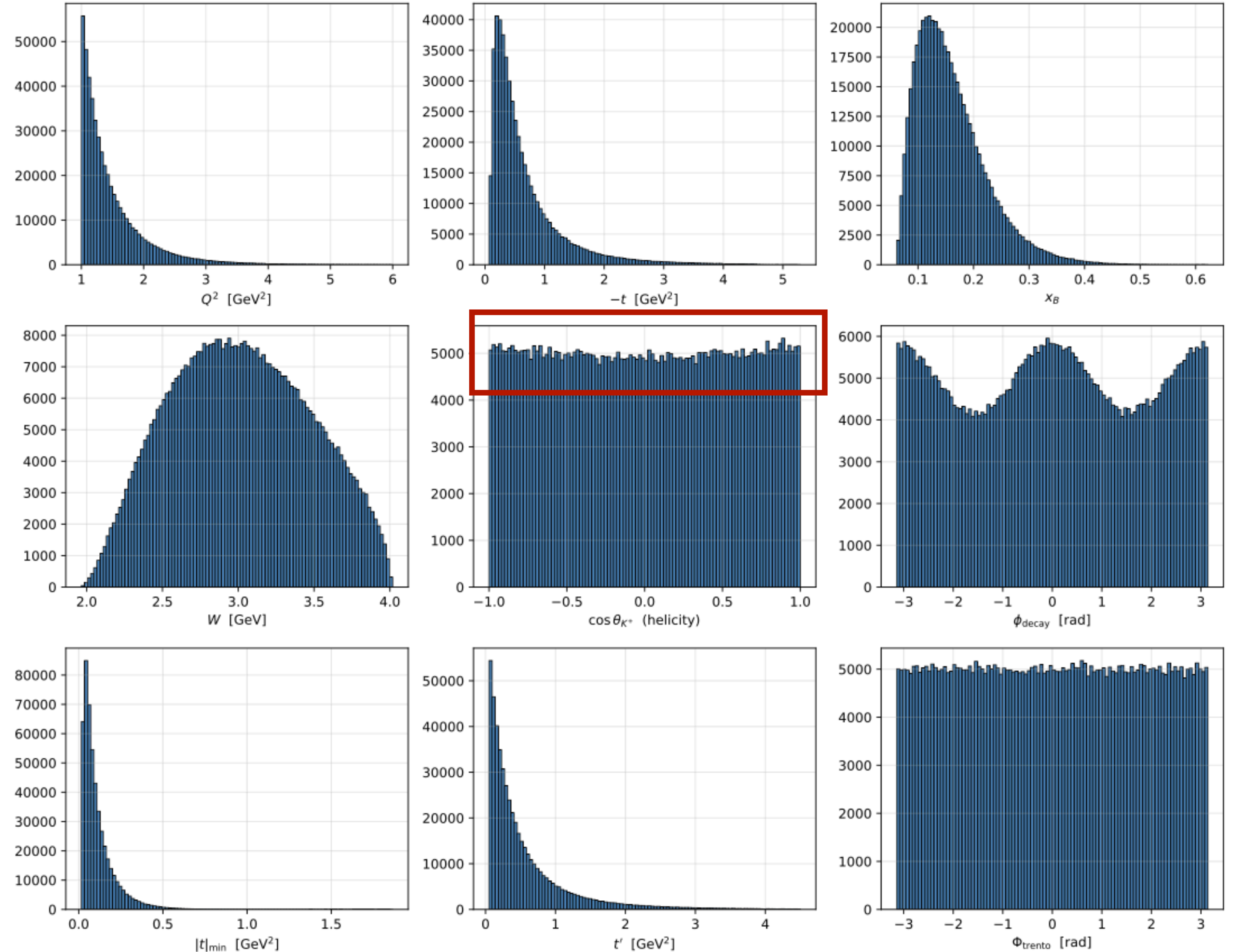
Closure test: to check if the fit works

- Only event at the generator level!

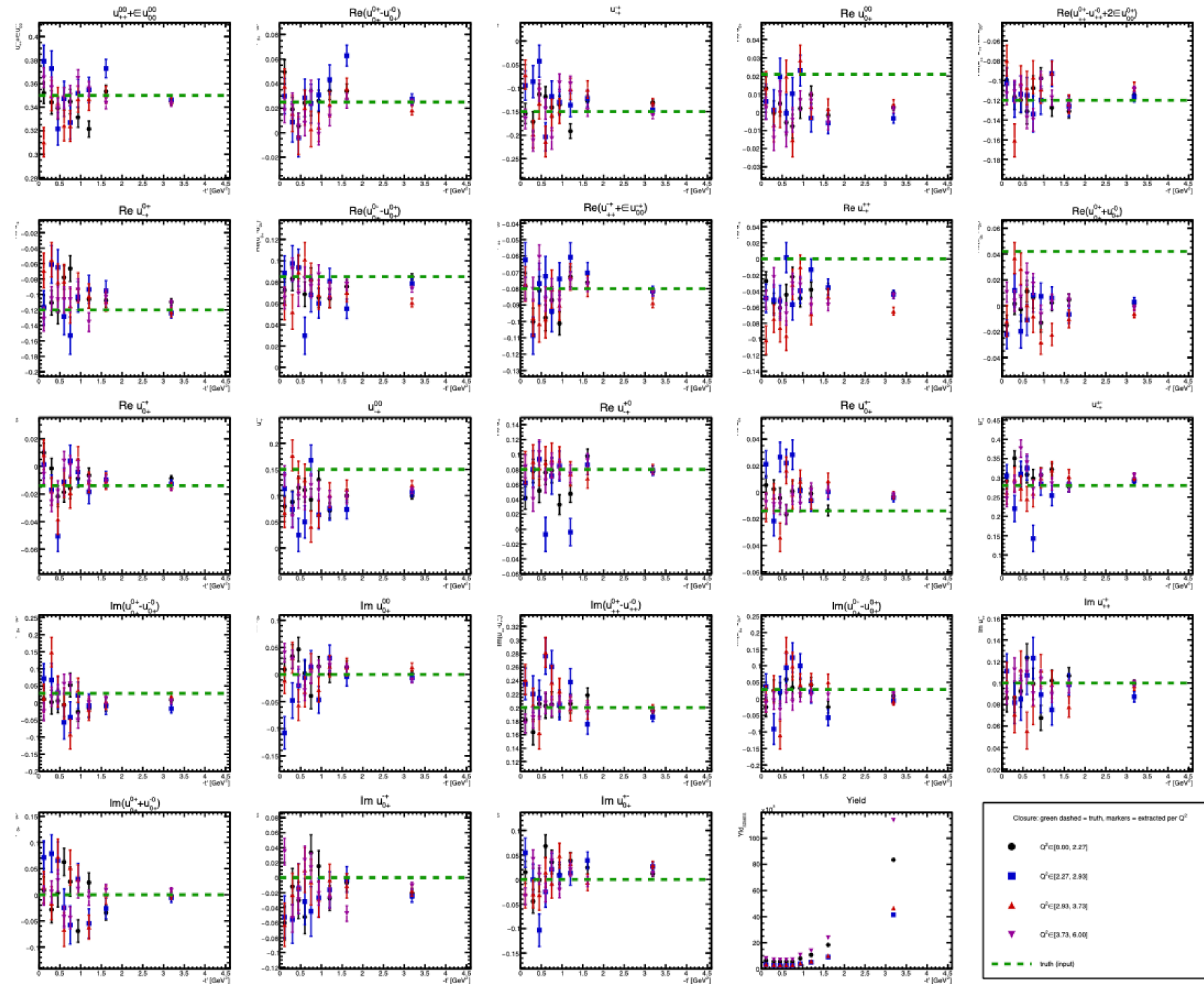


DVEP kinematics with Heuristic SDMEs

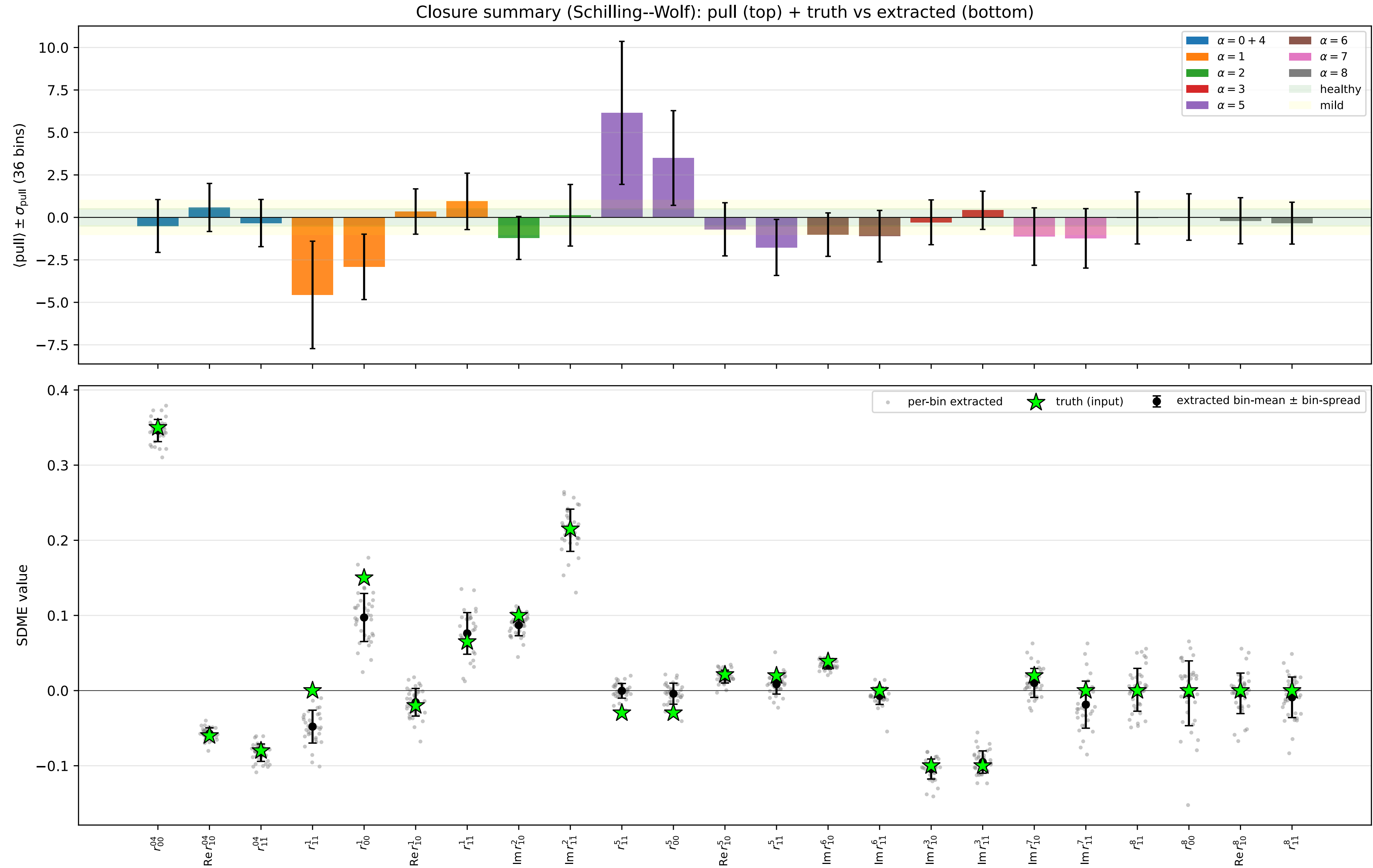
- Take 10.6 GeV CLAS12 setup
- Tried **5** Q^2 and **12** t' bins, similar to data
- 500K events
- Generator is tuned to 6 GeV CLAS data of ϕ -meson, Event Generator describes the Q^2 and t , modulations are accounted by Heuristic SDMEs



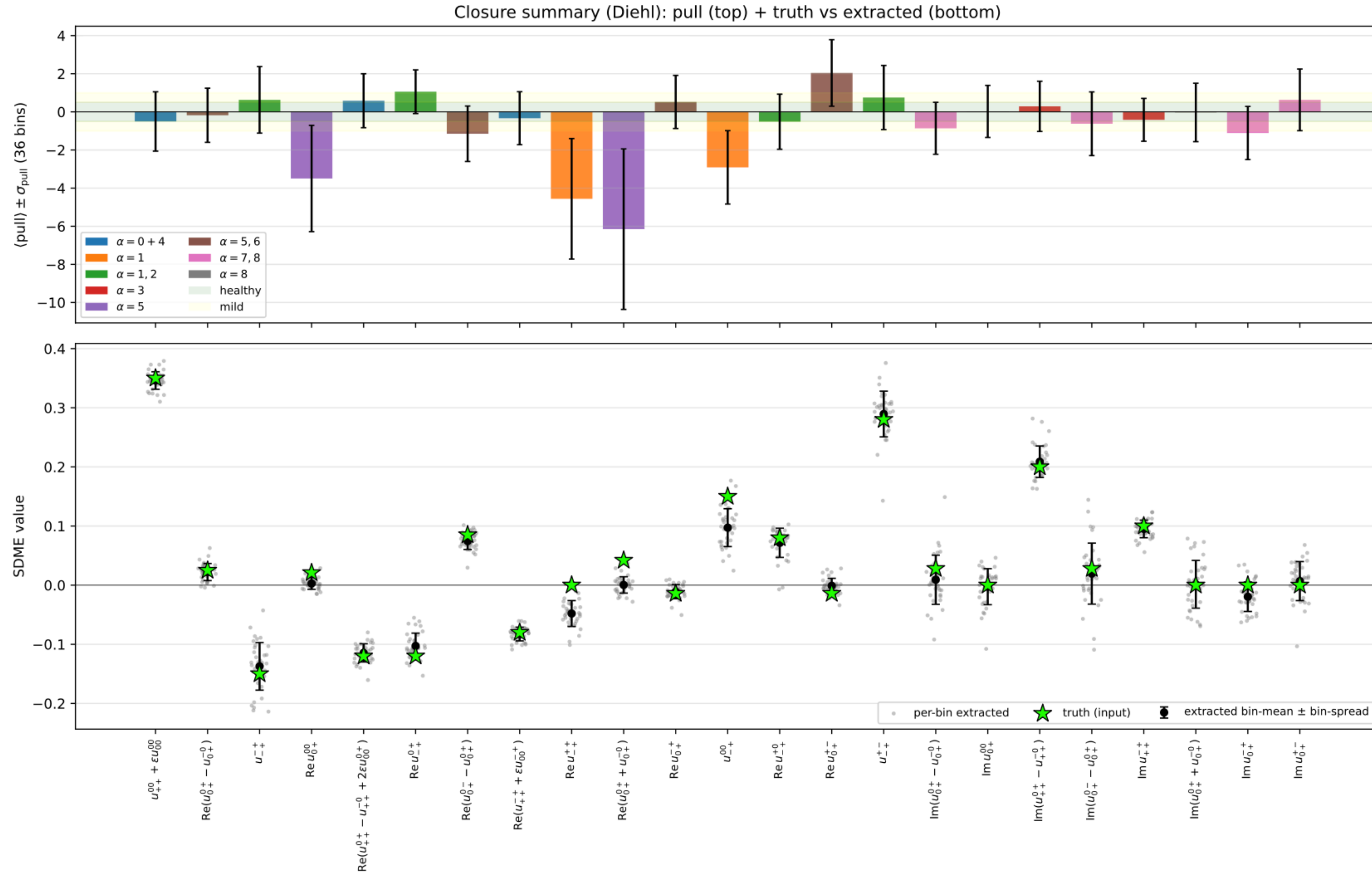
Fits in Q^2 and t bins (36 points)



Extracted SDMEs (sims only): S+W notation

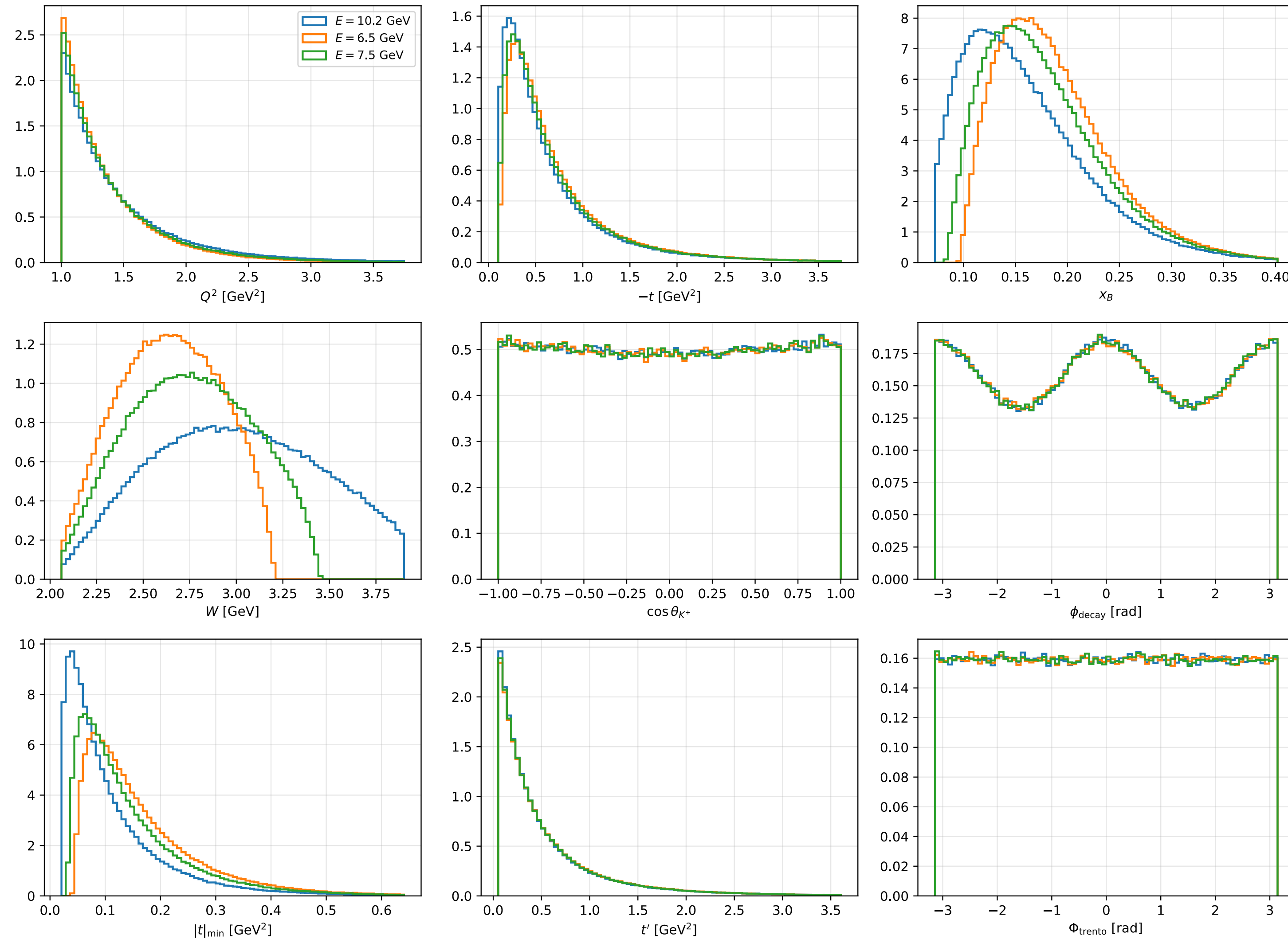


Extracted SDMEs (sims only): Diehl's notation



More energies: path to LT separation

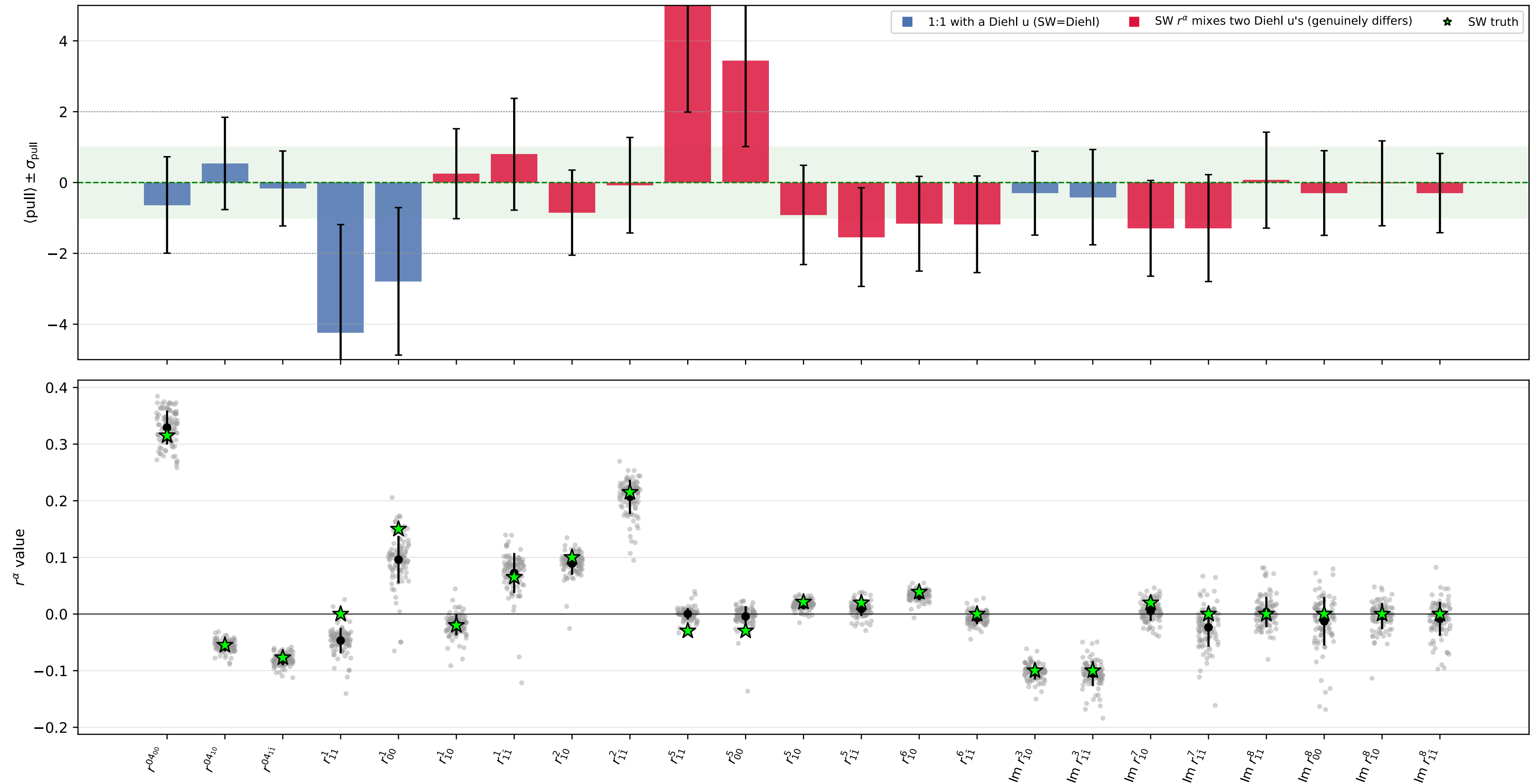
Closure-sim DVEP kinematics across RGA+RGK energies (normalised, merged 36-bin TreeData)



L-T separation in each (Q^2, t): S+W's notation

- L-T separated in each kinematics bin, extracted intercepts and slopes for $\langle \epsilon \rangle$

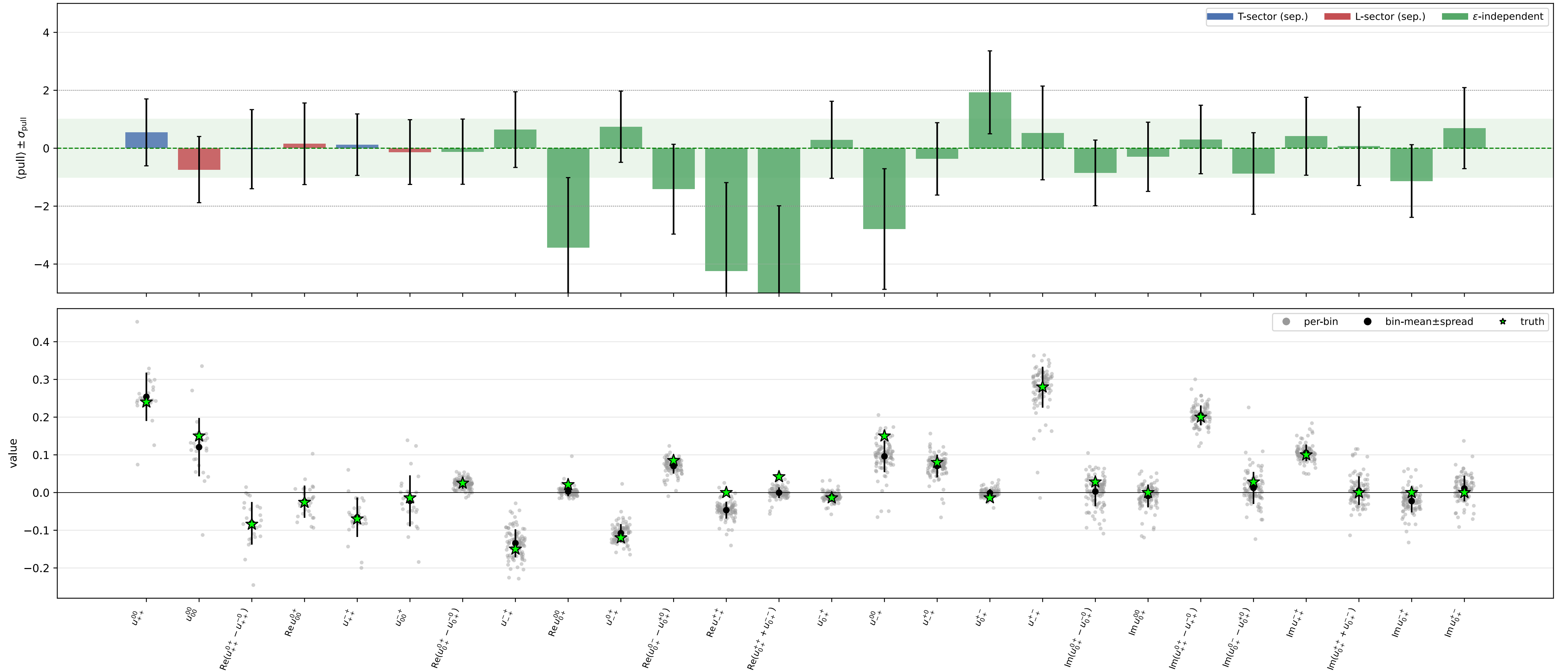
Path-1 (normalised) — GENUINE 23 Schilling-Wolf r^α pull summary (native fit params vs SW truth from injected u 's; 99 bin-fits/param)



L-T separation in each (Q^2, t): Diehl's notation

- L-T separated in each kinematics bin, extracted intercepts and slopes for $\langle \epsilon \rangle$

Path-1 (normalised) — full L/T-SEPARATED pull summary, all 23 SDMEs (Diehl notation; the 3 $\alpha = 04$ combos split into 6 T/L parts)



Diehl's unnormalized SDME and Rosenbluth Separation

- A generic cross-section depends on both SDMEs and the σ_L and σ_T

$$\left[\sigma_T(Q^2, x_B, t) + \epsilon \sigma_L(Q^2, x_B, t) \right] W(SDME(Q^2, x_B, t), \cos \theta, \Phi, \phi)$$

- We can absorb the σ_L and σ_T into the normalization of the W distribution

$$W_{\text{unnorm}}(\Omega; \varepsilon) = (\sigma_T + \varepsilon \sigma_L) W_{\text{SW}}(\Omega; \{r_{ij}^\alpha\}, \varepsilon), \quad \int W_{\text{unnorm}} d\Omega = \sigma_T + \varepsilon \sigma_L.$$

- Advantage is we don't need separate modeled functions for σ_L and σ_T but calculate from the form of Helicity amplitude/SDMEs
- Here: Each (Q^2 , t') bin is fit with the 28 unnormalized $u^{\{vv'\}}_{\{\mu\mu'\}}$, including the trace parameters that carry the cross sections:
- $\sigma_T = 2u_{++}^{++} + u_{++}^{00}$, $\sigma_L = 2u_{00}^{++} + u_{00}^{00}$. The fit loads 28 free parameters, but they sit on 25 independent physical degrees of freedom
- Three are tied by the natural-parity / symmetry relations Diehl uses (e.g. $u^{+- - -} = u^{++ ++}$). So eventually only independent dof: 25 (unnormalized) vs 23 (normalized)
- The 2 extra independent dof (25 vs 23) are exactly the absolute L/T scale that SW throws away — carried by $u^{++ ++}/u^{+00}$ and the L-partners. No assumption of the **SCHC** —> **try functions (Q^2 , t , W)**

BruFit based maximum likelihood fit

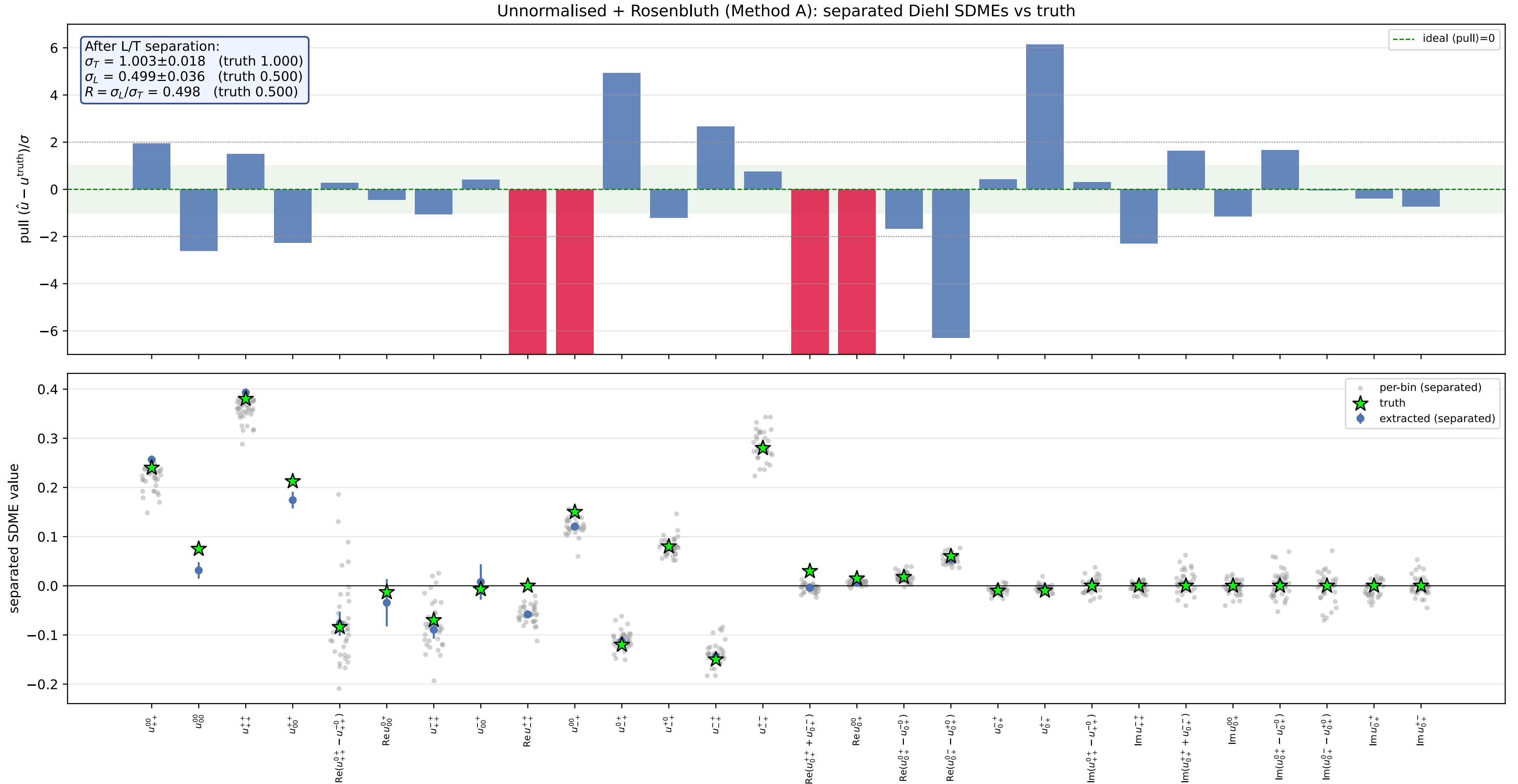
- Per bin, the extended negative log-likelihood over the $\Omega = (\cos \theta, \phi, \Phi)$ (and the per-event ε) is

$$-\ln \mathcal{L} = - \sum_{i=1}^{N_{\text{obs}}} \ln \frac{W_{\text{unnorm}}(\Omega_i; \varepsilon_i)}{N_{\text{pred}}} + (N_{\text{pred}} - N_{\text{obs}} \ln N_{\text{pred}}), \quad N_{\text{pred}} = K_{\text{lumi}} \int W_{\text{unnorm}} \eta(\Omega) d\Omega,$$

- Where the second bracket being the Poisson (extended) term. The normalization integral is evaluated by Monte Carlo over the high-statistics FlatMC sample
- $\Omega_i = (\cos \theta, \varphi, \Phi)_i$ — the three decay angles of event i
- ε_i the per-event virtual-photon polarization, a fixed number carried by each event (not a parameter). It tells W how much longitudinal photon flux that event had.
- $W_{\text{unnorm}}(\Omega_i; \varepsilon_i)$ — the model intensity (the Diehl angular function built from the 28 u's). "Unnorm" = it is not rescaled to integrate to 1; its overall size carries σ_T, σ_L .
- N_{pred} the model's predicted event count in the bin.
- K_{lumi} — the per-bin luminosity factor required to convert cross-section to event-counts (required for the Generator)

Extracted parameters after Rosenbluth separation

- Only Diehl's notation here

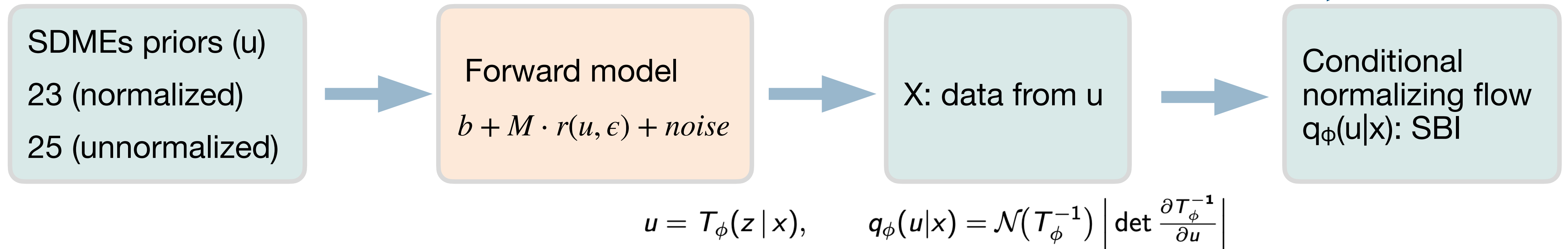


Neural Posterior Estimation (NPE)

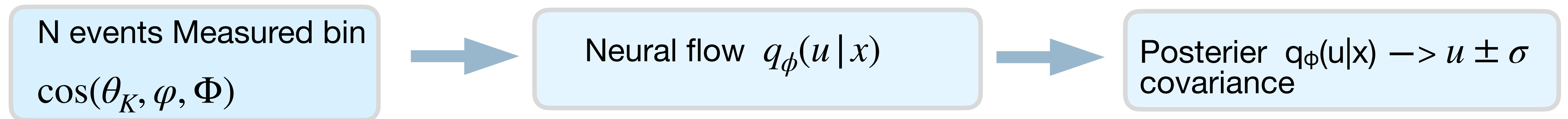
- Train a neural network on simulated (SDME $\rightarrow$ data) pairs to learn the inverse
- Given observed data, NPE returns the posterior over SDMEs — with calibrated uncertainties, no per-fit likelihood maximization

Train ϕ by maximizing $\sum_i \log q_\phi(u_i | x_i)$.

- Training stage

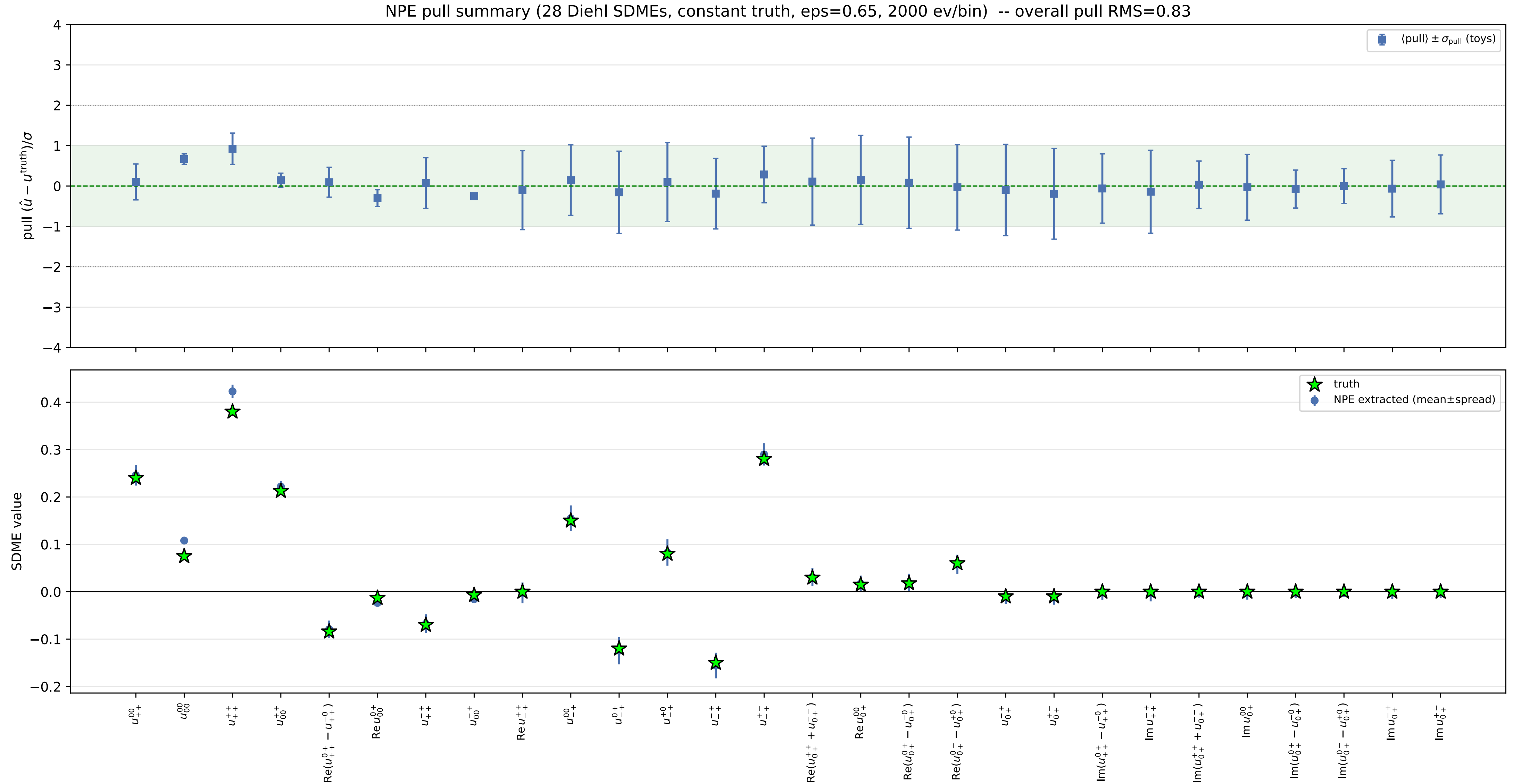


- Inference stage



- For event-level-extraction: unbinned data, the SDME function $u_\theta(Q^2, t')$, likelihood-based NN fit

Extraction (sim only)

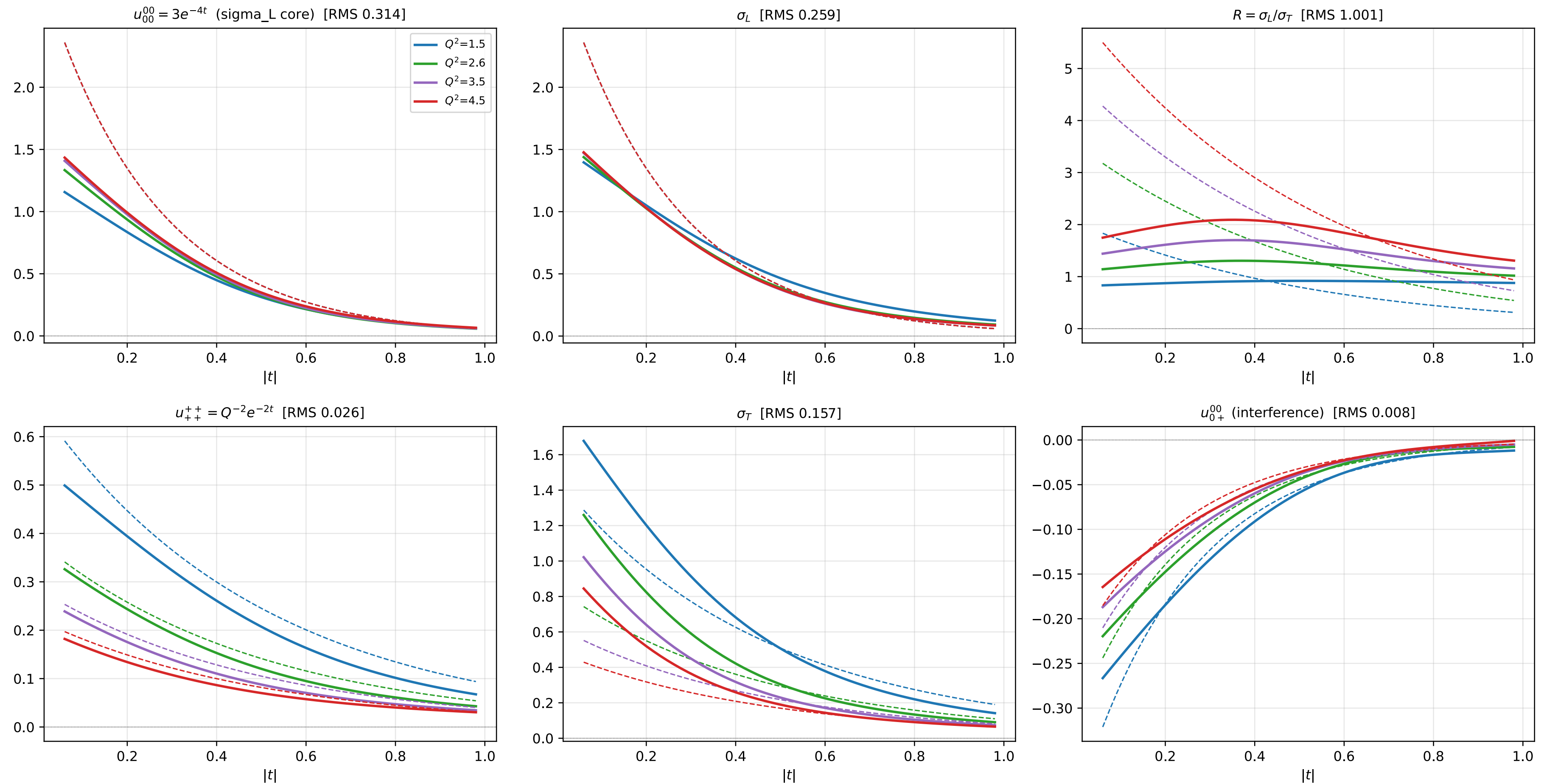


Event by event extractions

- Kinematics dependencies, event-by-event extraction, **with stress functions given by Harut**

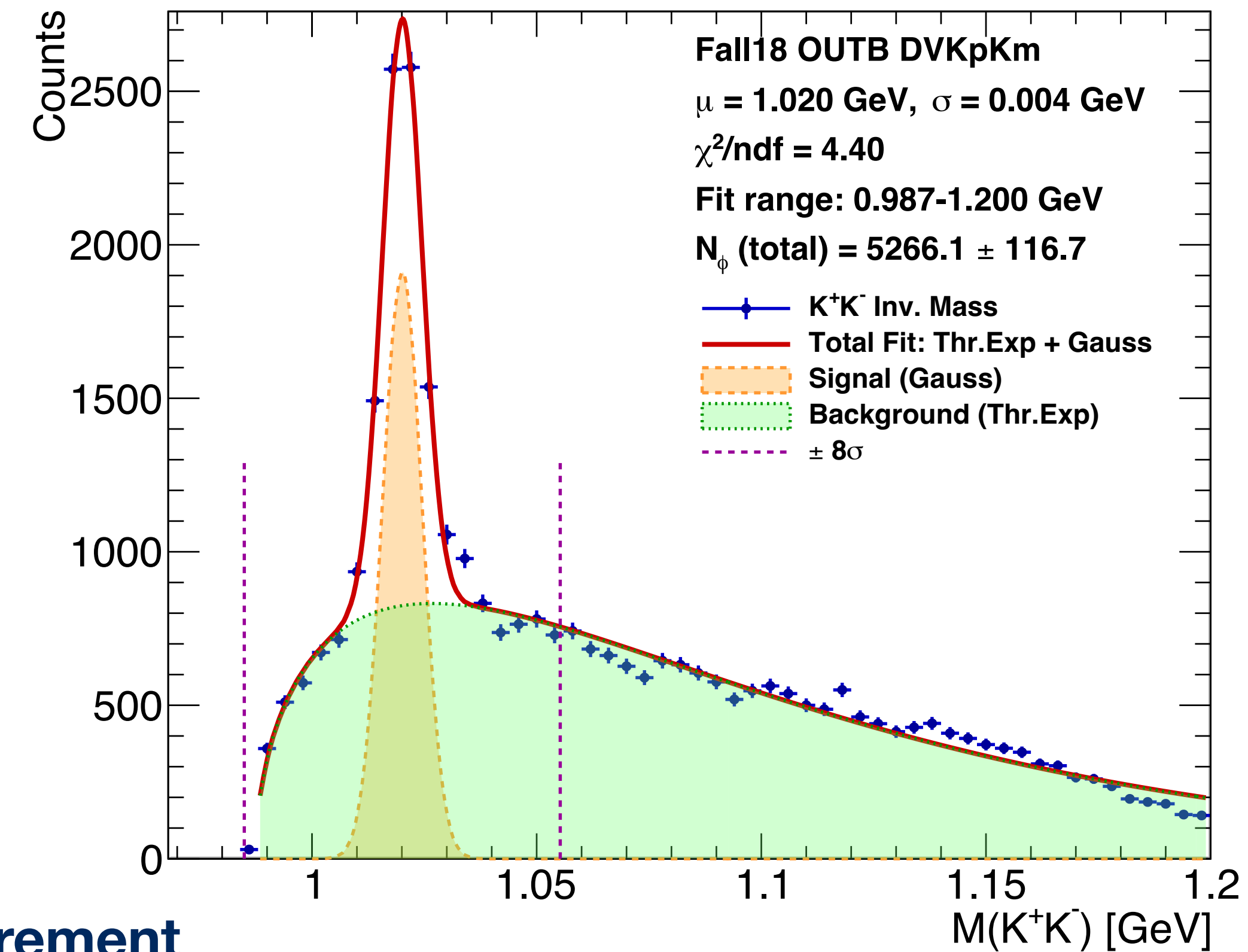
$$u_{00}^{00} = 3e^{-4t}, \quad u_{++}^{++} = Q^{-2}e^{-2t}, \quad u_{0+}^{00} = -0.5Q^{-1}e^{-4t}, \quad u_{++}^{00} = 0.2Q^{-2}e^{-4t},$$

EVENT-LEVEL fit on harut2 truth (large sigma_L): extracted (solid) vs truth (dashed). Per-bin MCMC gave sigma_L 1.9 → 0.36; does the rate term hold it up?



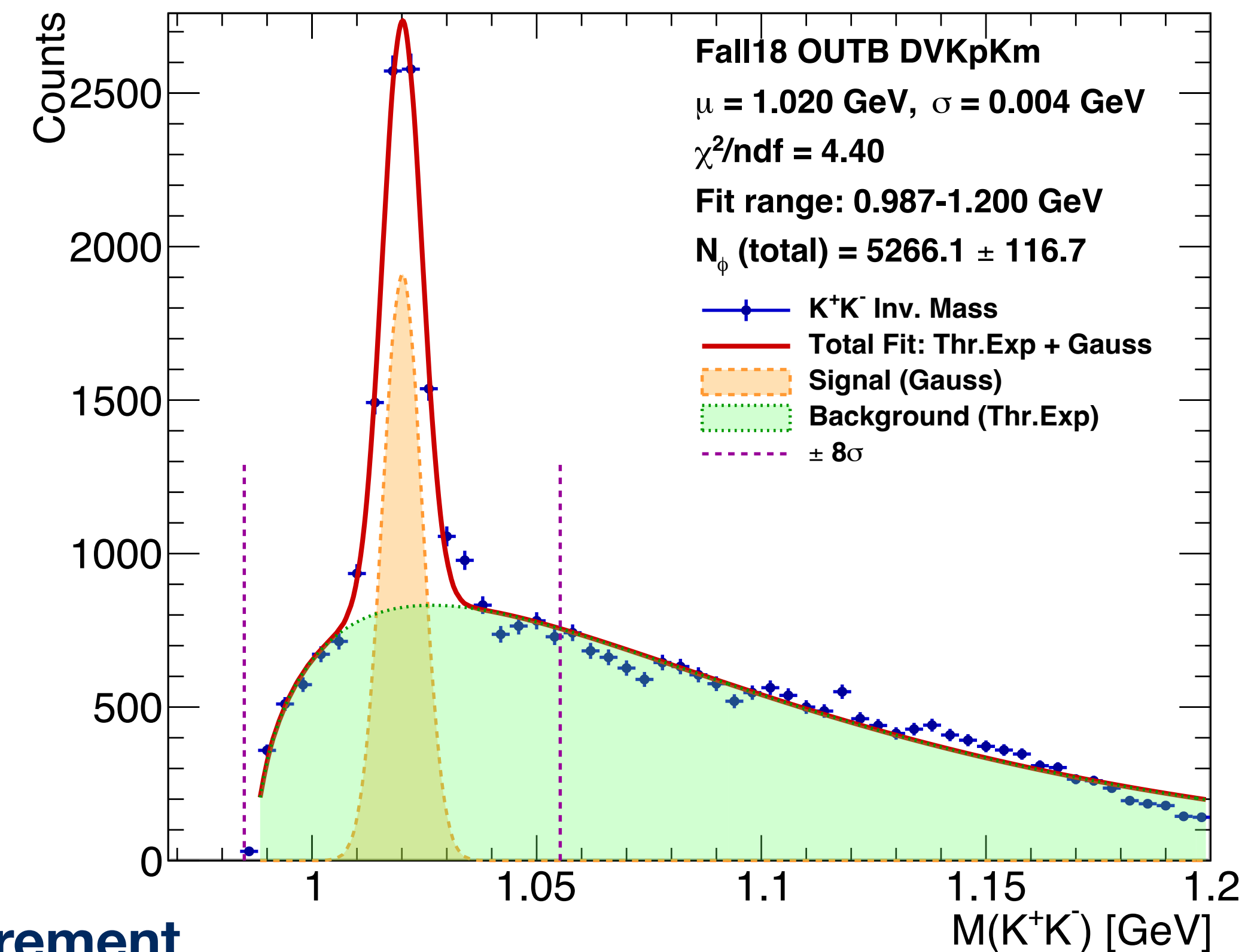
Summary

- So far
 - First look at the exclusive ϕ meson production combining all data set from RGA 10.6-10.2 GeV
 - Established missing mass analysis to enhance the statistics
- Next steps
 - Development of realistic **event generator with SDMEs**
 - Systematics on **acceptance** and efficiency corrections!
 - **More** data from different energies at **6.4, 6.5, 7.5, 8.4 GeV!**
- We need
 - **Theoretical calculations for better interpretation the measurement**



Summary

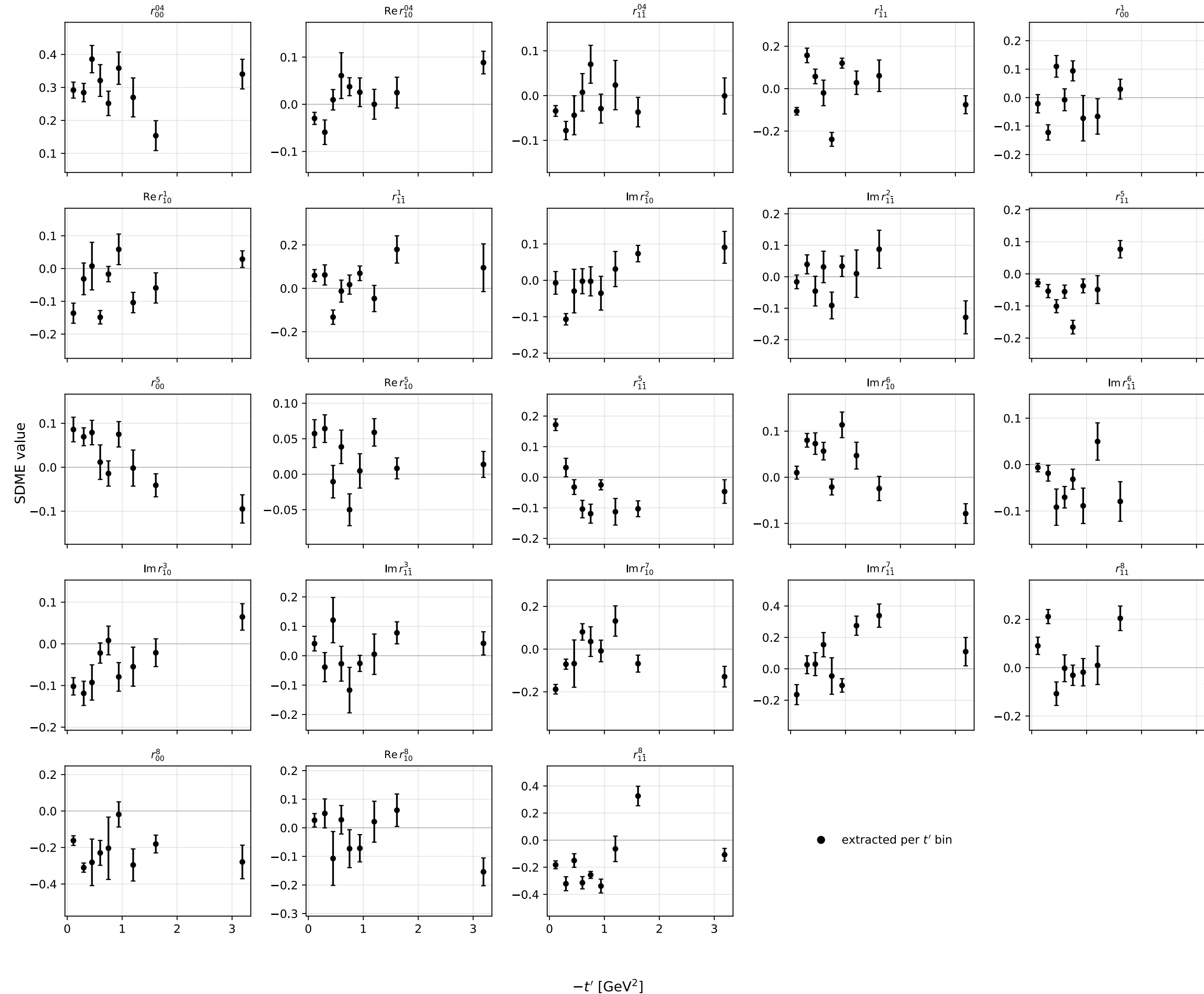
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Thank you for your attention!

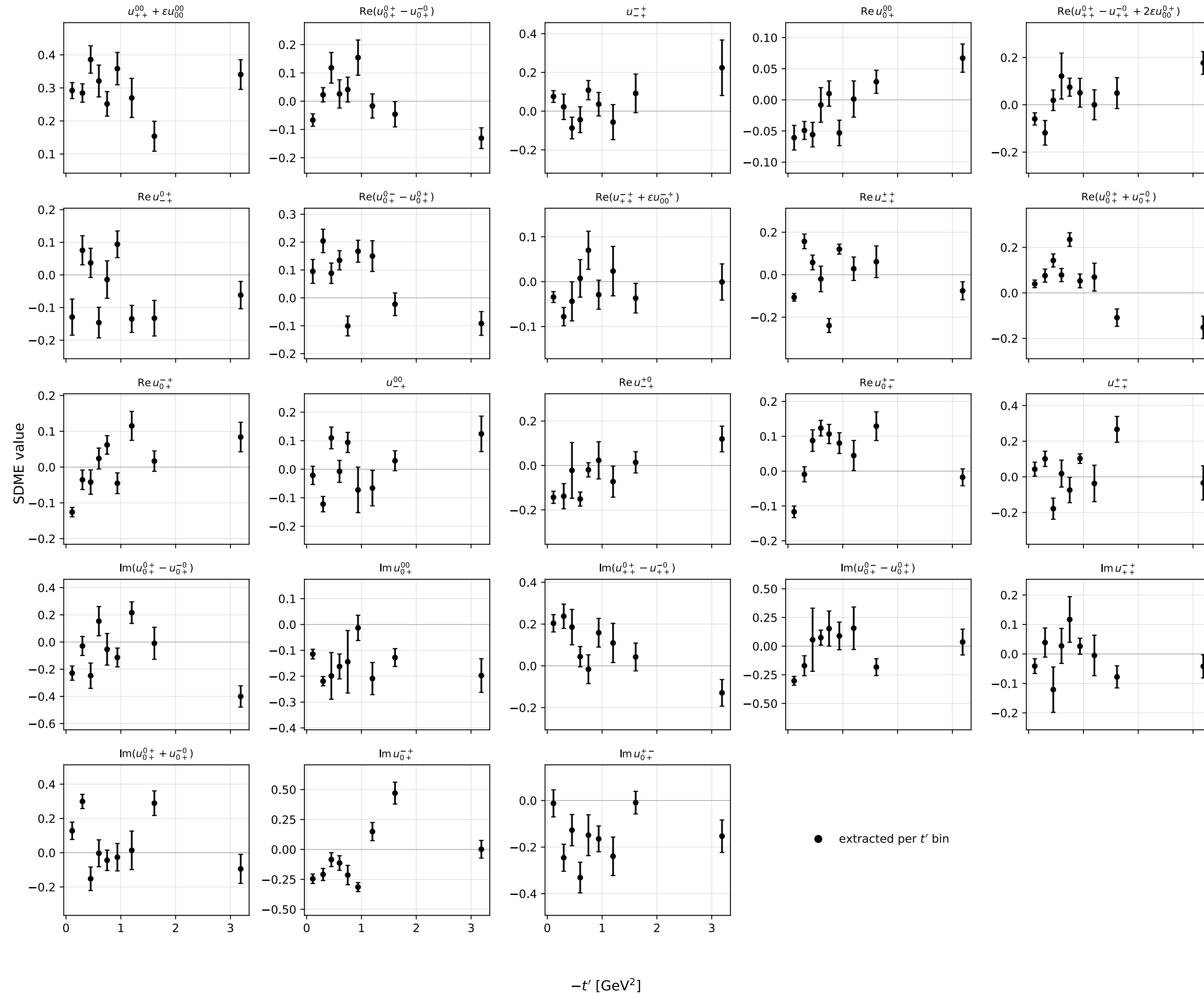
Spring 2019 inb (S+W's approach: CLAS12 data)

Data per- t' extraction (Schilling--Wolf, sp19 inb): $Q_{\text{cen}}^2 = 1.13 \text{ GeV}^2$



Spring 2019 inb (Diehl's approach: CLAS12 data): first look

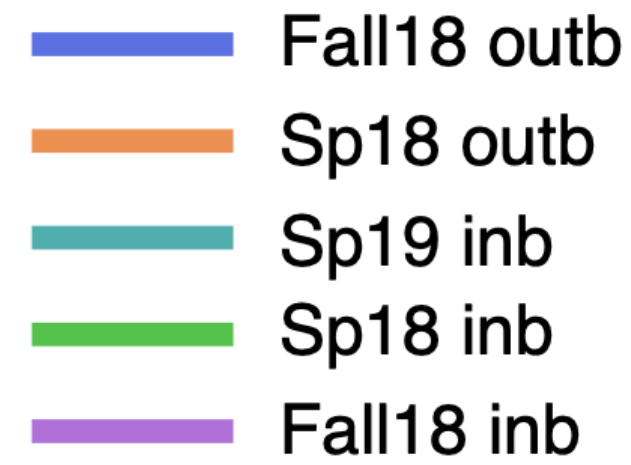
Data per- t' extraction (Diehl, sp19 inb): $Q_{\text{cen}}^2 = 1.13 \text{ GeV}^2$



Particle Kinematics (exclusive reaction) for RGA

- **Datasets** from Run group A (10.6 & 10.2 GeV beam)
- Torus -1 (inbending) Spring & Fall 2018, and Spring 2019

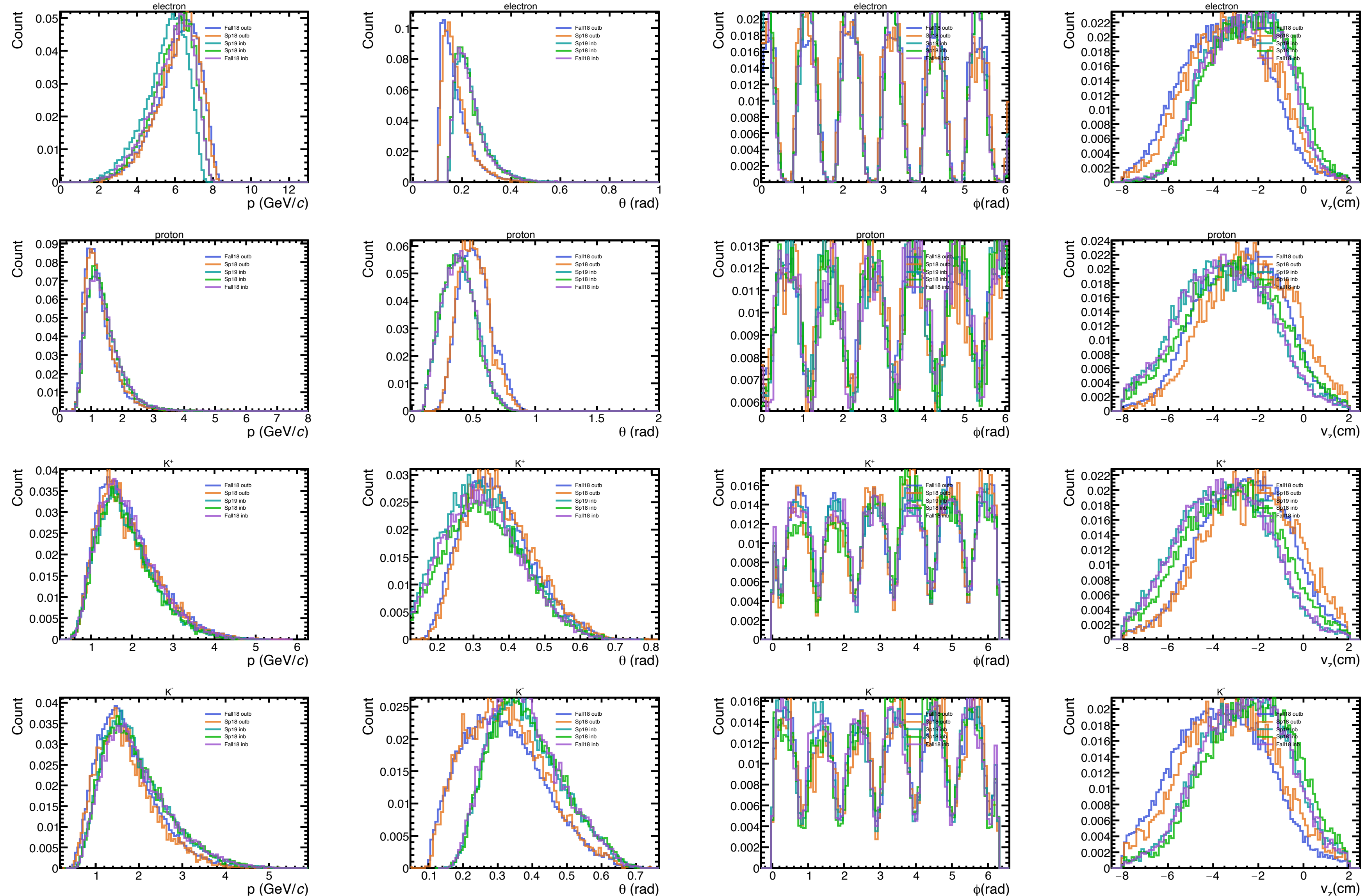
- Torus+1 (outbending) Spring & Fall 2018



- Minimum cuts

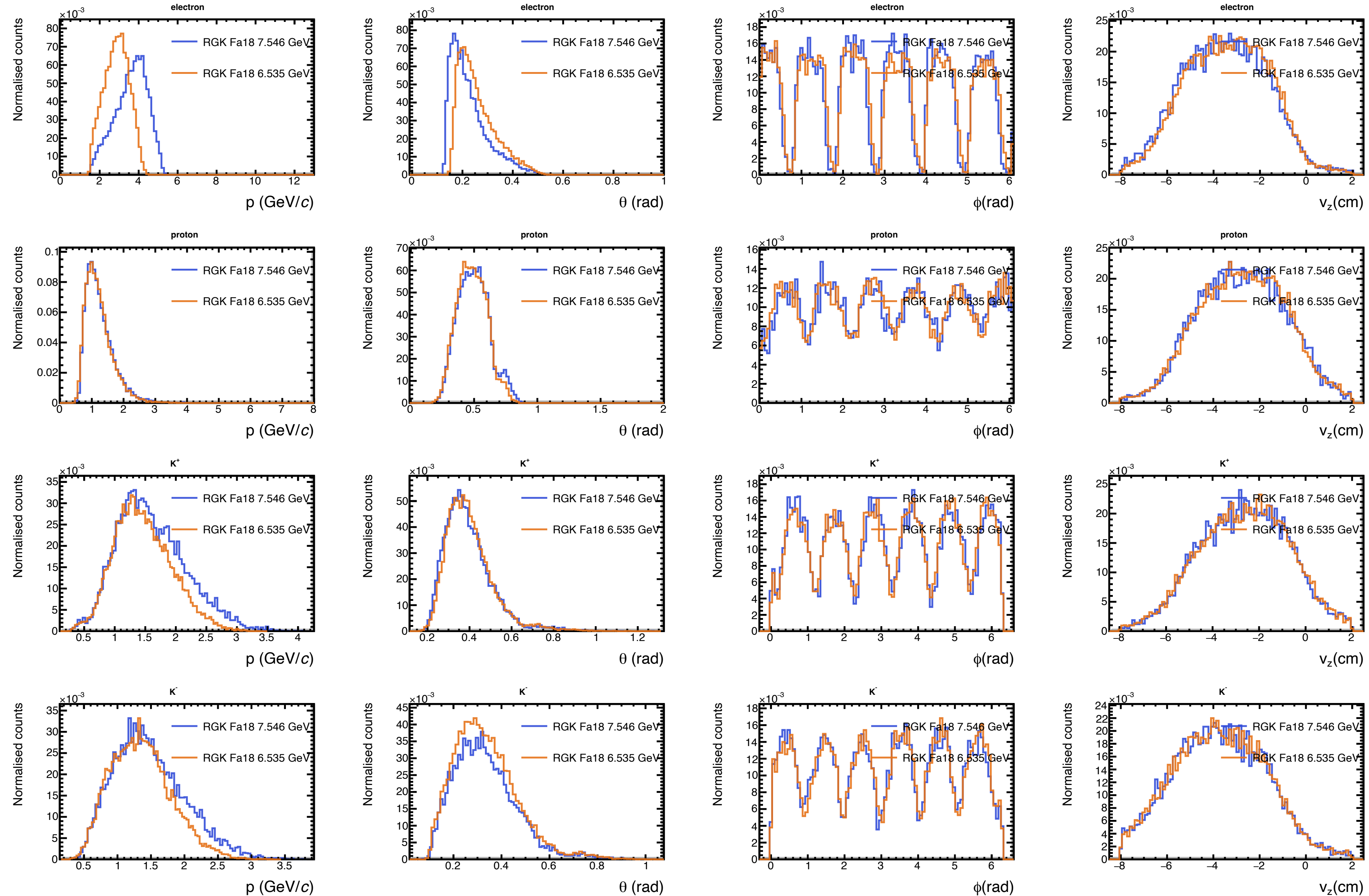
$p_e > 1.5$ GeV in FD
 $p_p > .4$ GeV in FD and CD

$0.2 < p_K < 7.5$ GeV in FD
 Vertex for all particles
 $-8\text{cm} < v_z < 2\text{ cm}$

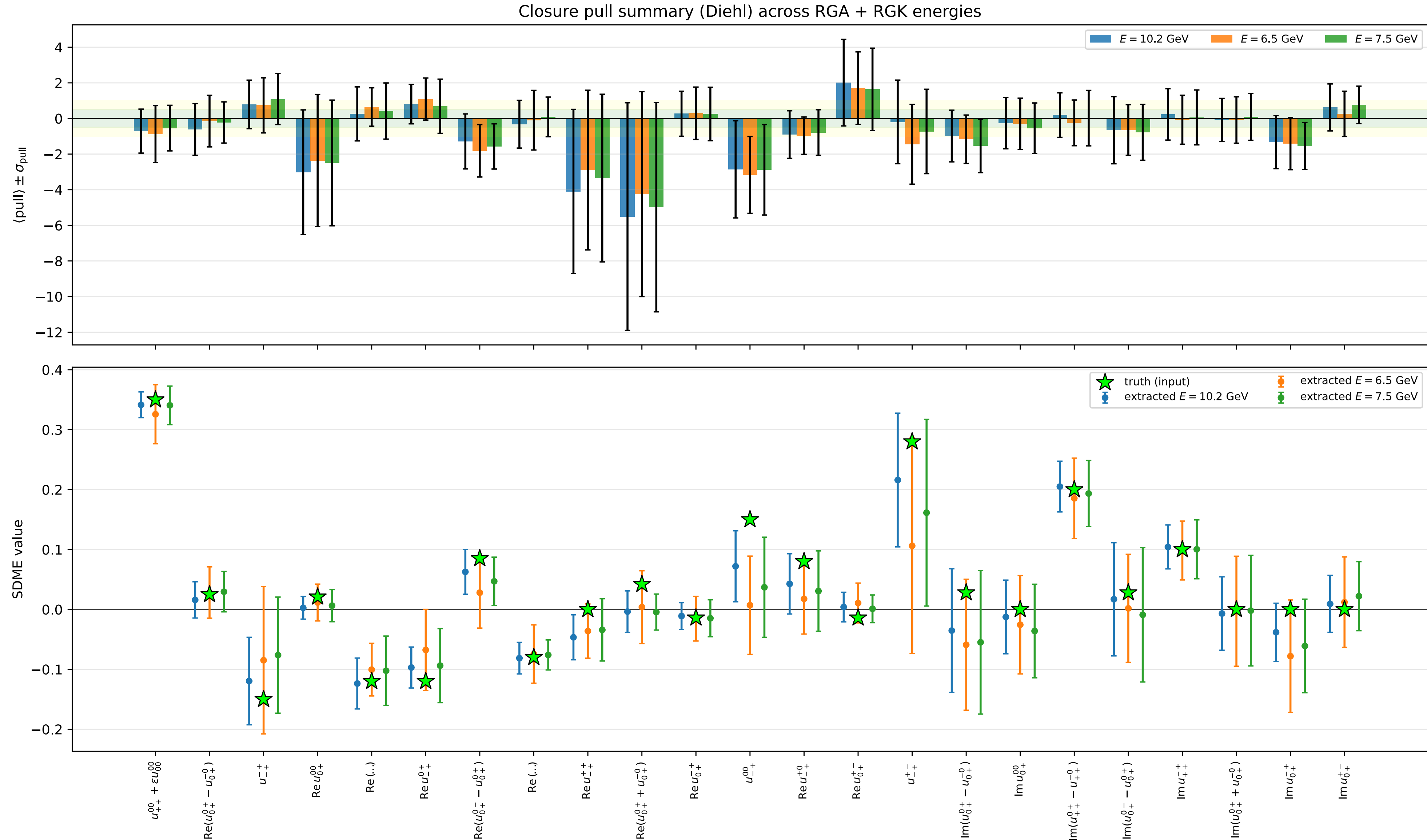


Particle Kinematics (exclusive reaction) for RGK

- Fall 2018 6.5 and 7.5 GeV
- Electron momentum is differs from each other
- Possible smaller theta contributions in the 7.5 GeV data more Forward contributions

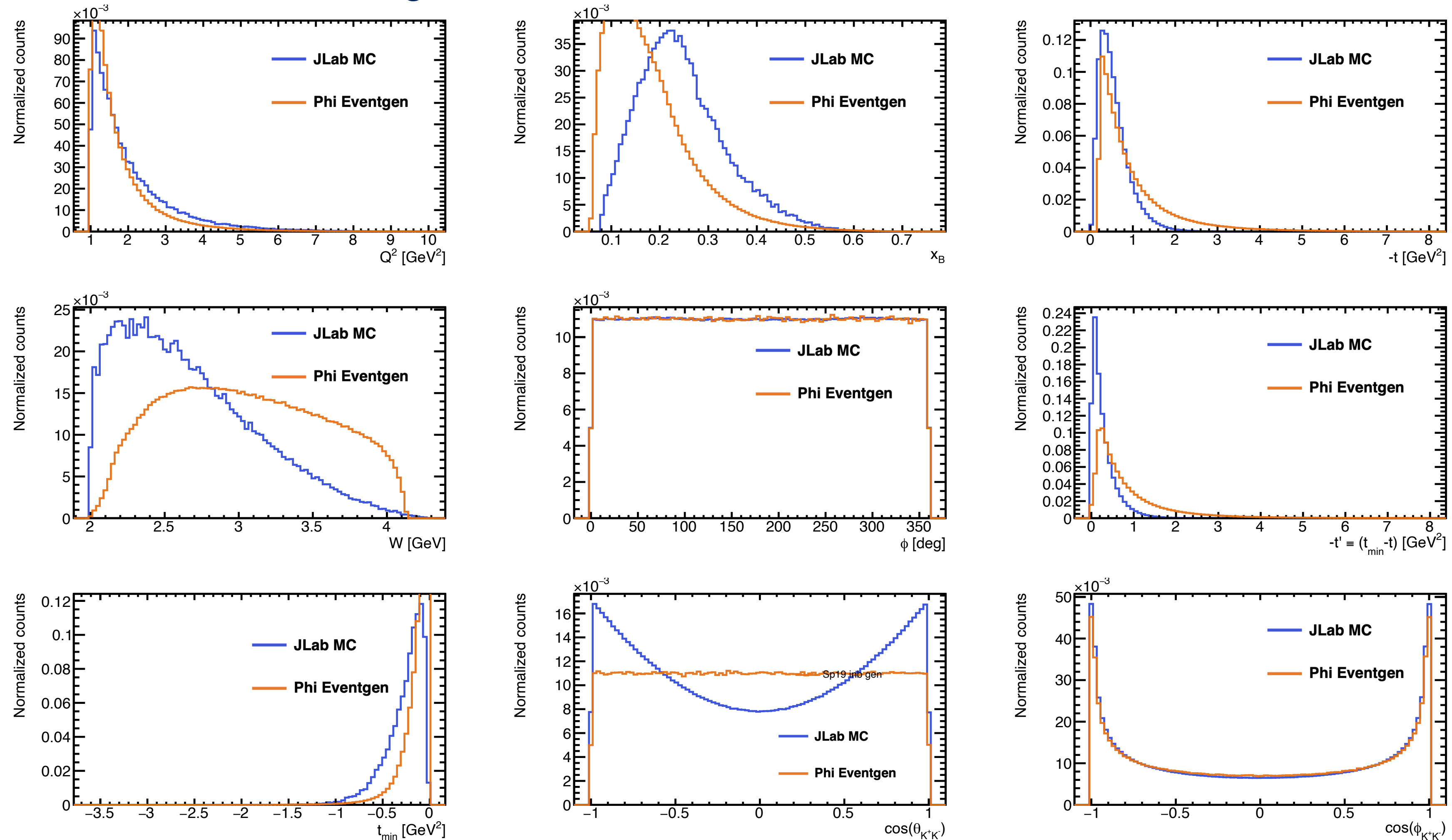


More energies



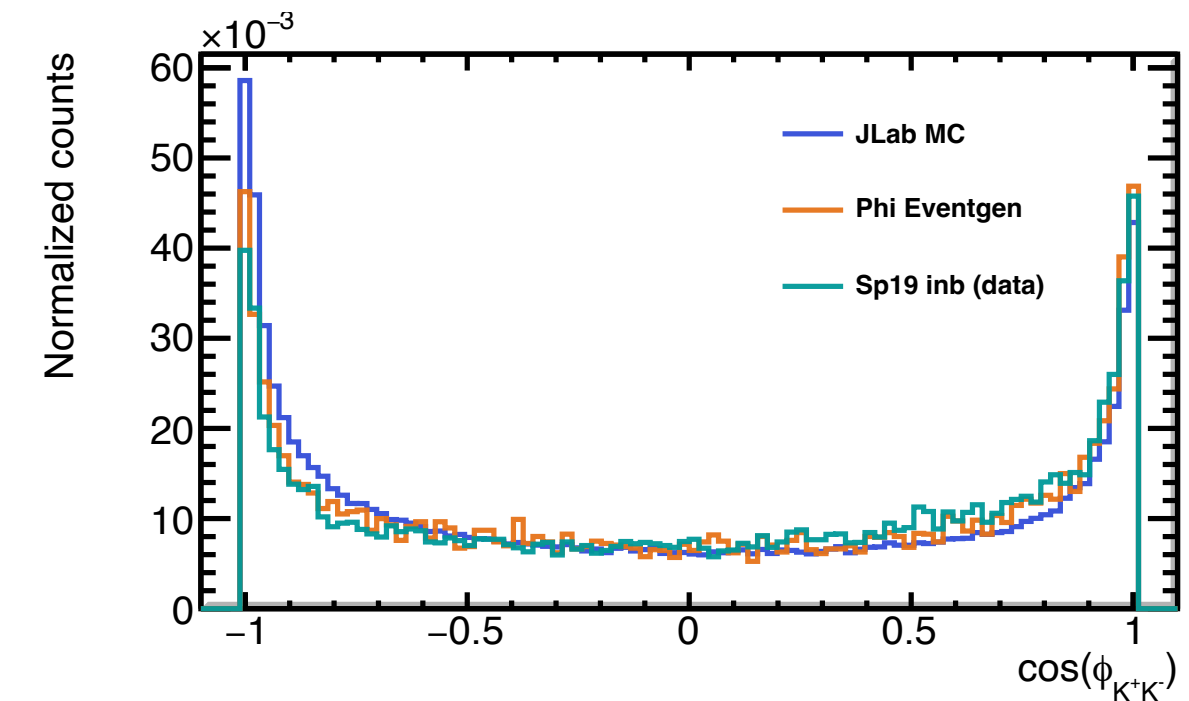
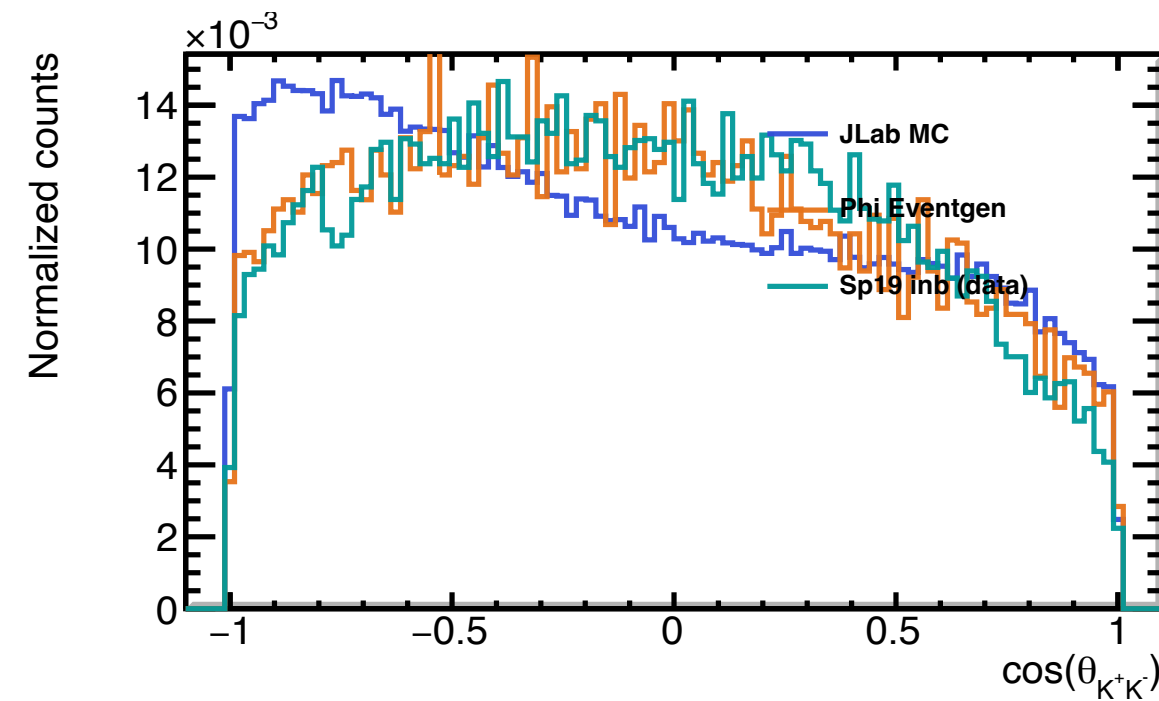
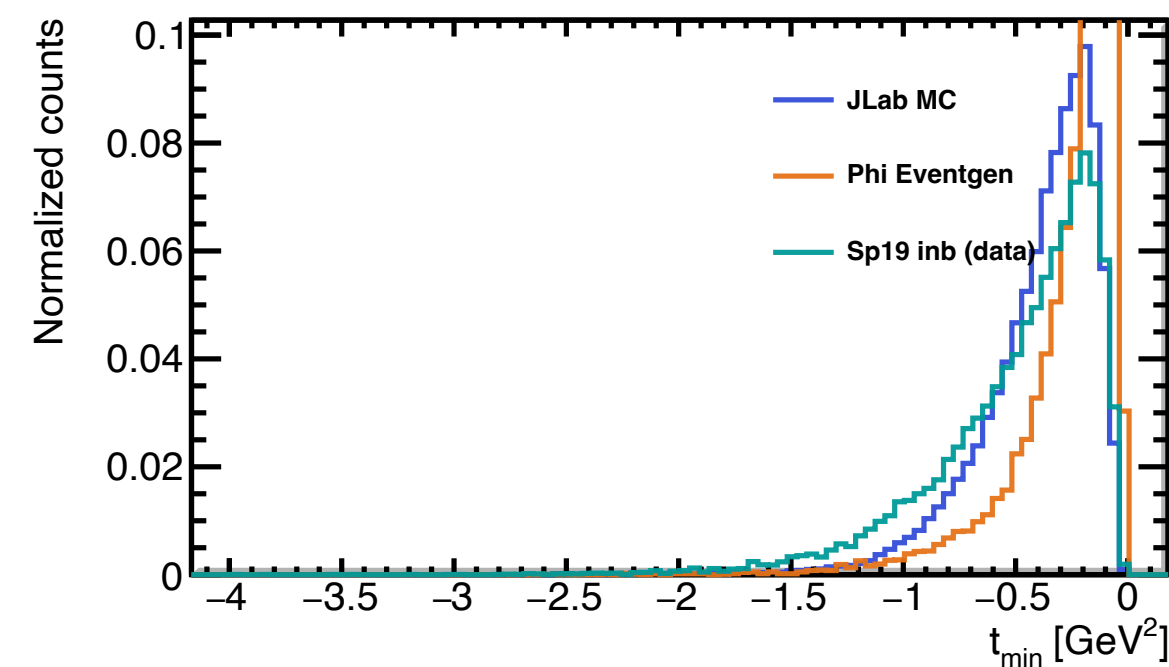
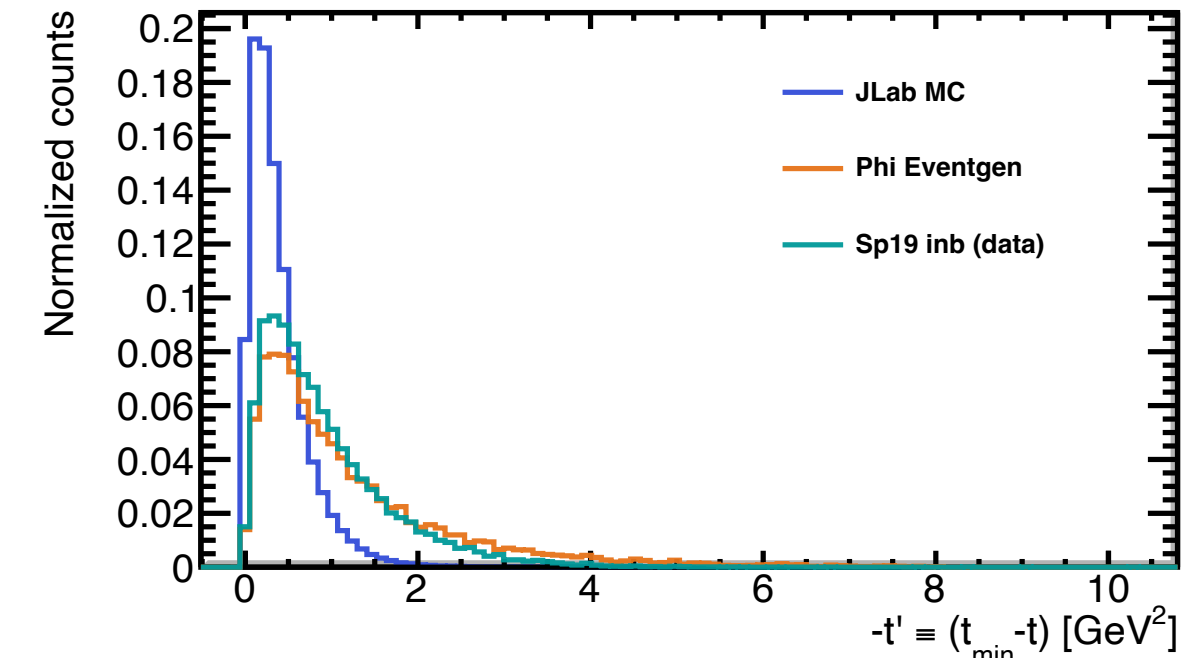
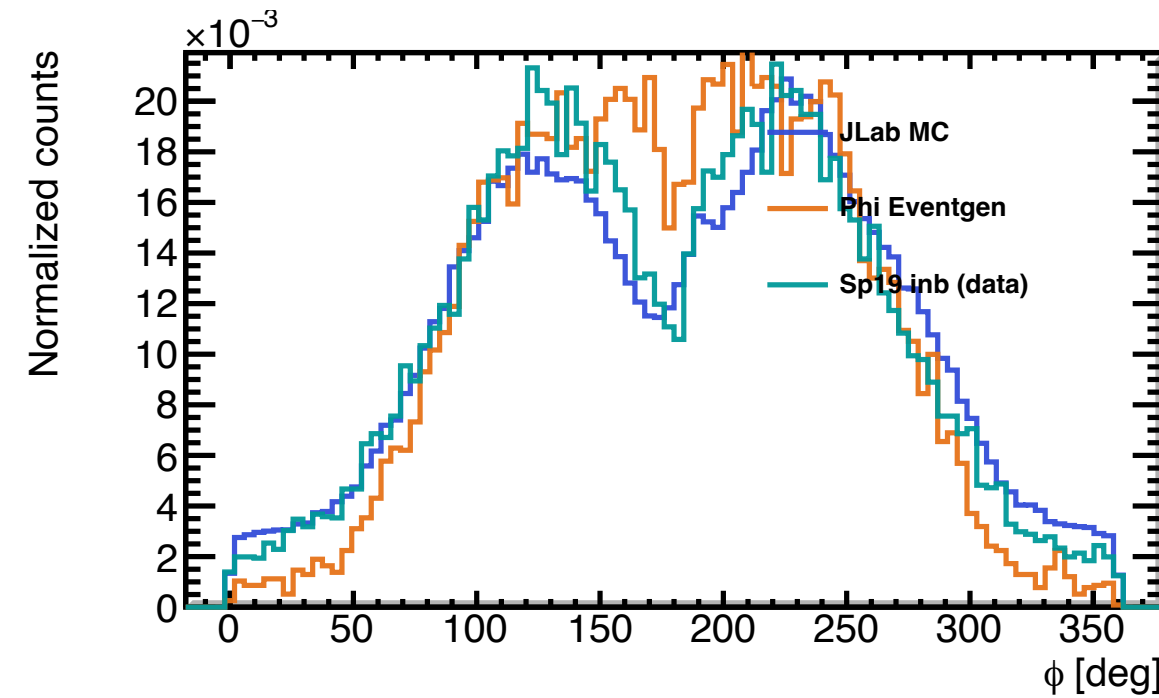
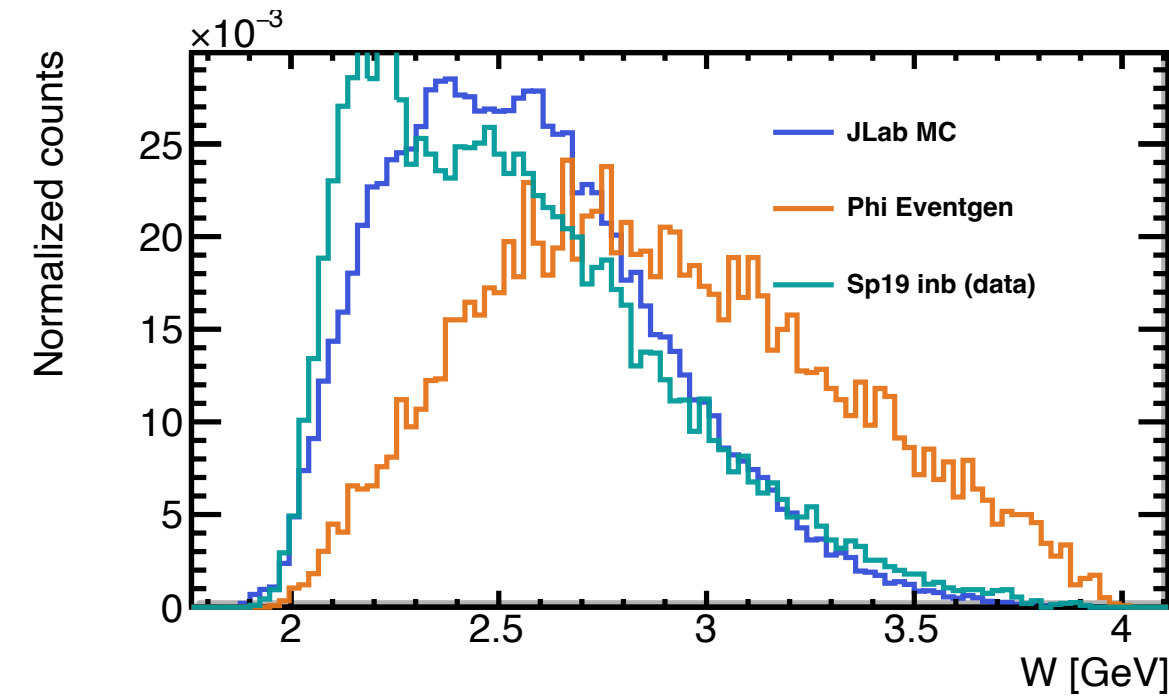
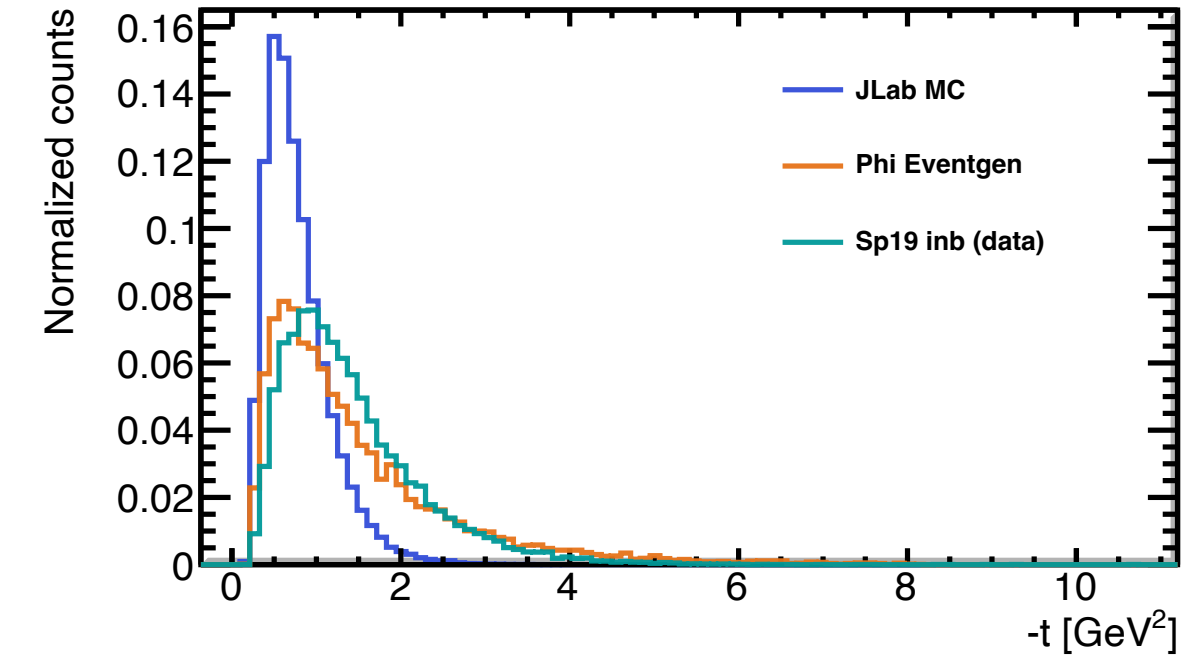
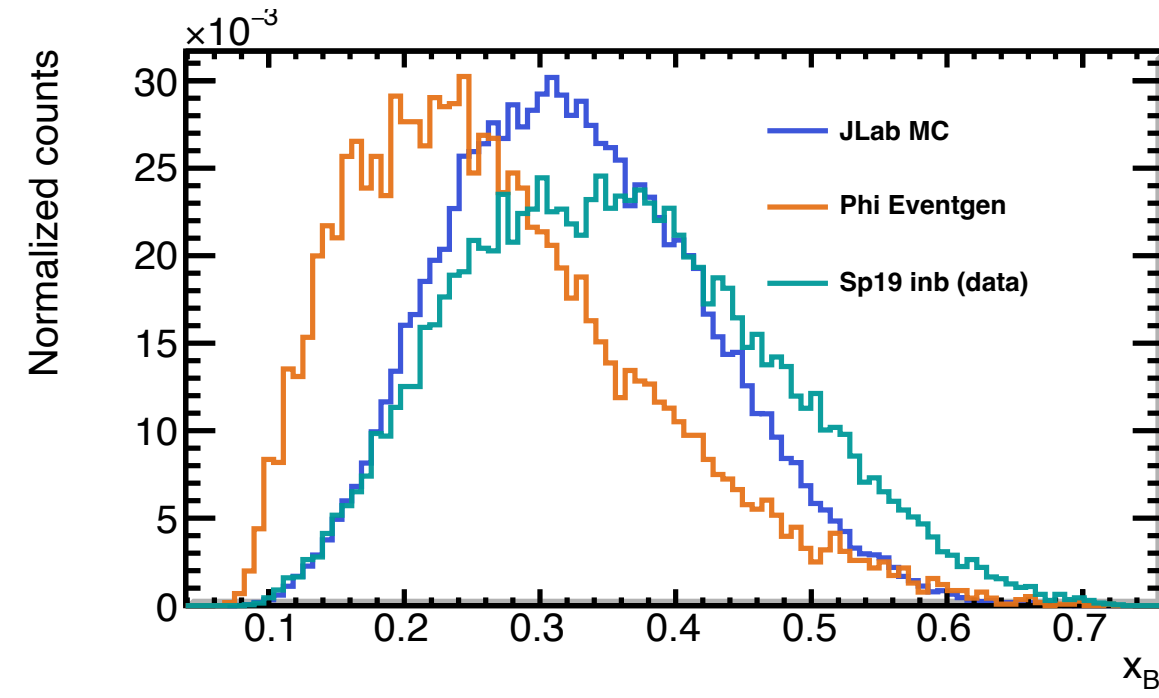
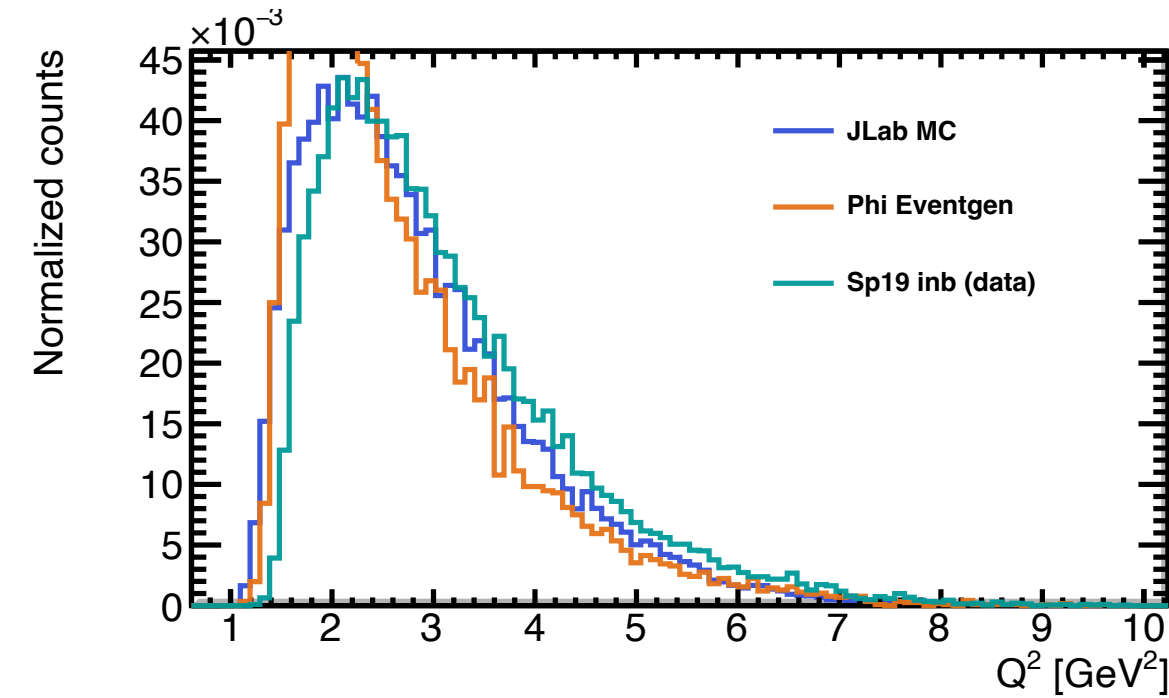
MC can change things drastically (Gen only)

- Two generator **Argonne group** and **JLab vector meson event generator (JLab MC)** with ρ^0 like decay
- In house **JLab MC** has enhanced longitudinal contribution in the cross-section

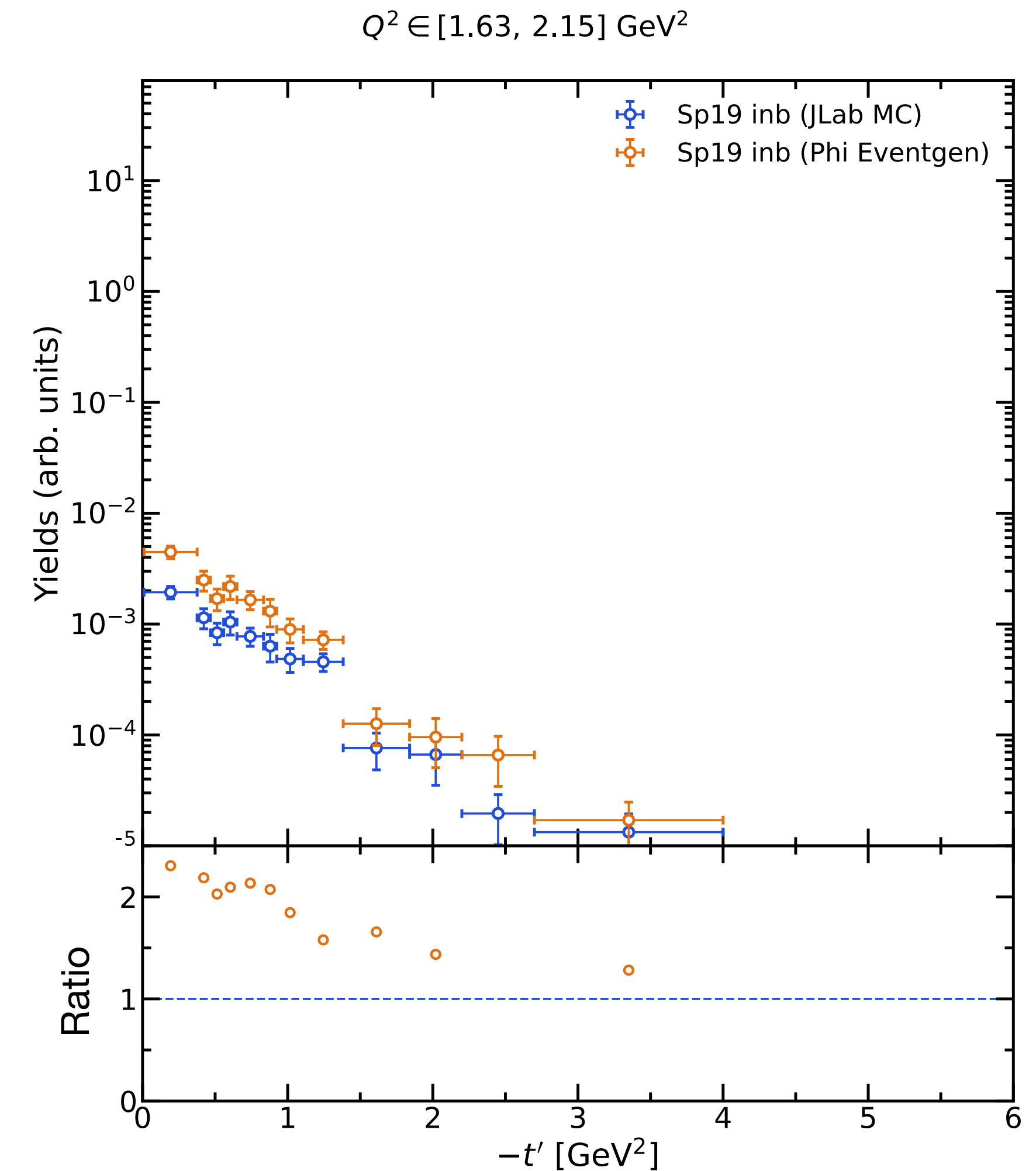
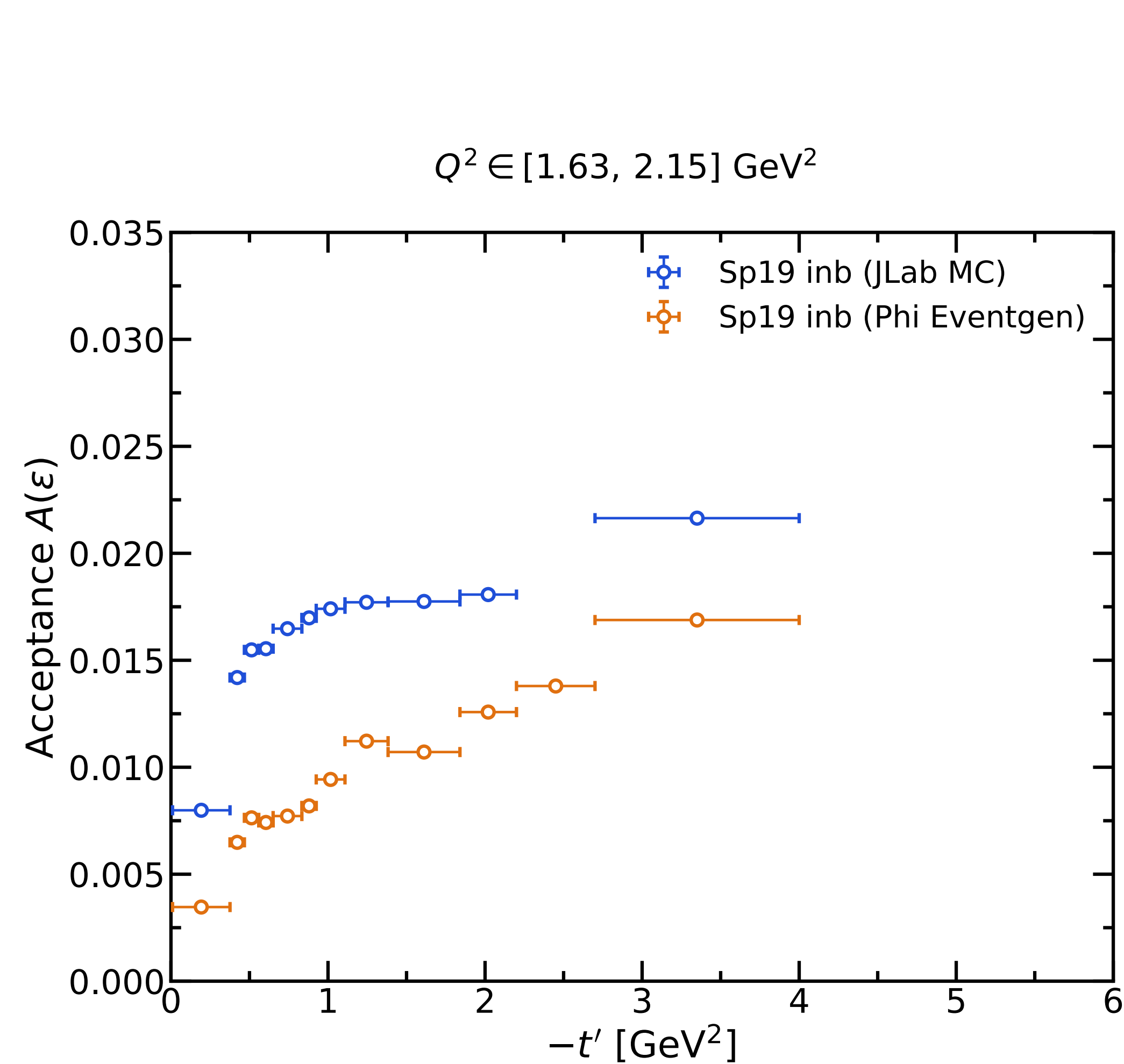


MC can change things drastically (Reconstruction GEMC)

- While the reconstructed events have similar decay angle from both MC



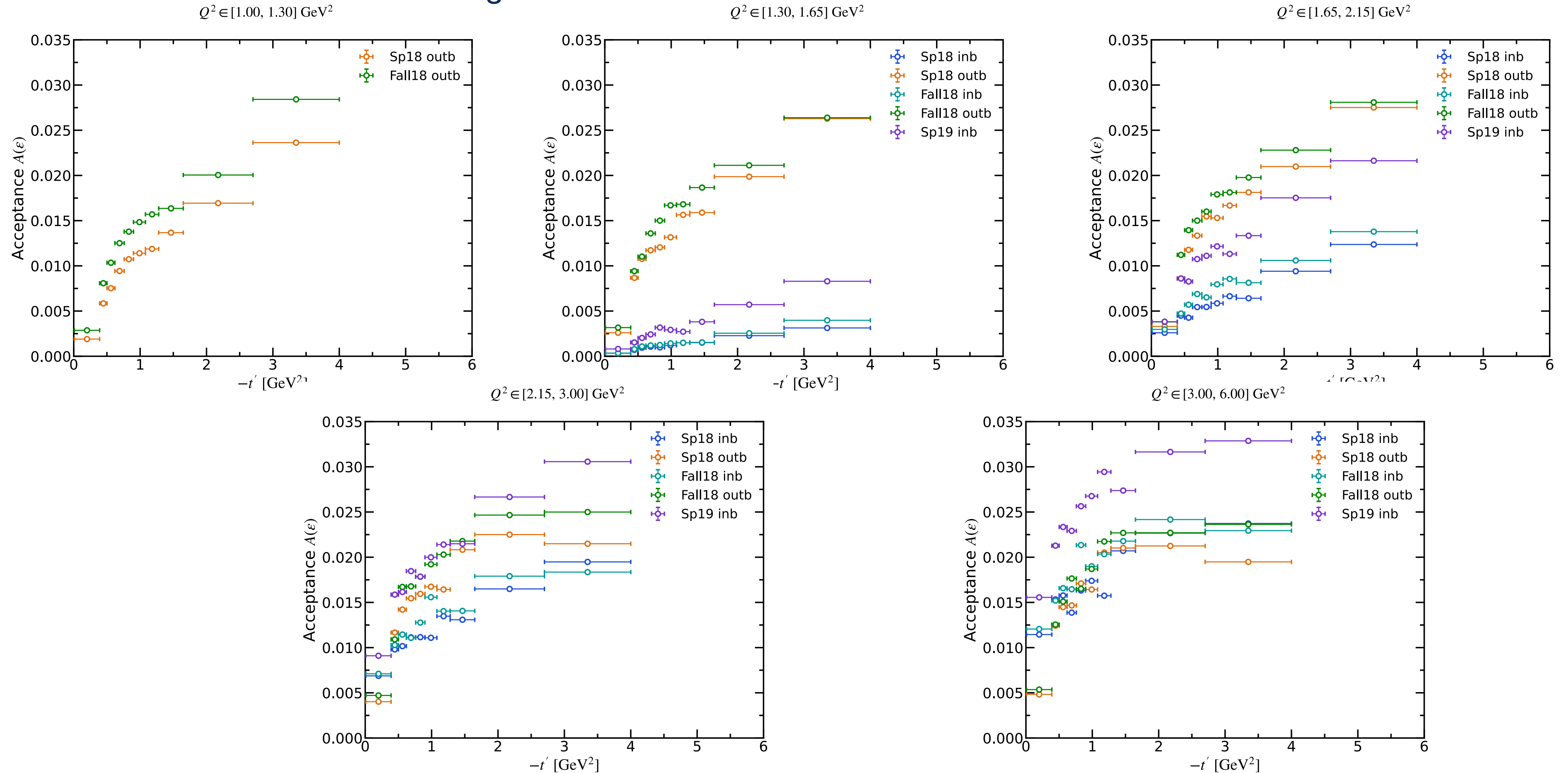
Impact on the acceptance



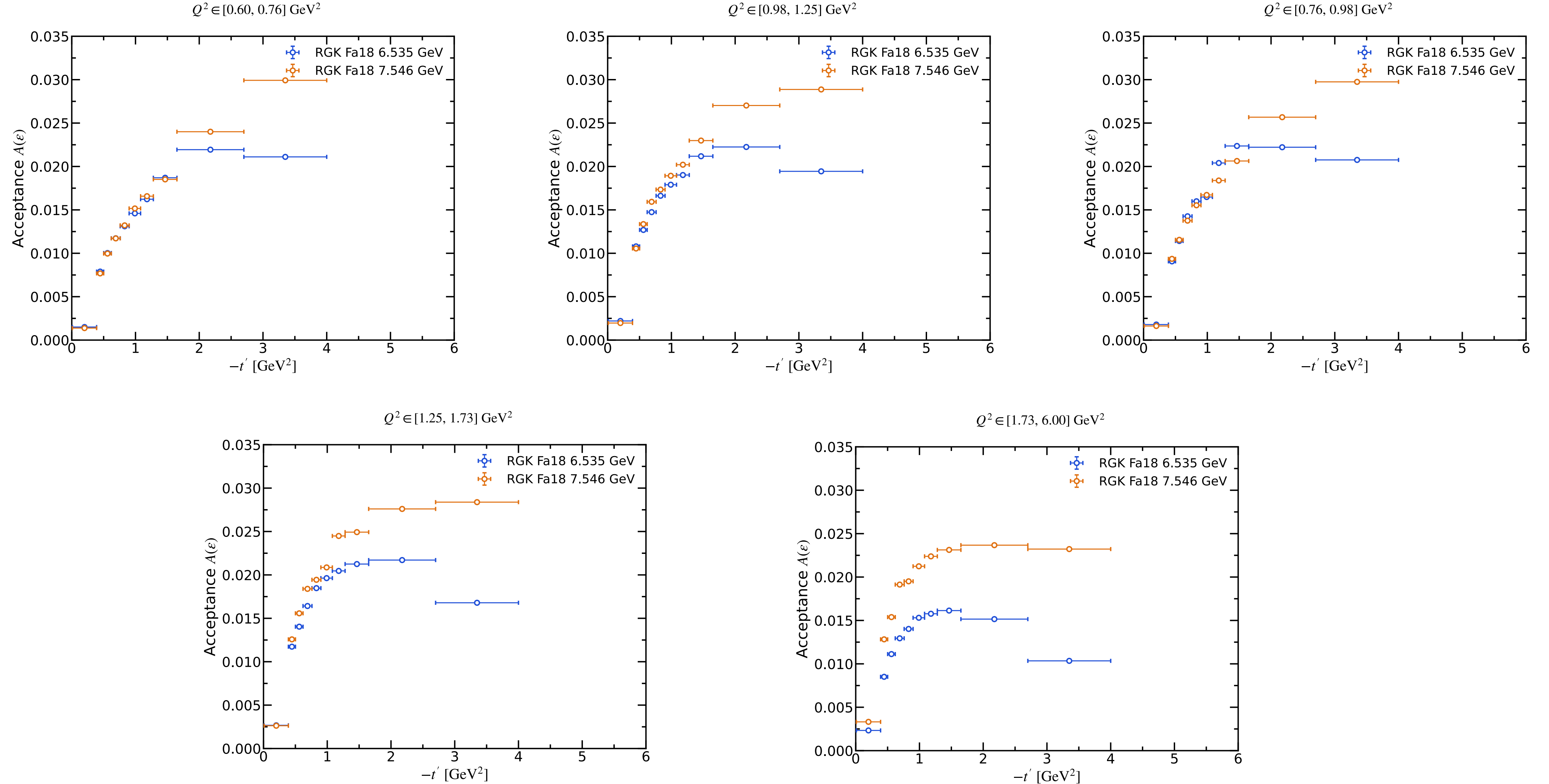
The appropriate SDMEs in the generator is crucial for acceptance corrections for low statistics analysis!

Detector acceptance effects RGA

- **Without** the efficiency for background merging corrections!



RGK Efficiency corrections: acceptance using Argonne Gen



SW ↔ Diehl's approach

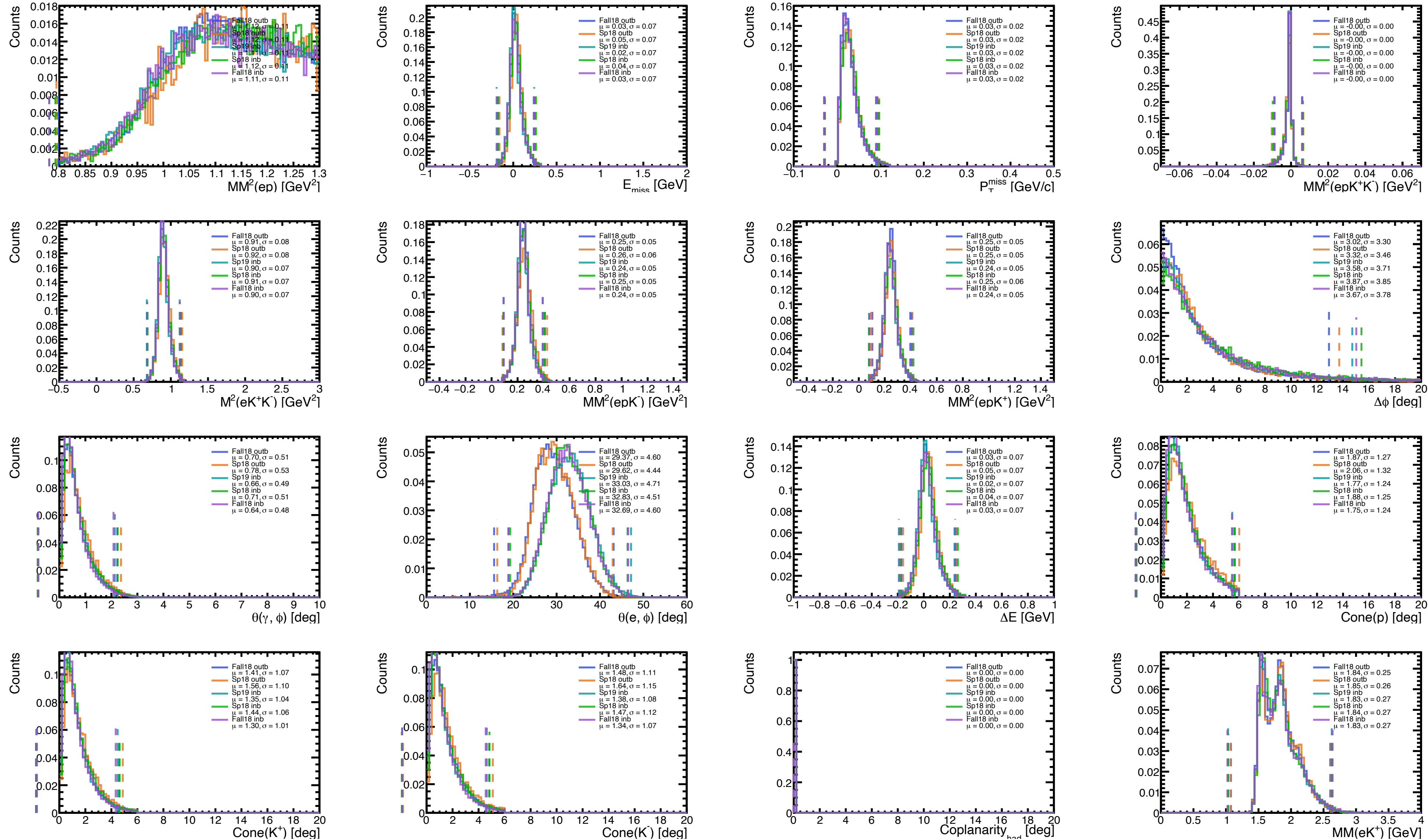
- A generic cross-section depends on both SDMEs and the σ_L and σ_T

Diehl LHS combination	= Schilling–Wolf RHS
<i>From eq. (4.20): W_{UU}, real</i>	
$u_{++}^{00} + \varepsilon u_{00}^{00}$	$= r_{00}^{04}$
$\text{Re}(u_{0+}^{0+} - u_{0+}^{-0})$	$= \sqrt{2} (\text{Im } r_{10}^6 - \text{Re } r_{10}^5)$
u_{-+}^{-+}	$= r_{1,-1}^1 - \text{Im } r_{1,-1}^2$
$\text{Re } u_{0+}^{00}$	$= -r_{00}^5/\sqrt{2}$
$\text{Re}(u_{++}^{0+} - u_{++}^{-0} + 2\varepsilon u_{00}^{0+})$	$= 2 \text{Re } r_{10}^{04}$
$\text{Re } u_{-+}^{0+}$	$= \text{Re } r_{10}^1 - \text{Im } r_{10}^2$
$\text{Re}(u_{0+}^{0-} - u_{0+}^{0+})$	$= \sqrt{2} (\text{Im } r_{10}^6 + \text{Re } r_{10}^5)$
$\text{Re}(u_{++}^{-+} + \varepsilon u_{00}^{-+})$	$= r_{1,-1}^{04}$
$\text{Re } u_{-+}^{++}$	$= r_{11}^1$
$\text{Re}(u_{0+}^{0+} + u_{0+}^{-0})$	$= -\sqrt{2} r_{11}^5$
$\text{Re } u_{0+}^{-+}$	$= (\text{Im } r_{1,-1}^6 - r_{1,-1}^5)/\sqrt{2}$
u_{-+}^{00}	$= r_{00}^1$
$\text{Re } u_{-+}^{+0}$	$= \text{Re } r_{10}^1 + \text{Im } r_{10}^2$
$\text{Re } u_{0+}^{+-}$	$= -(\text{Im } r_{1,-1}^6 + r_{1,-1}^5)/\sqrt{2}$
u_{-+}^{+-}	$= r_{1,-1}^1 + \text{Im } r_{1,-1}^2$
<i>From eq. (4.21): W_{LU}, imaginary</i>	
$\text{Im}(u_{0+}^{0+} - u_{0+}^{-0})$	$= \sqrt{2} (\text{Im } r_{10}^7 + \text{Re } r_{10}^8)$
$\text{Im } u_{0+}^{00}$	$= r_{00}^8/\sqrt{2}$
$\text{Im}(u_{++}^{0+} - u_{++}^{-0})$	$= -2 \text{Im } r_{10}^3$
$\text{Im}(u_{0+}^{0-} - u_{0+}^{0+})$	$= \sqrt{2} (\text{Im } r_{10}^7 - \text{Re } r_{10}^8)$
$\text{Im } u_{-+}^{-+}$	$= -\text{Im } r_{1,-1}^3$
$\text{Im}(u_{0+}^{0+} + u_{0+}^{-0})$	$= \sqrt{2} r_{11}^8$
$\text{Im } u_{0+}^{-+}$	$= (\text{Im } r_{1,-1}^7 + r_{1,-1}^8)/\sqrt{2}$
$\text{Im } u_{0+}^{+-}$	$= -(\text{Im } r_{1,-1}^7 - r_{1,-1}^8)/\sqrt{2}$

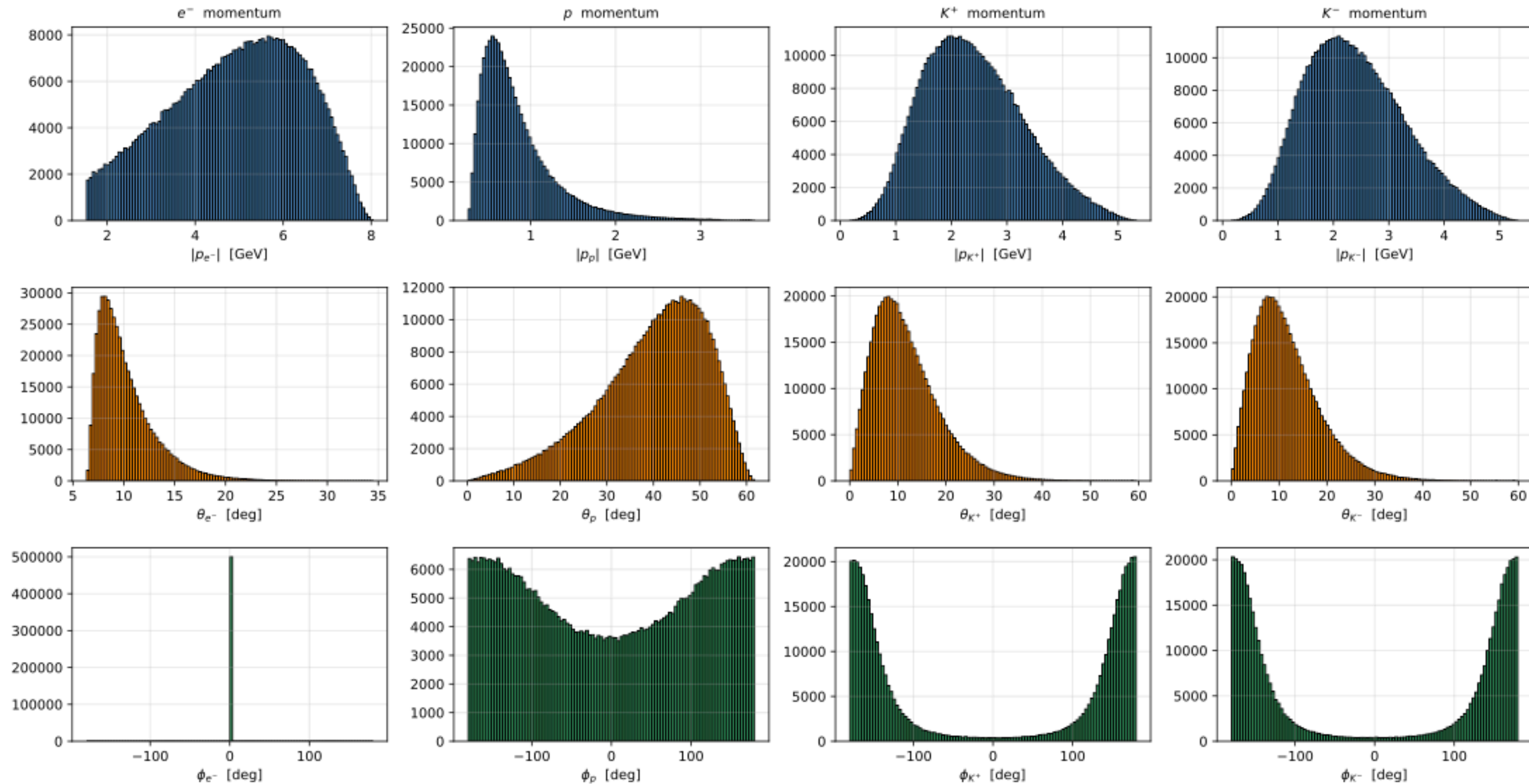
Exclusivity cuts for further refinements

- Exclusivity variables are prior to phi mass peak cut
- Exclusivity cuts

$E_{\text{miss}} \in [-0.0075, 0.32] \text{ GeV}$
 $P_{T\text{miss}} < 0.12 \text{ GeV}$
 $M_{X^2}(\text{e}K^+K^-) \in [0.64, 1.1664] \text{ GeV}^2$
 $M_{X^2}(\text{ep}K^+K^-) < 0.0075 \text{ GeV}^2$
 $M_{X^2}(\text{ep}K^-) \in [0.08, 0.48] \text{ GeV}^2$
 $M_{X^2}(\text{ep}K^+) \in [0.08, 0.48] \text{ GeV}^2$
 cone angles $K_p/K_m/p < 6 \text{ deg}$
 coplanarity $< 15 \text{ degrees}$

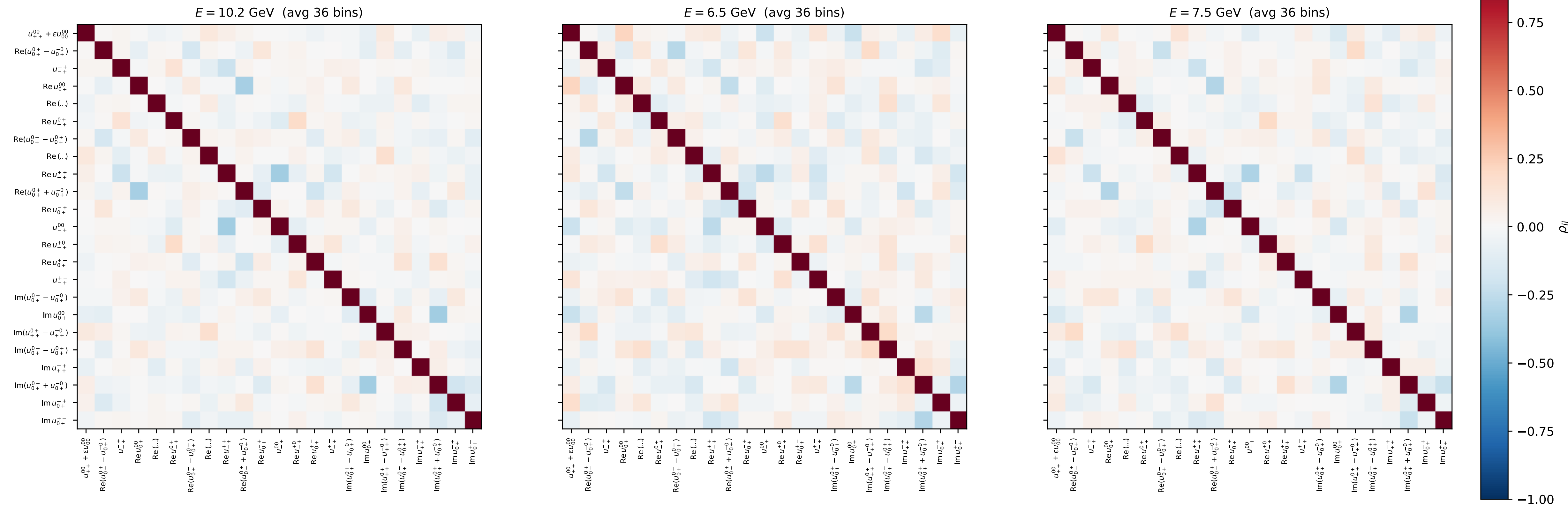


Generate the simulation 500 K events



Correlations plots

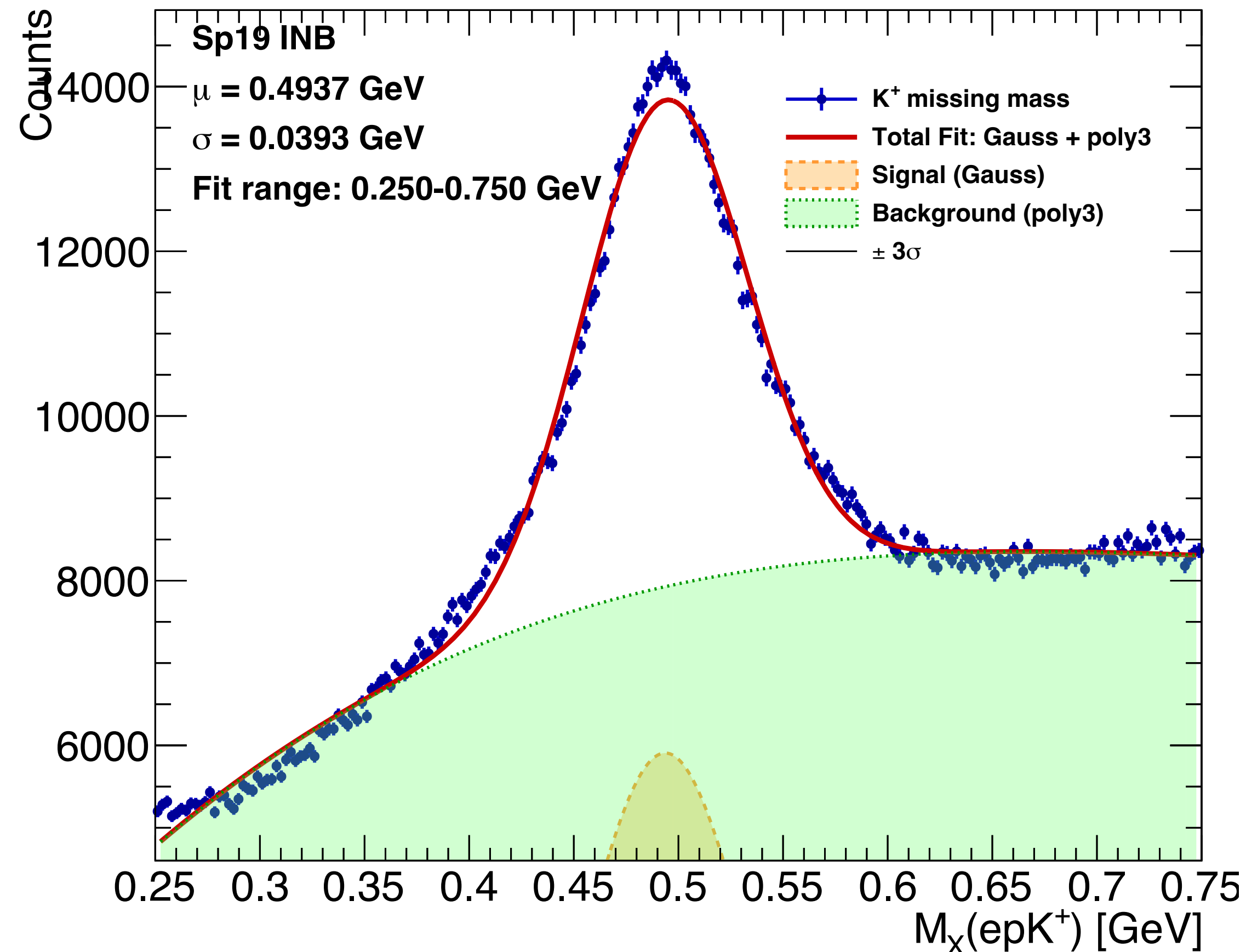
Diehl correlations across the RGA+RGK energies



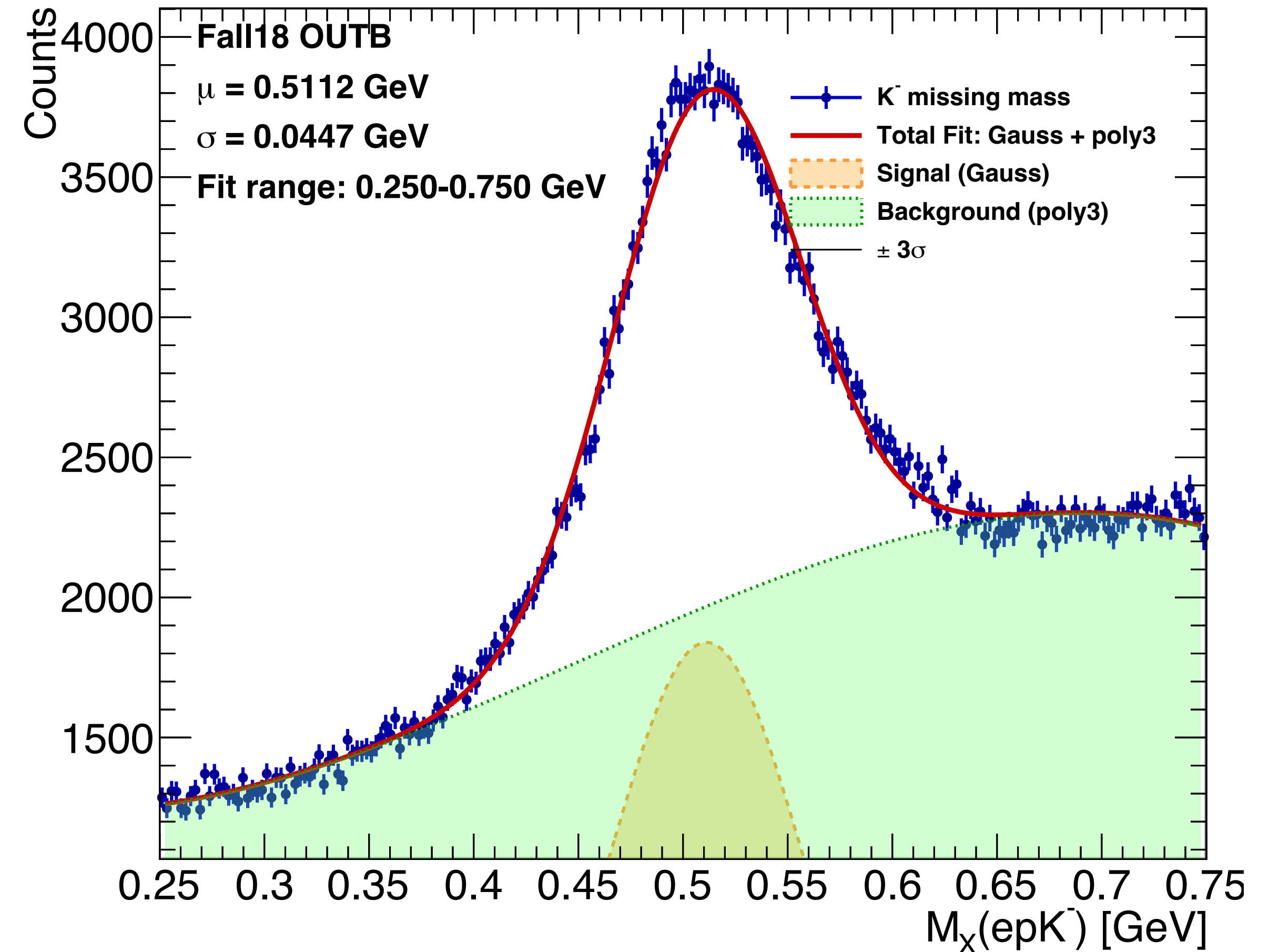
Missing mass analysis

- Reconstruct the missing K^- peak at ~ 493 MeV: $\pm 3\sigma$ cut around the the peak

K^- peak for $ep \rightarrow epK^+(K^-)$



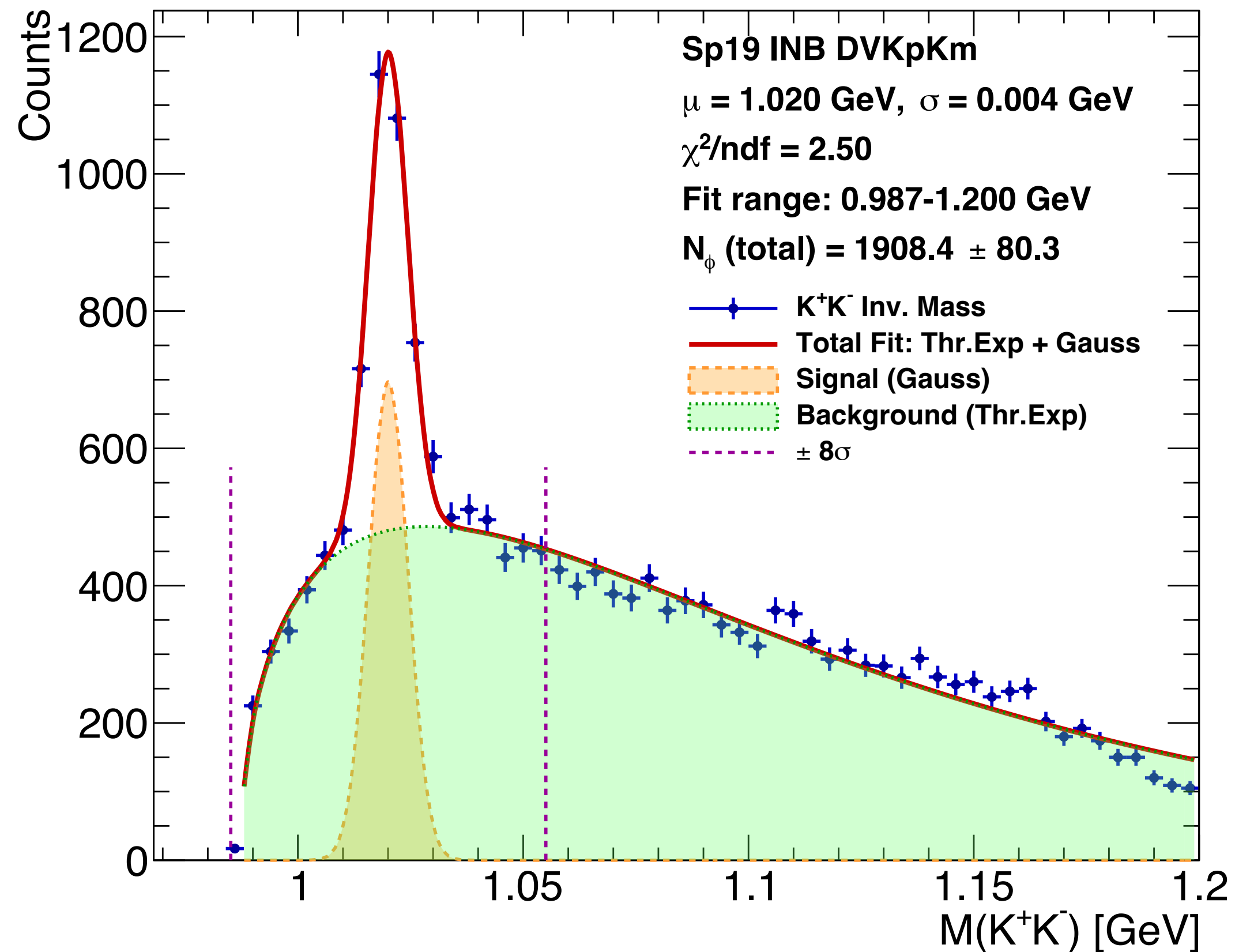
K^+ peak for $ep \rightarrow epK^-(K^+)$



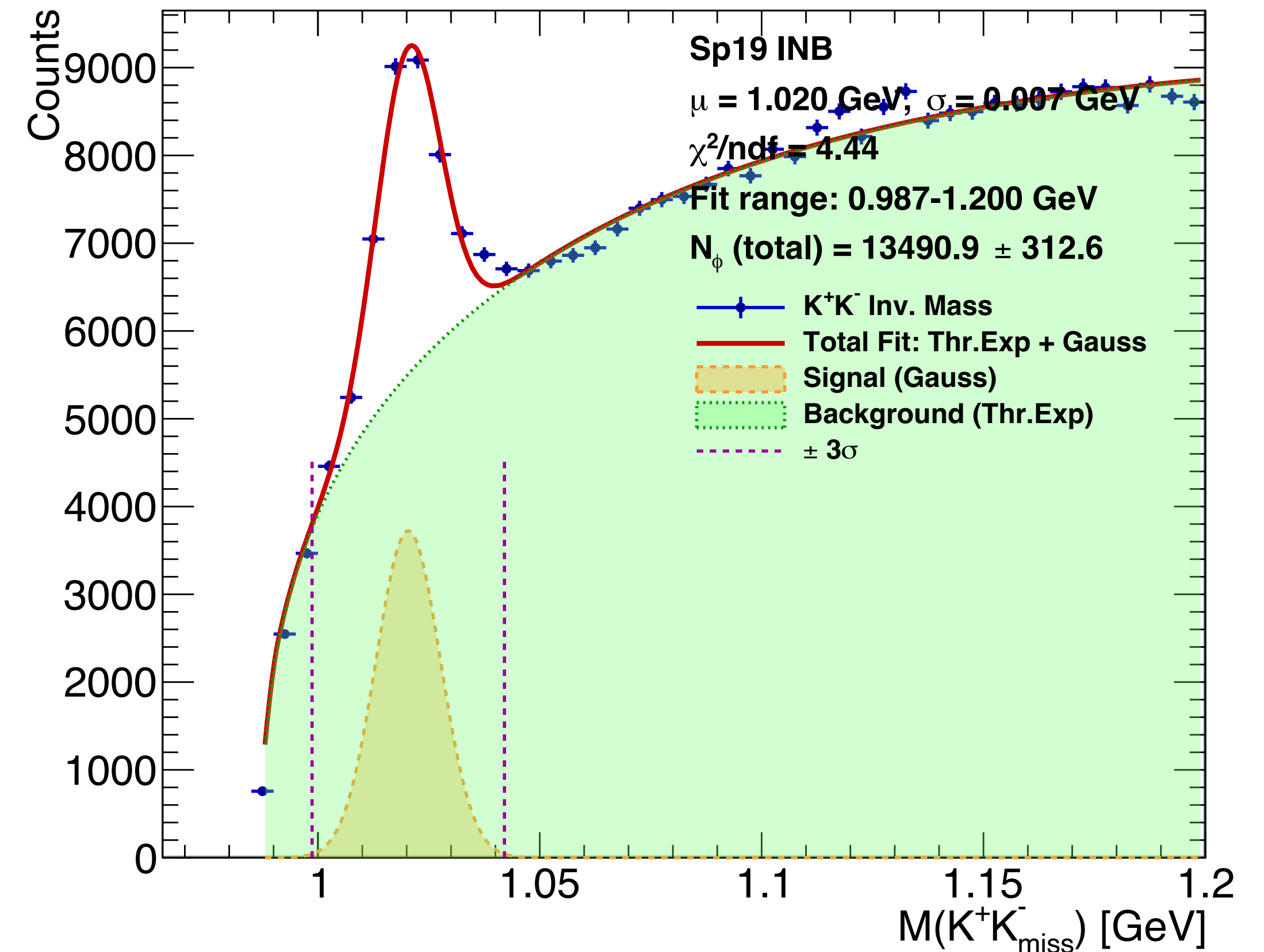
Missing Mass vs Exclusive topology

- Enhanced statistics ~7-8 fold in the missing mass analysis.
- Larger background!

1908 ϕ candidates



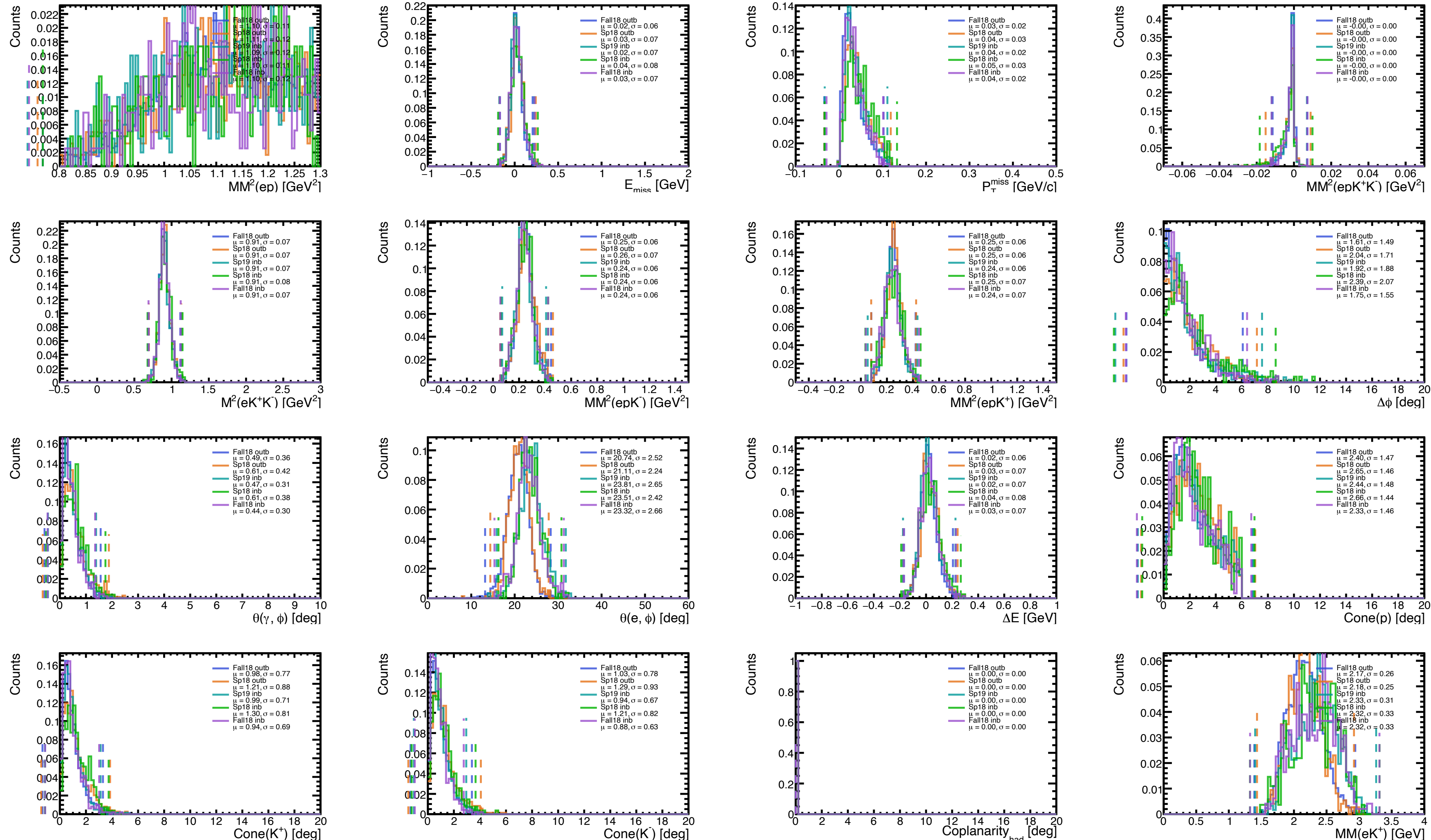
13490 ϕ candidates



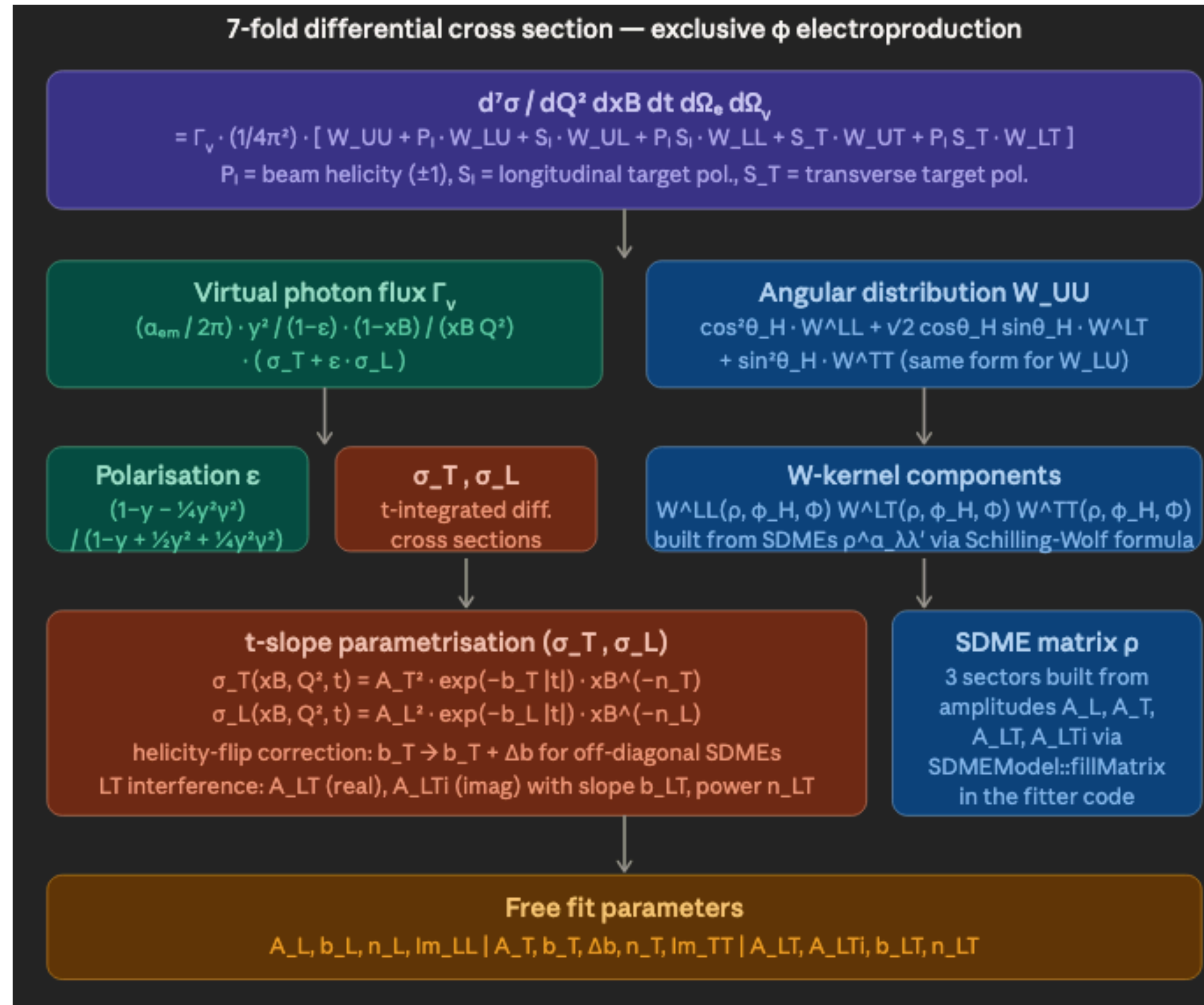
Exclusivity cuts

- Proton in CD and Kaons in FD (less stat)
- Exclusivity variables are prior to phi mass peak cut
- Exclusivity cuts

$E_{\text{miss}} \in [-0.0075, 0.32] \text{ GeV}$
 $P_{T\text{miss}} < 0.12 \text{ GeV}$
 $M_{x^2}(\text{eK}^+\text{K}^-) \in [0.64, 1.1664] \text{ GeV}^2$
 $M_{x^2}(\text{epK}^+\text{K}^-) < 0.0075 \text{ GeV}^2$
 $M_{x^2}(\text{epK}^-) \in [0.08, 0.48] \text{ GeV}^2$
 $M_{x^2}(\text{epK}^+) \in [0.08, 0.48] \text{ GeV}^2$
 cone angles $K_p/K_m/p < 6 \text{ deg}$
 coplanarity $< 15 \text{ degrees}$

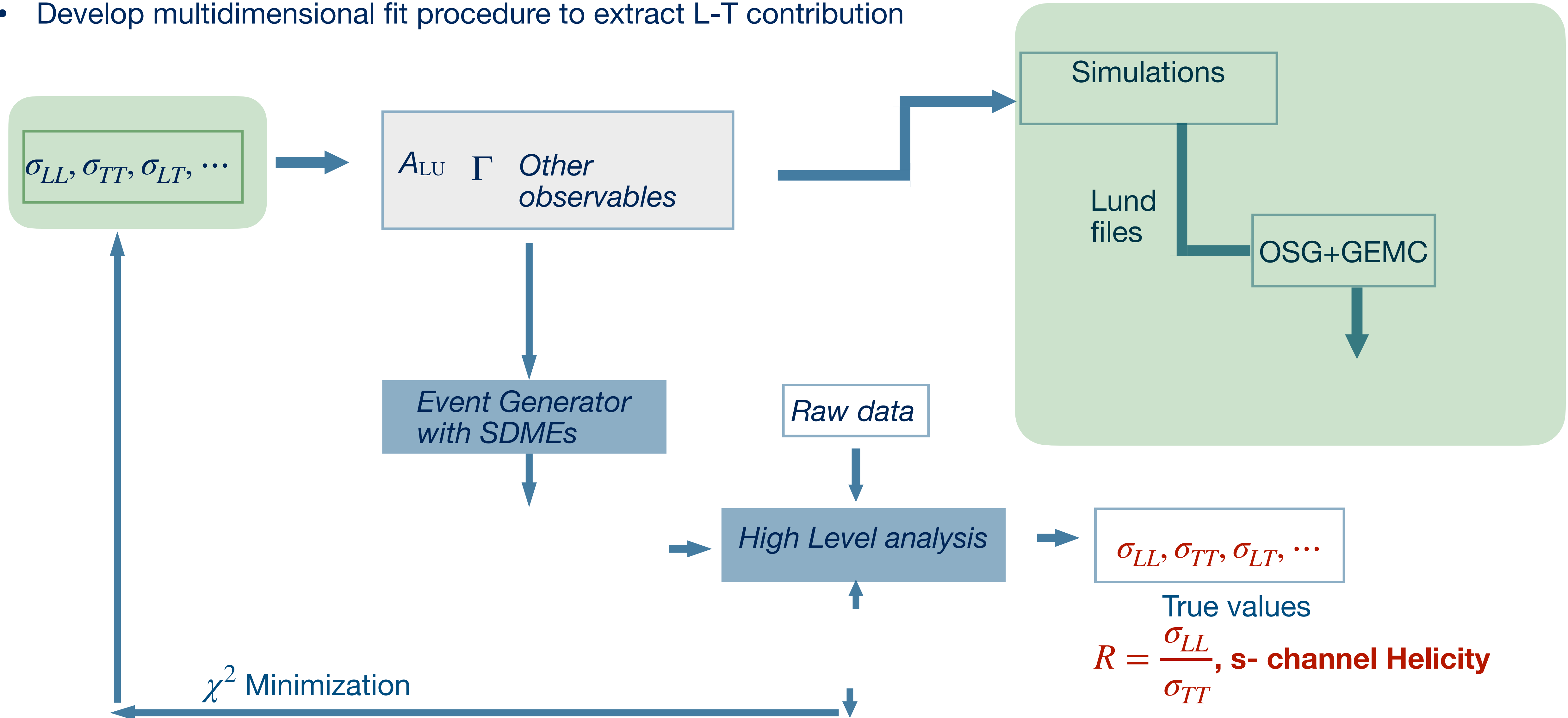


The way we can compute directly the R



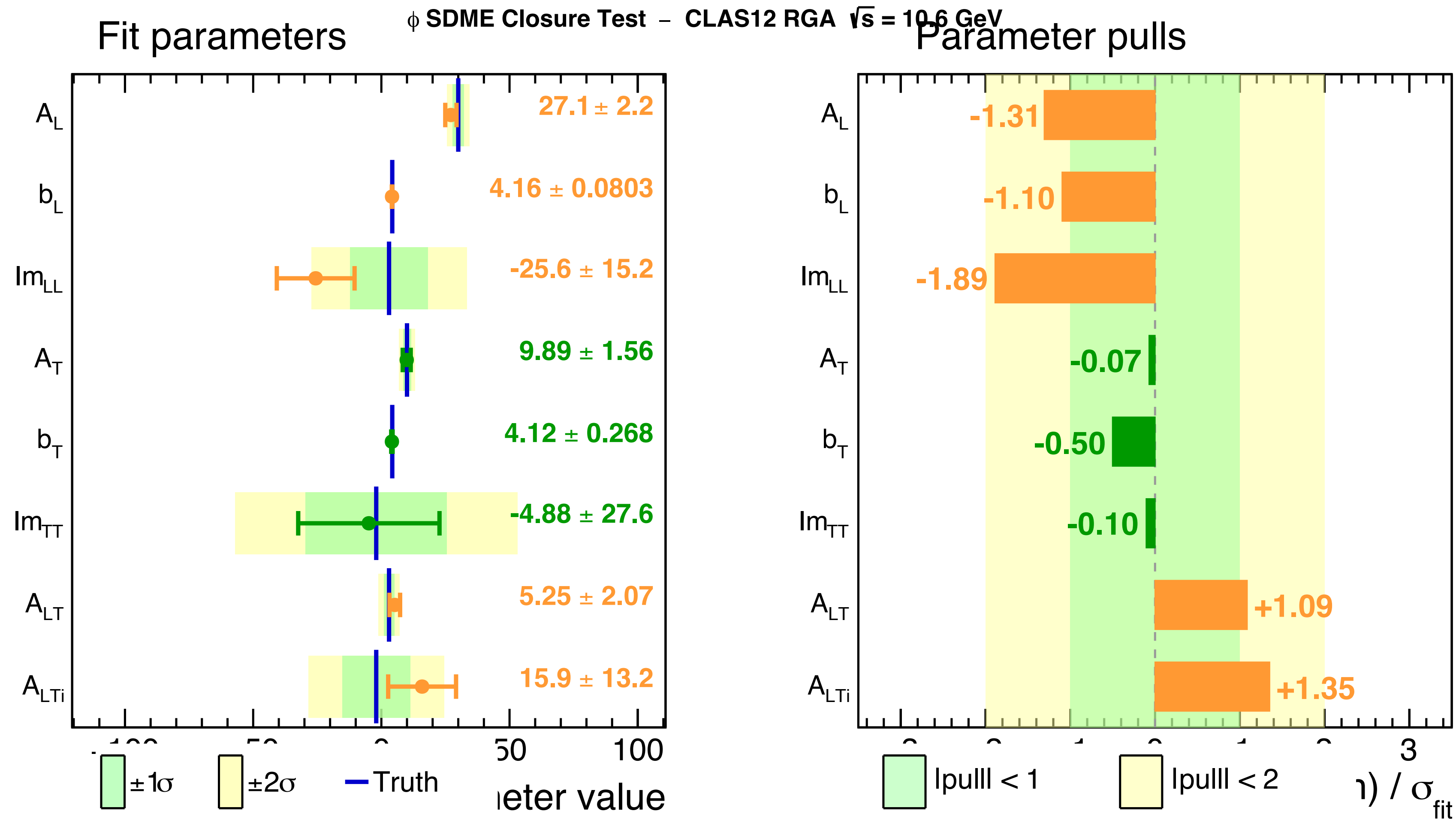
Plan to tackle the MC situation

- Develop multidimensional fit procedure to extract L-T contribution



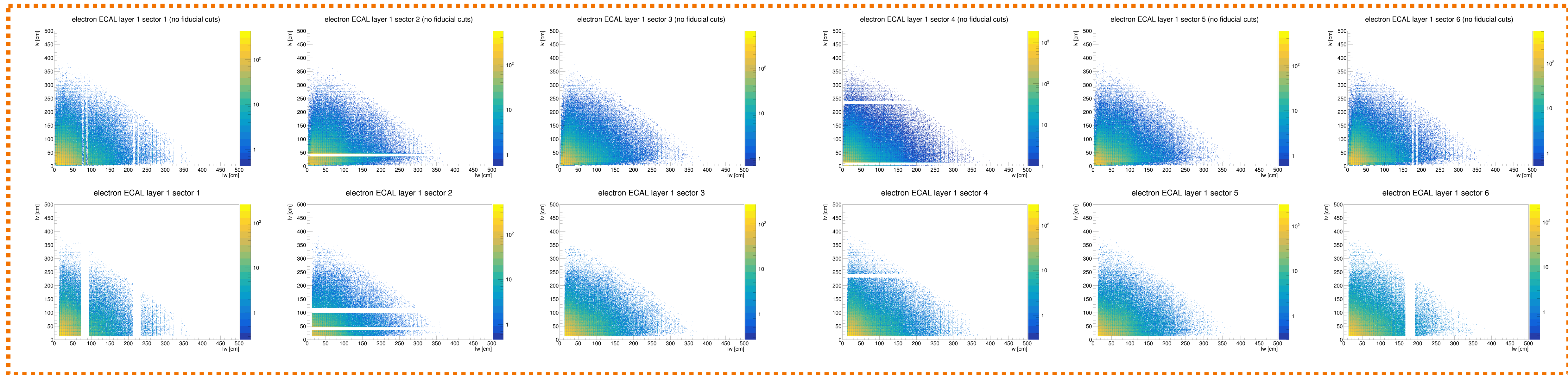
Closure test for fitting procedure

- Take the generated cross-section with parameters +5 % smearing and expect the fits to return the similar parameters —> **Closure test passed!**



Fiducial volume for electron and hadrons

- FT, **FD**, and CVT regions with possible reconstruction inefficiencies are removed.



Excluded PCAL cuts for electron

Edge cuts (all sectors): lw: 0.0–13.5, lv: 0.0–13.5cm

Sector 1: lw: 72–94.5cm, 211.5–234cm

Sector 2: lv: 99–117.5cm

Sector 3: lv: 346.5–378cm

Sector 4: lv: 0–13.5cm, 229.5–243cm

Sector 6: lw: 166.5–193.5cm

Similarly for EC_{in}

Sector 1 lv: 67.5cm — 94.5cm

Sector 4 lw: 0.0cm — 23.5cm

Sector 5 lv: 0.0cm — 23.5cm

Sector 6 lv: 0.0cm — 23.5cm

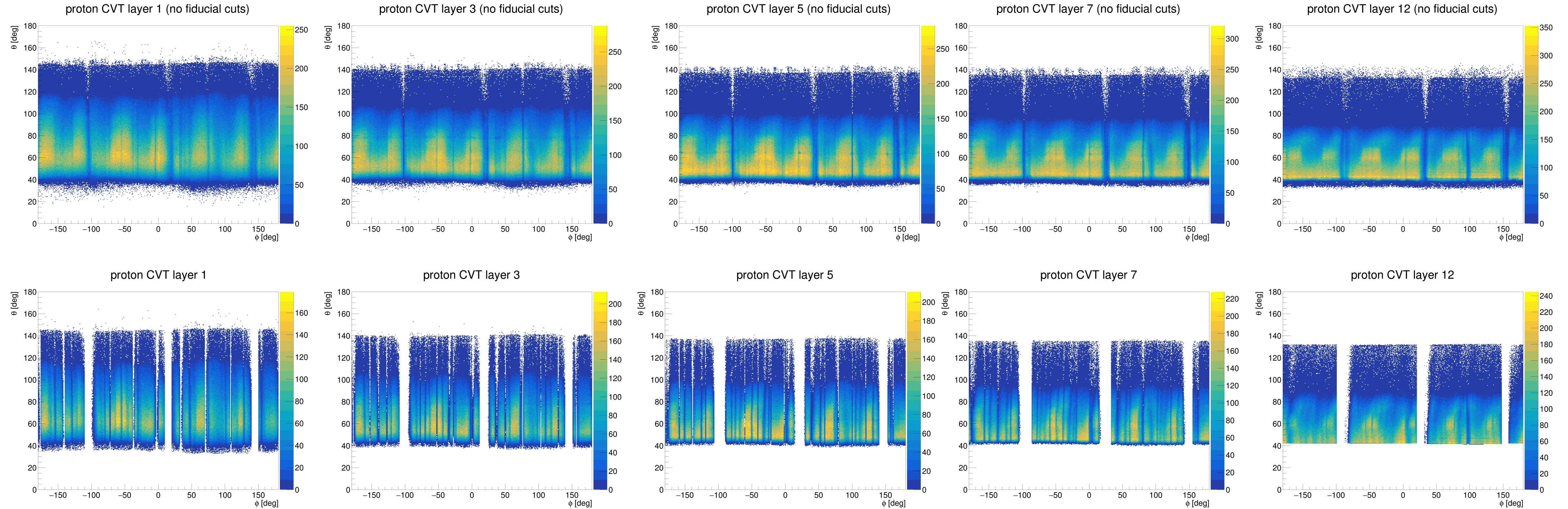
Similarly for EC_{out}

Sector 1 lv: 0.0cm → 40.5cm

Sector 5 lw: 193.5cm → 216.0cm

Fiducial volume for electron and hadrons

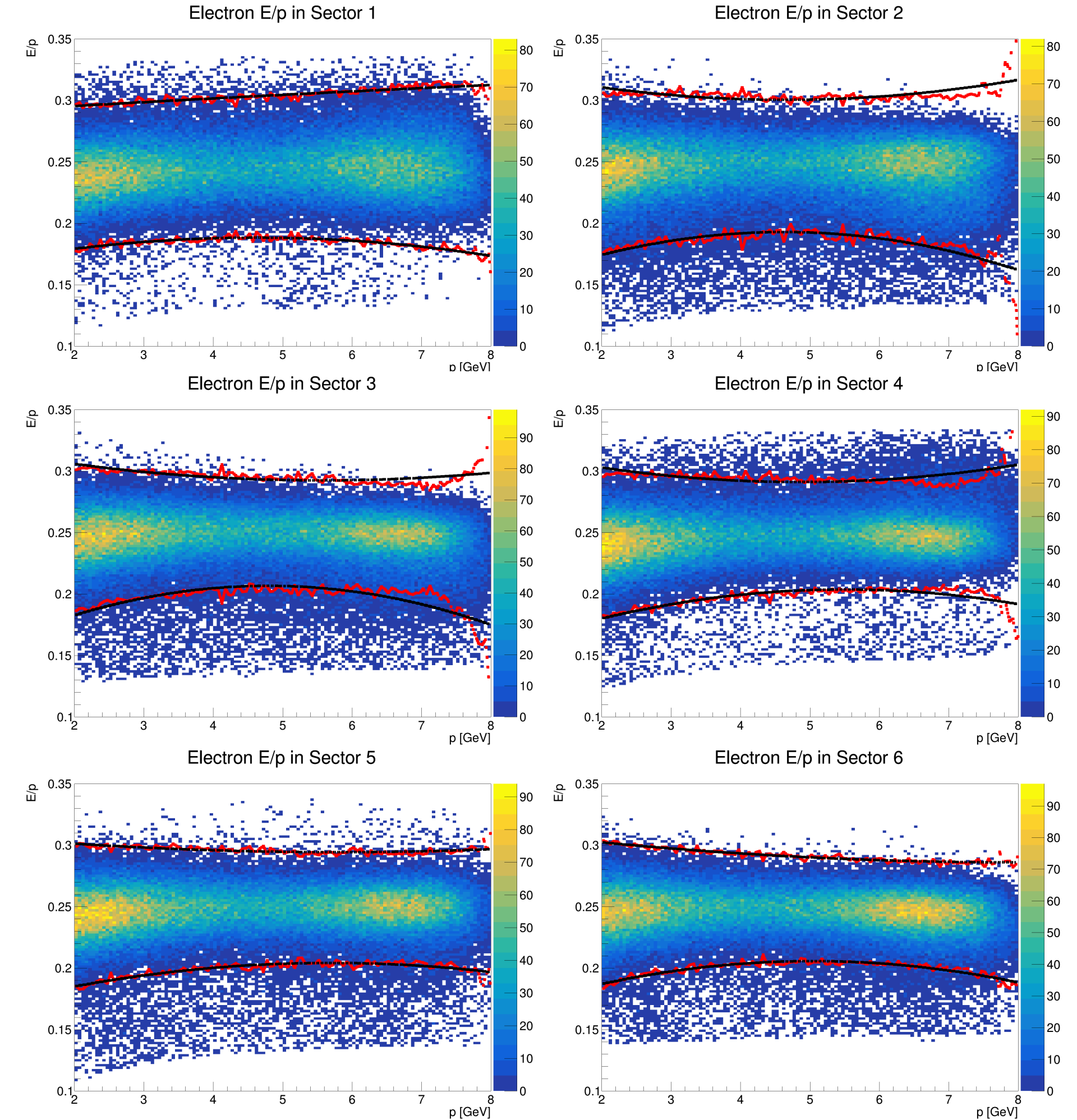
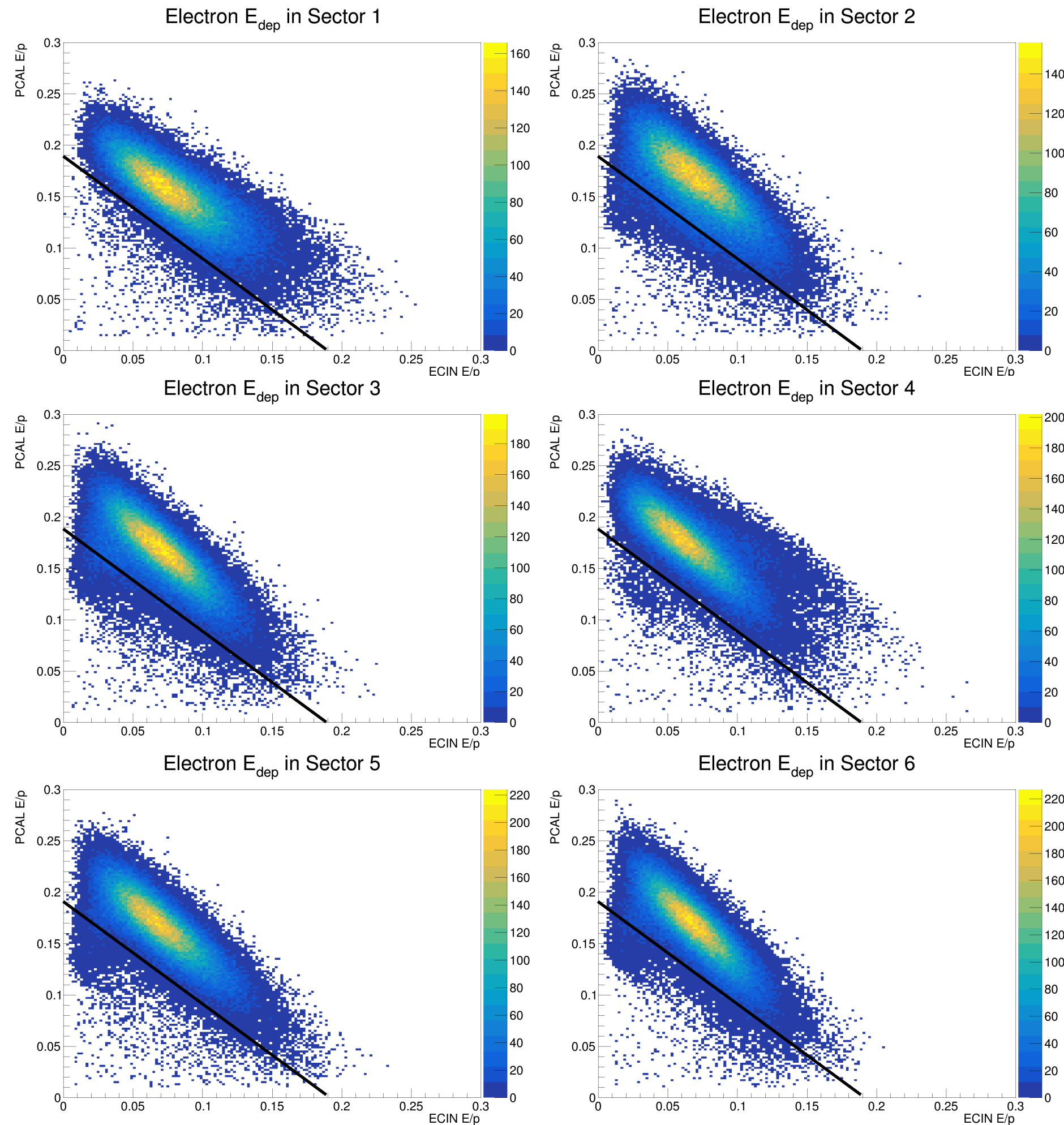
- FT, FD, and **CVT** regions with possible reconstruction inefficiencies are removed.



- CVT regions for χ^2/NDF is non-flat below the edge variable **Fiducial cuts for the layer 1, 3, 5, 7, and 12)**
- Sampling fraction cuts for electron, and energy loss corrections for proton are applied.**
- QADB cuts to select the good run/events**

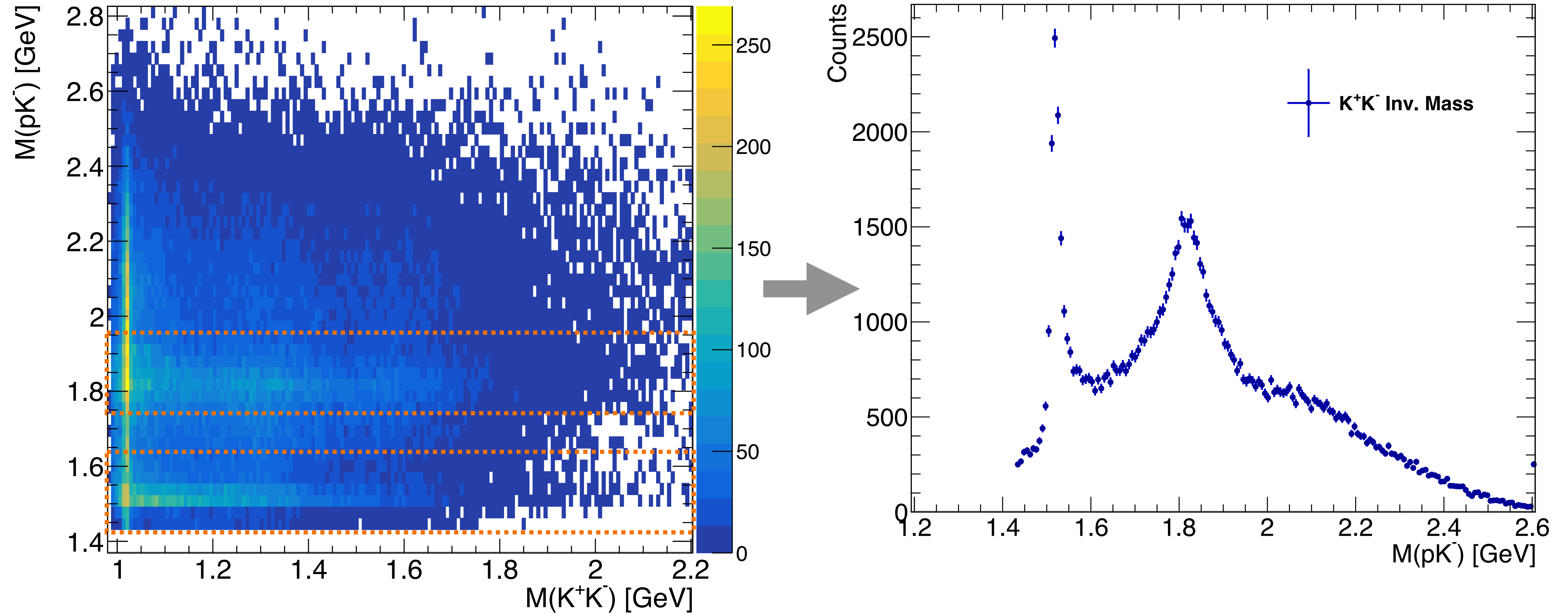
Electron sampling fraction (spring 2018 inb)

- To reduce the contamination in the electron sample we enforce ± 3 sigma cuts on E/P distributions and PCAL E/p vs ECin E/p diagonals cuts to separate possible pi- contaminations



Background under the signal

- Production of $\Lambda^*(1520,1830)$ can lead to contamination in the ϕ DVMP channel



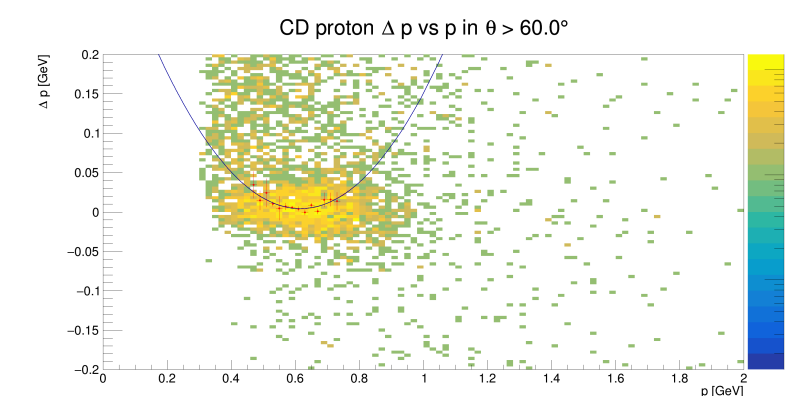
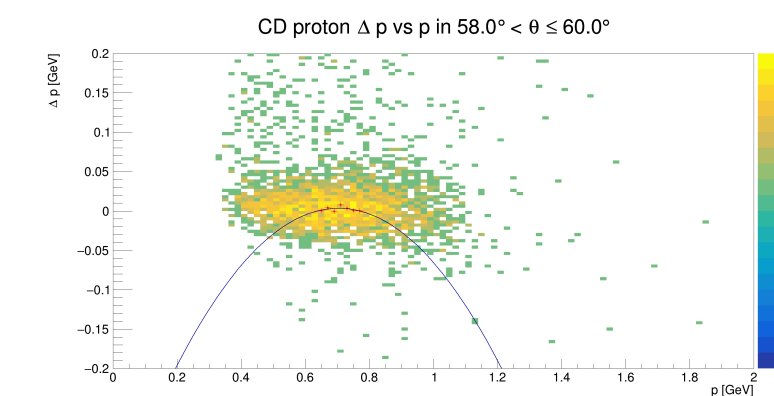
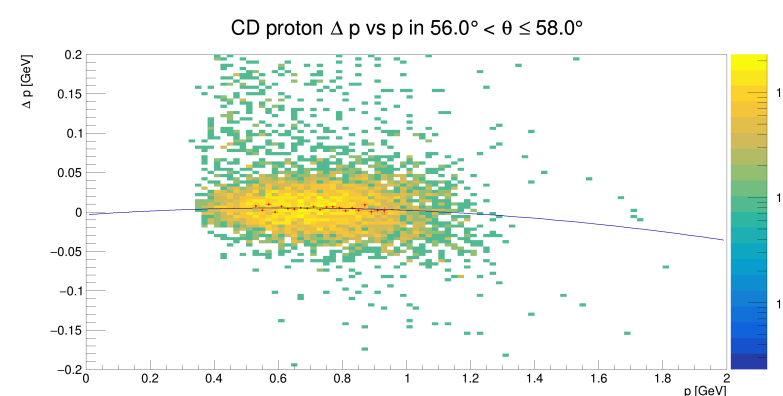
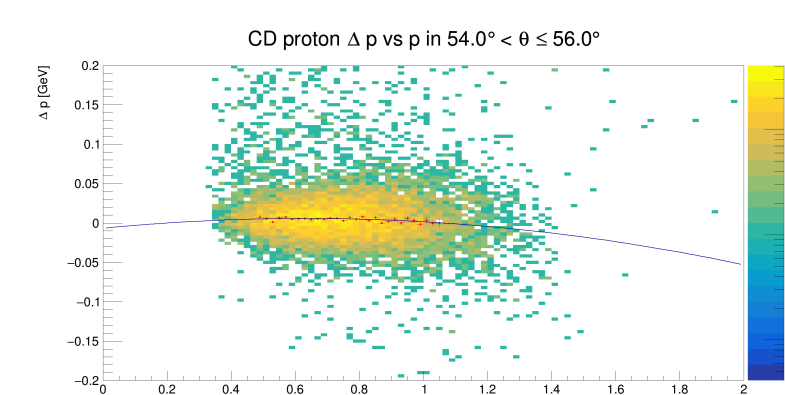
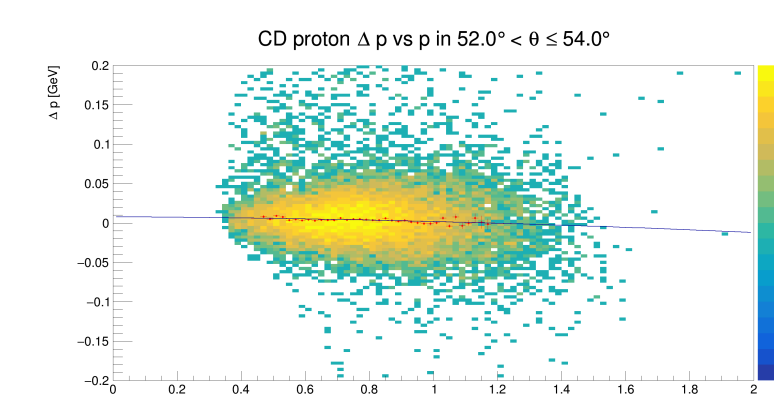
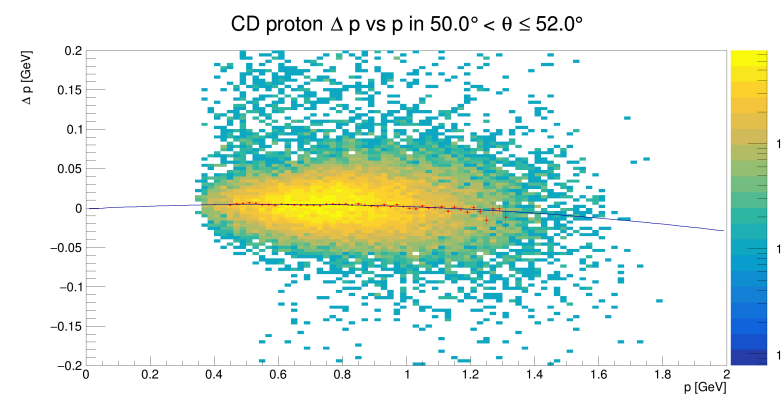
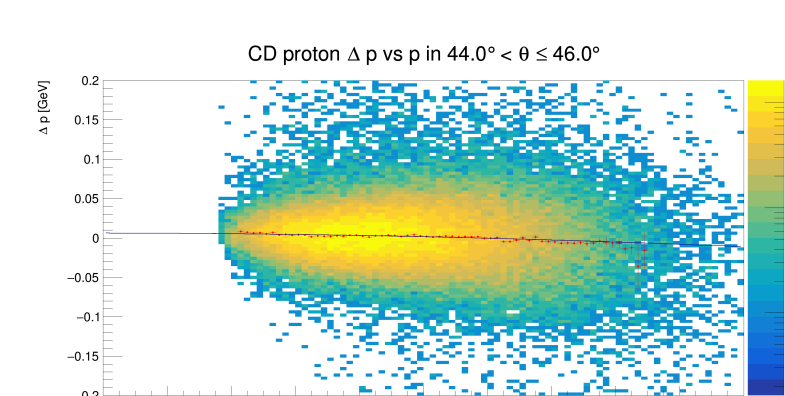
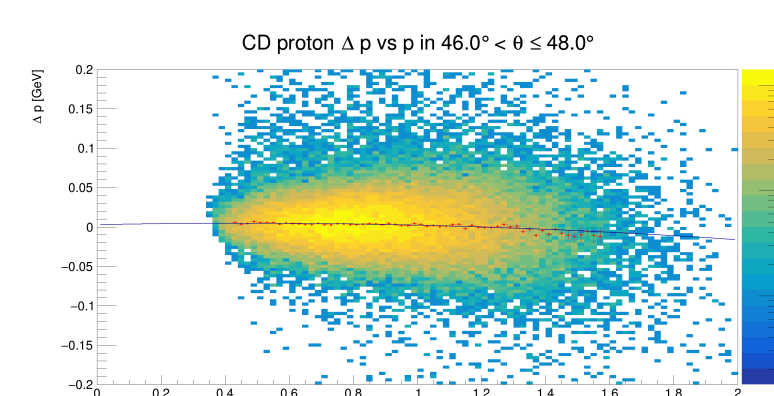
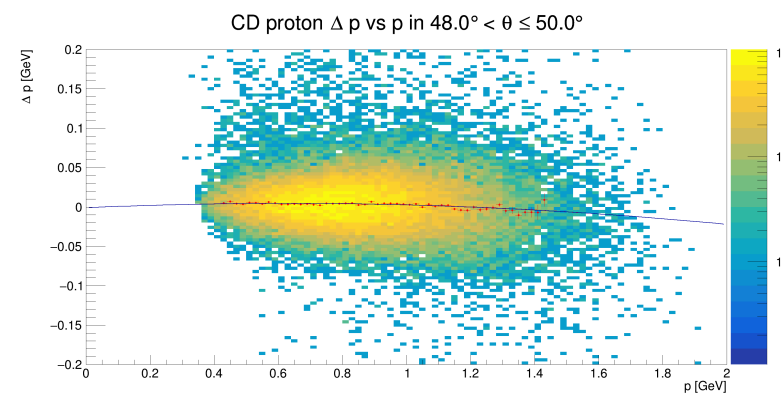
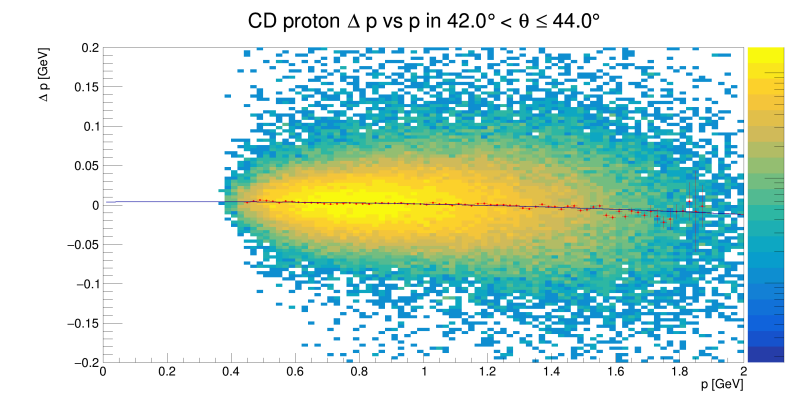
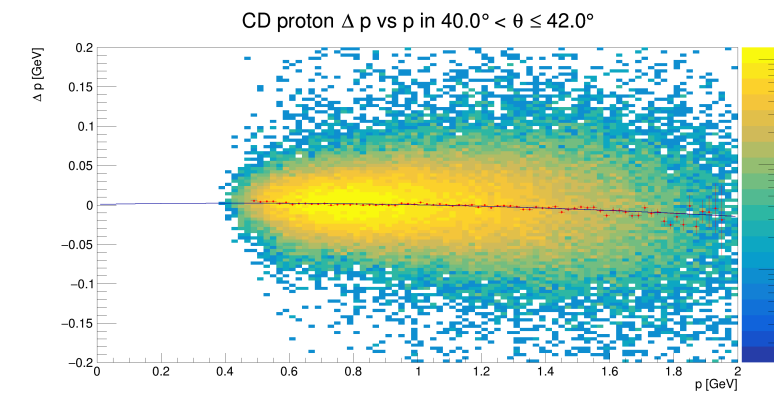
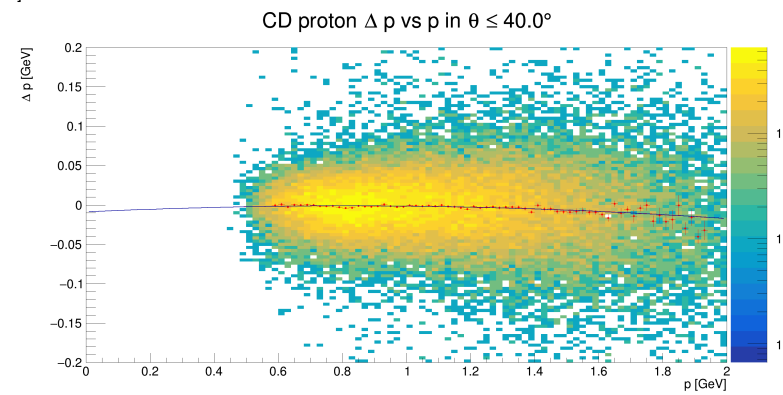
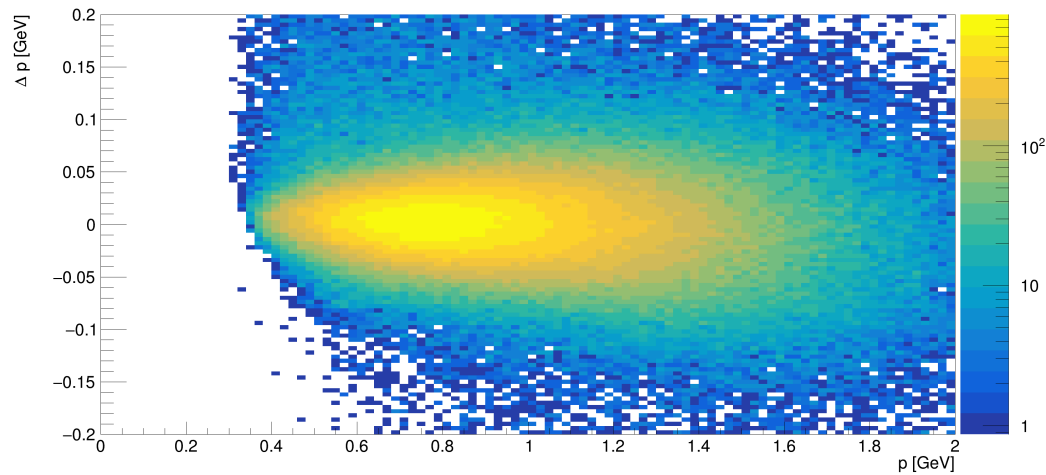
Energy loss corrections RGA (spring 2018 inb)

- Here spring 2018 (Fall 2018, spring 2019 T. Hayward see slides:)

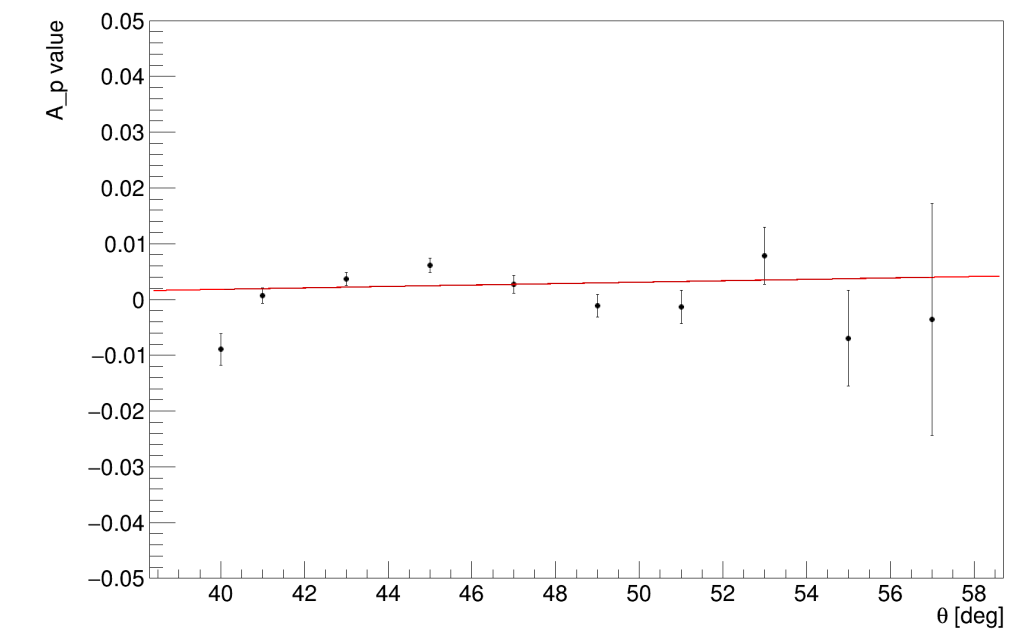
$$\Delta p = A + B \cdot p + C \cdot p^2$$

**CD
Proton**

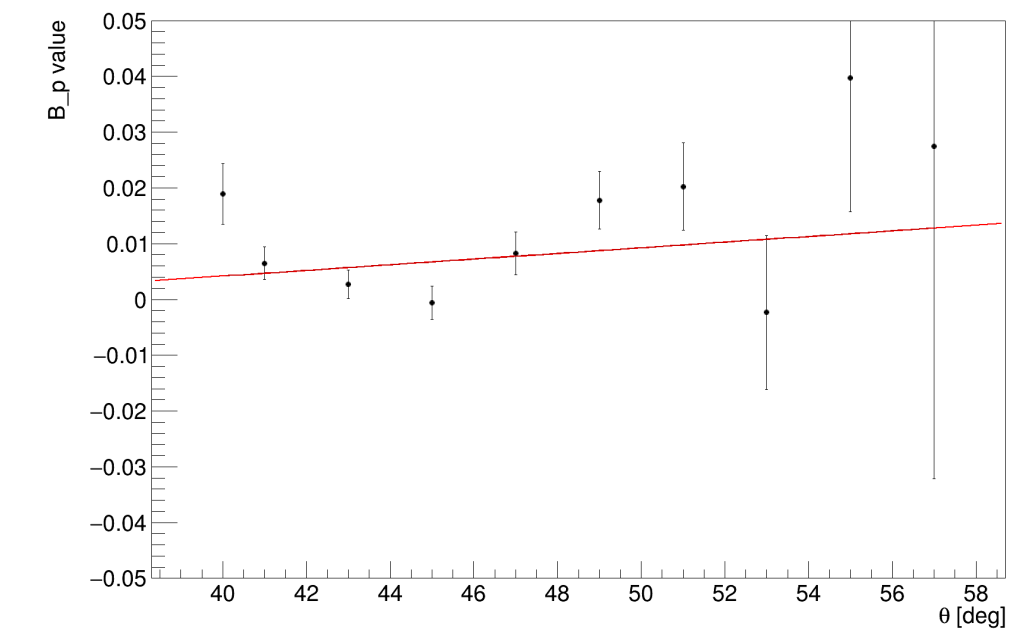
CD proton Δp vs p



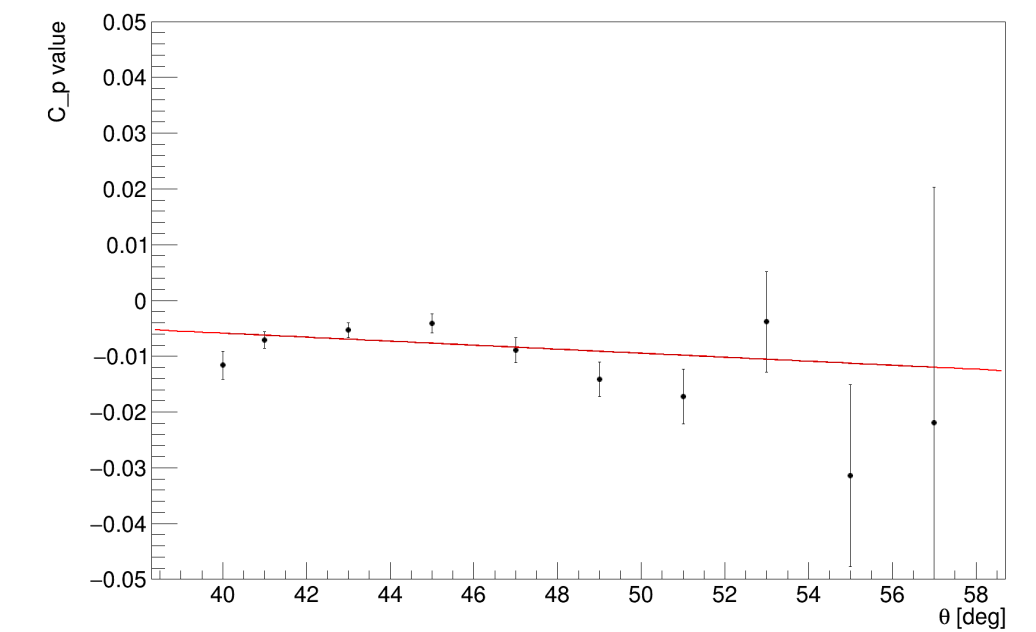
proton_CD: A_p vs θ



proton_CD: B_p vs θ



proton_CD: C_p vs θ



Benchmark: Fall2018_inb proton energy loss correction

CD

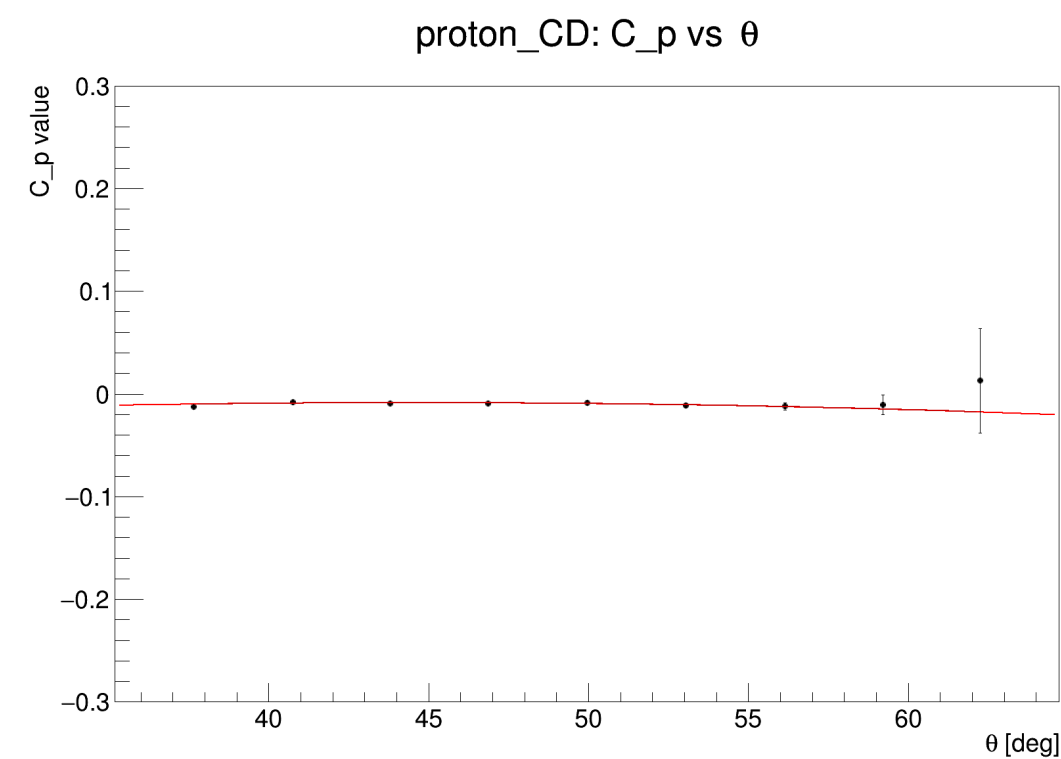
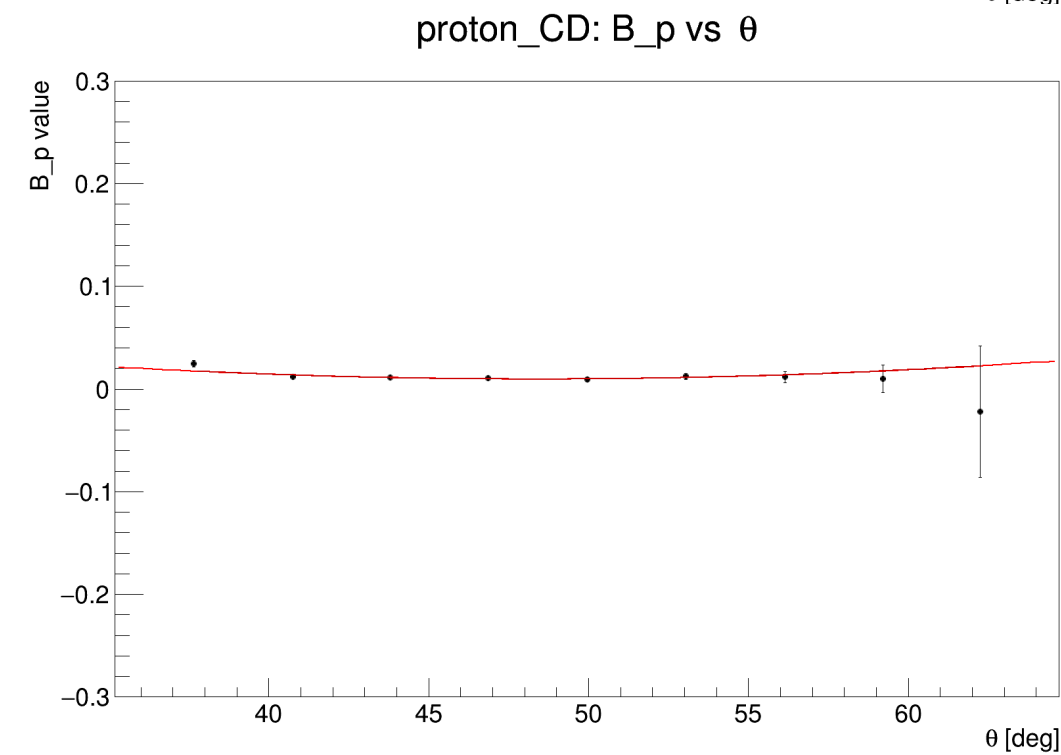
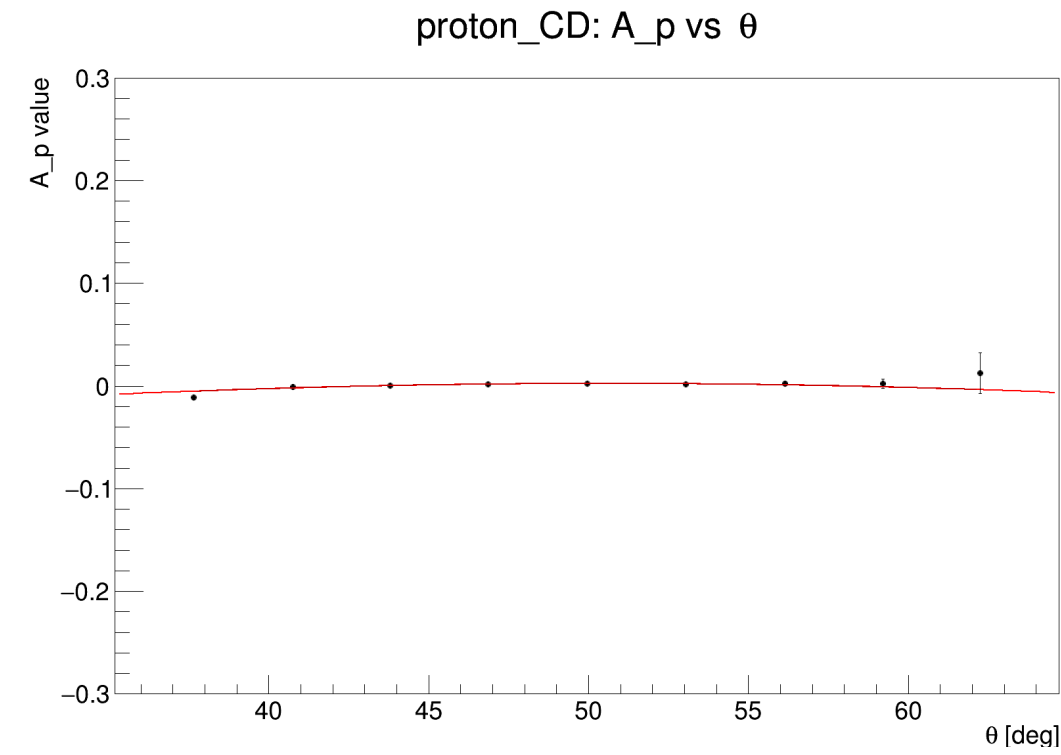
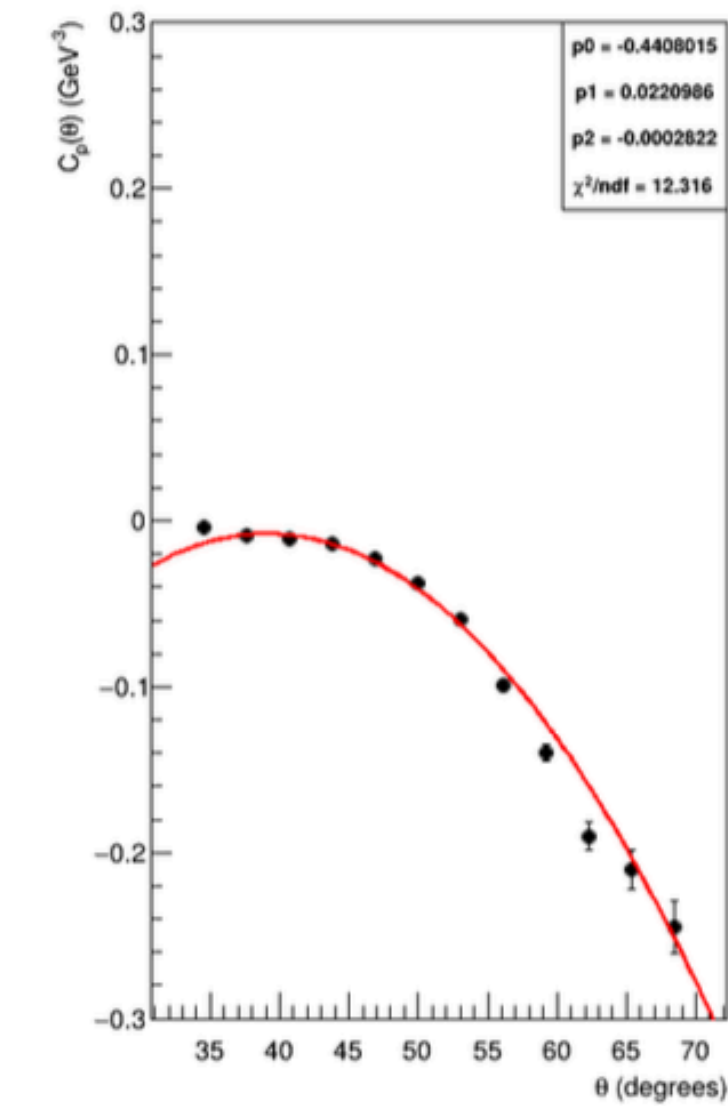
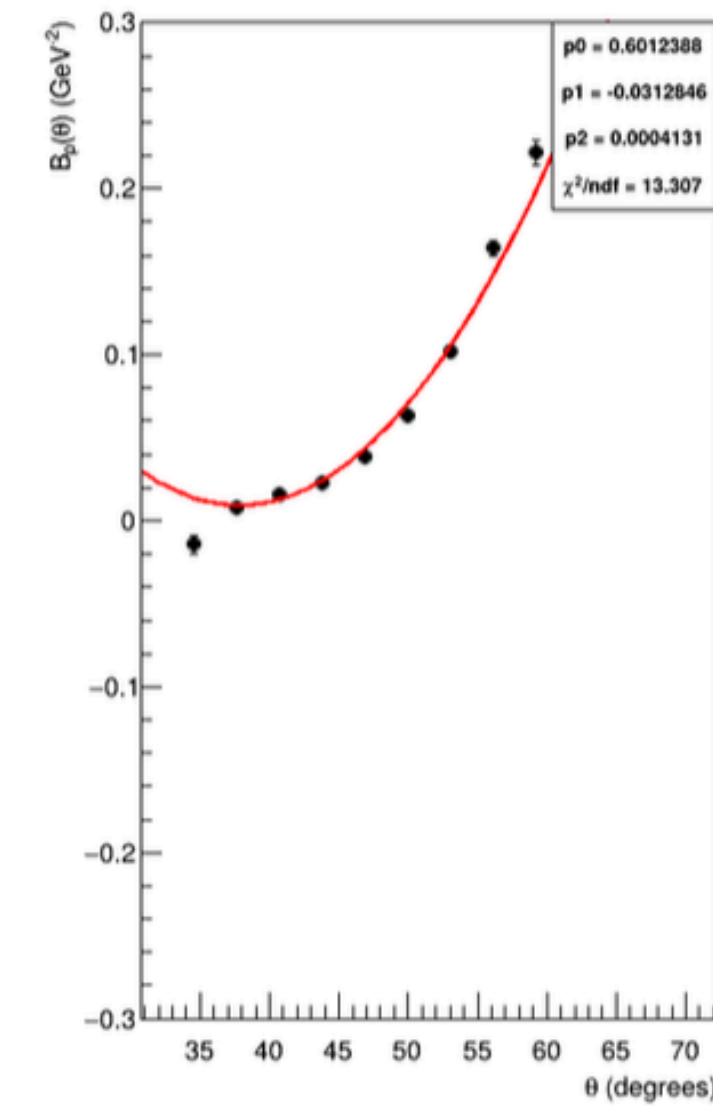
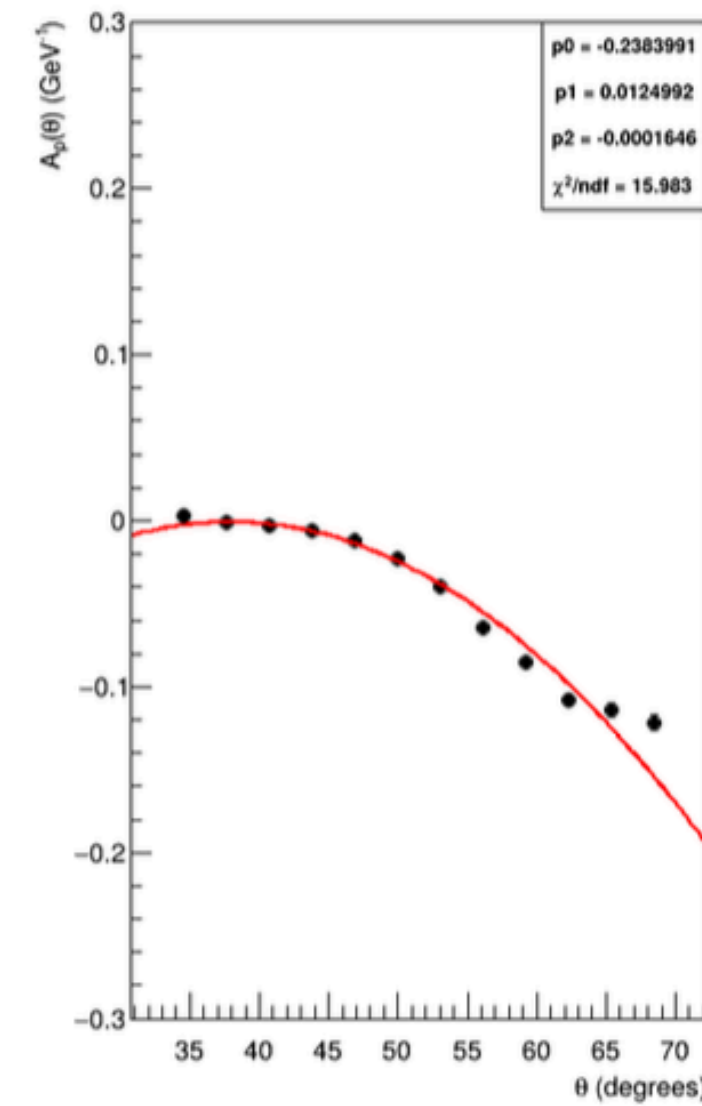
From Timothy

$$p \rightarrow p + A_p^{\text{CD}}(\theta) + B_p^{\text{CD}}(\theta)p + C_p^{\text{CD}}(\theta)p^2$$

A_p , Δp , rga_fa18_inb, CD

B_p , Δp , rga_fa18_inb, CD

C_p , Δp , rga_fa18_inb, CD

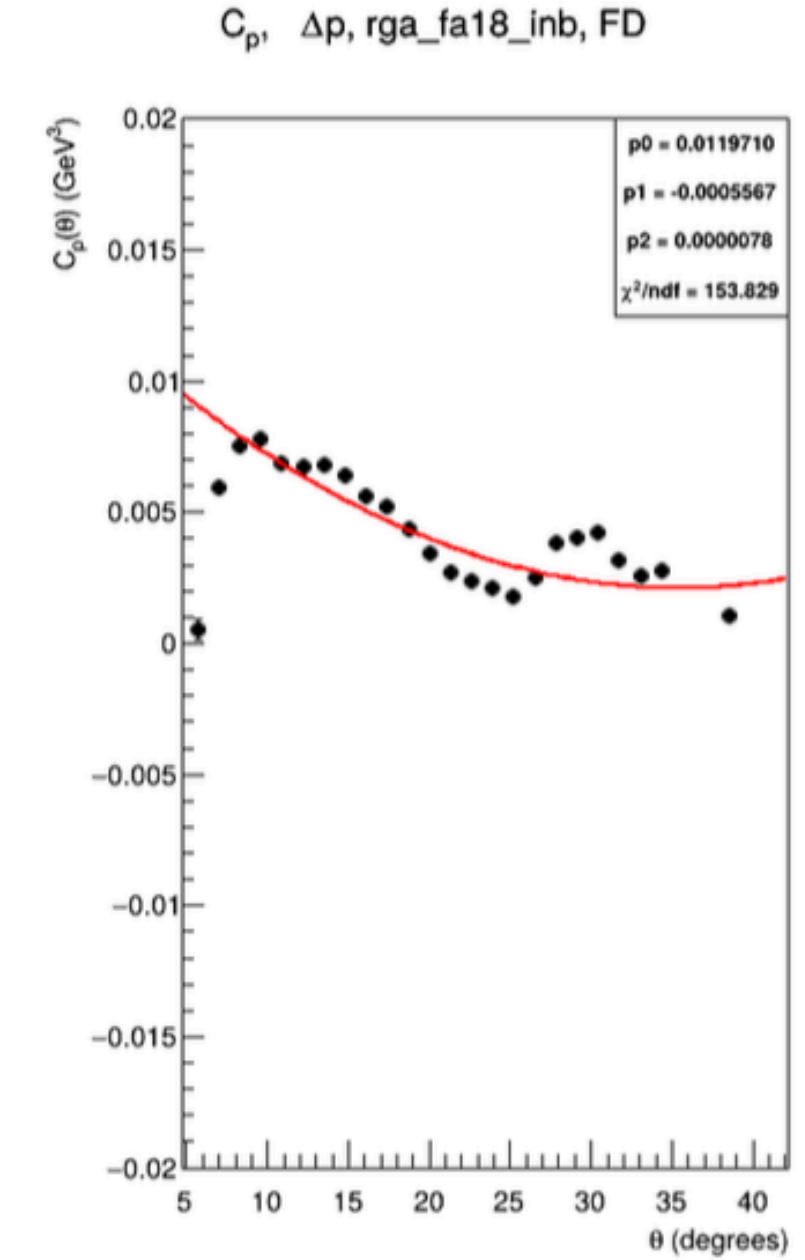
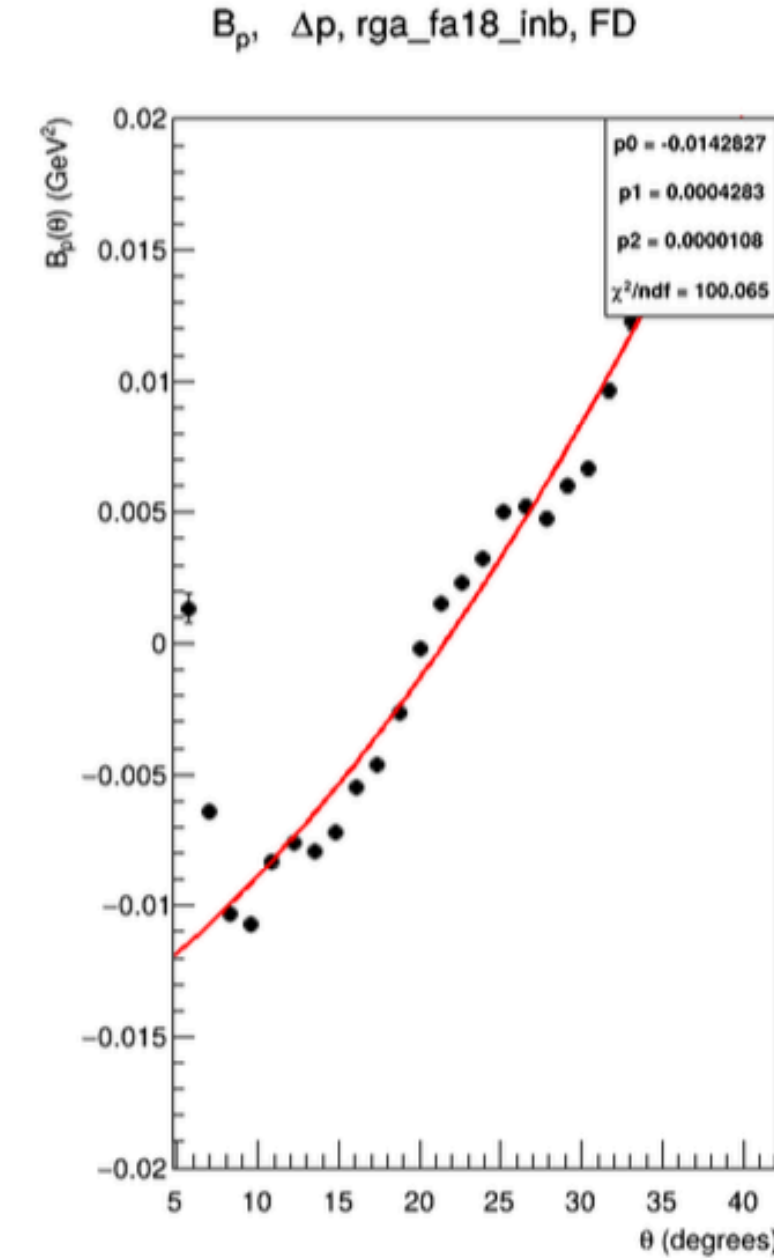
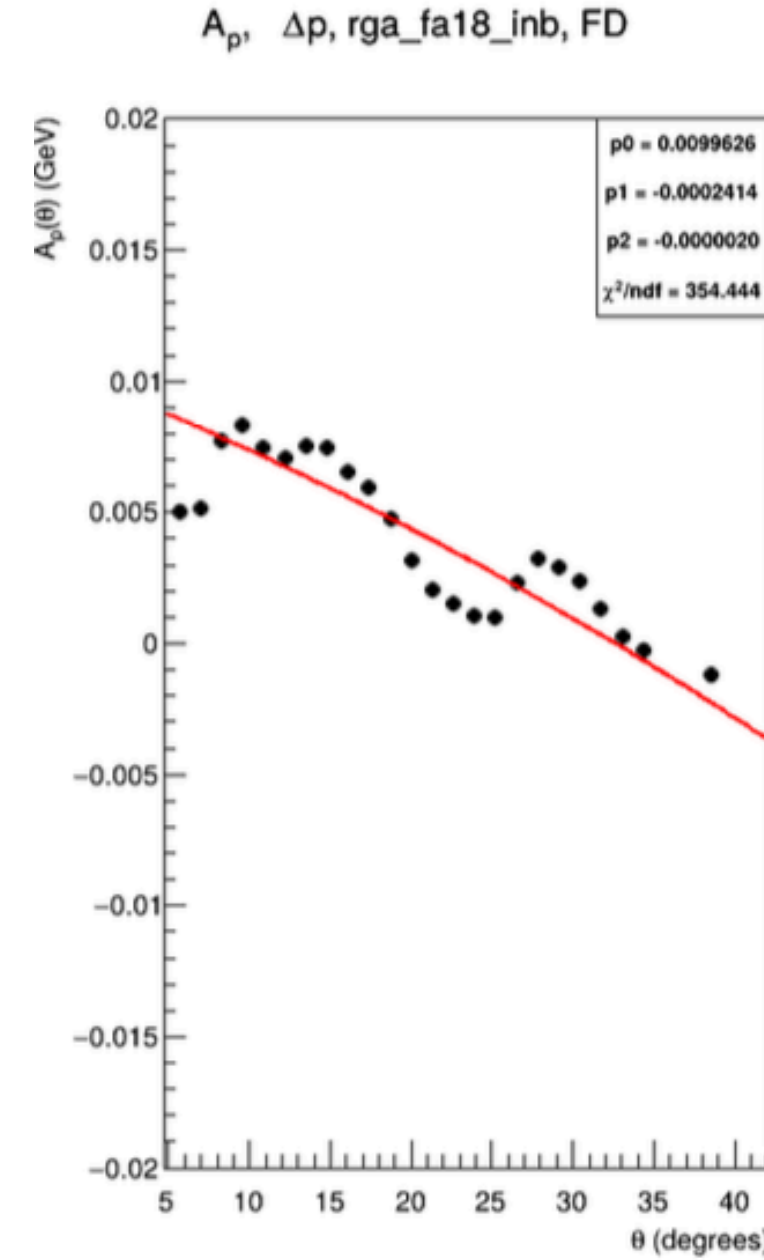
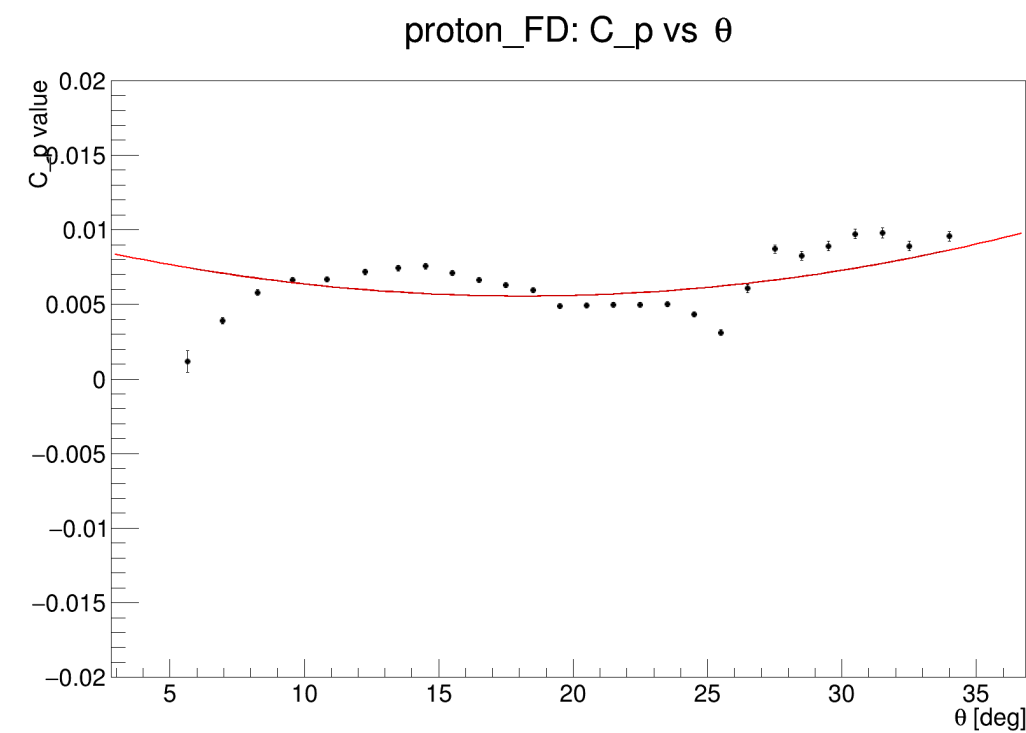
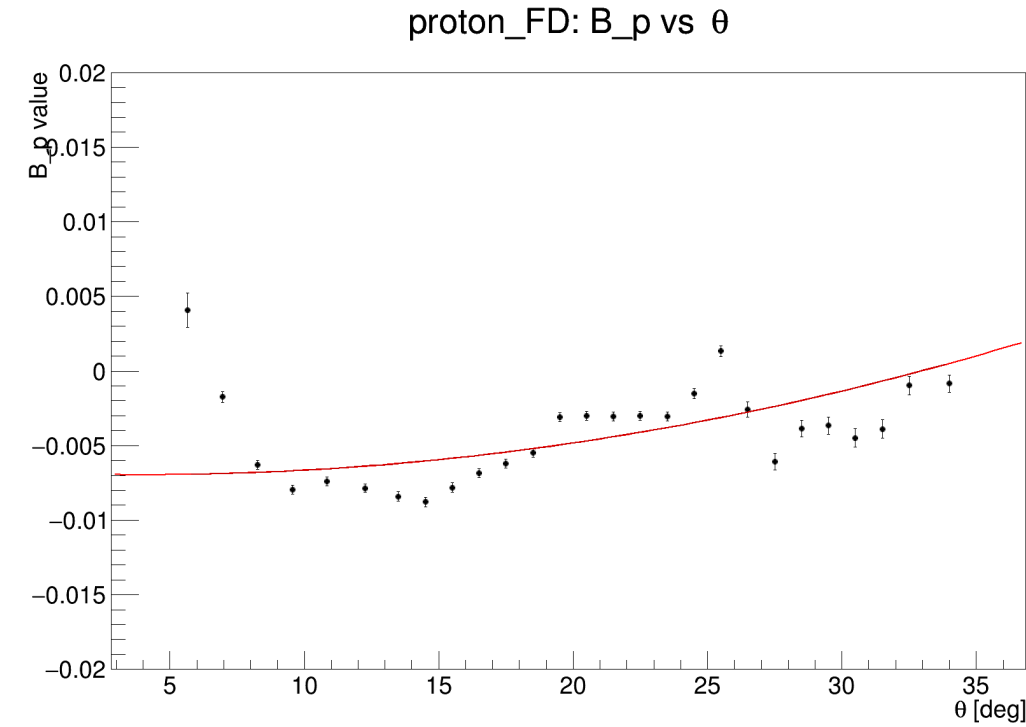
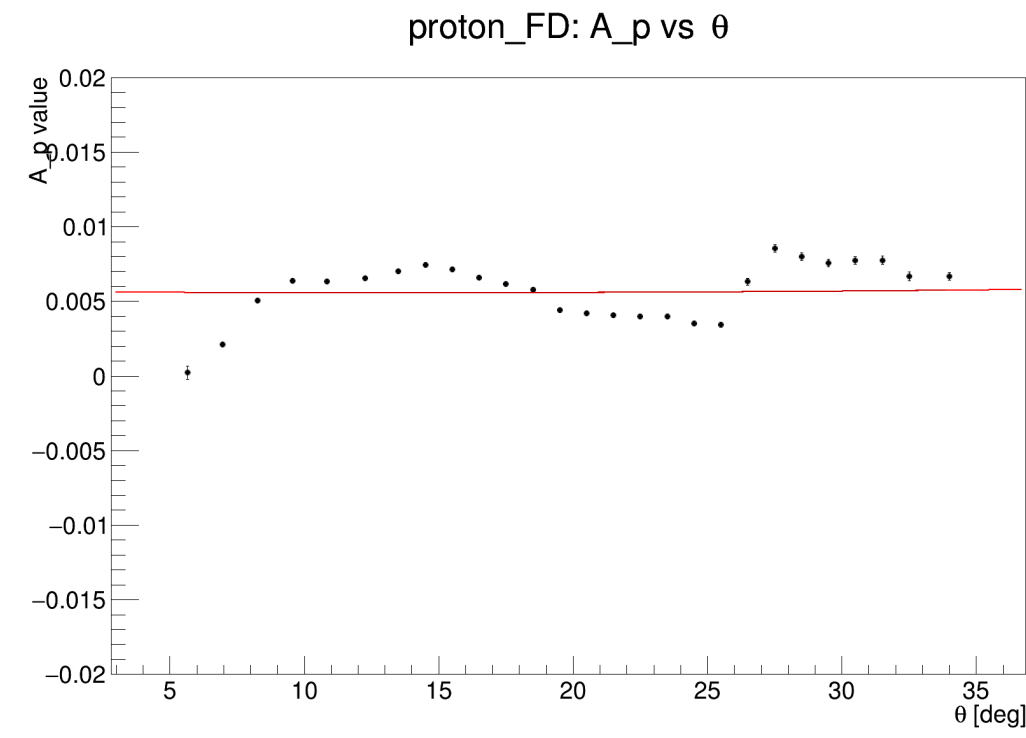


Benchmark: Fall2018_inb proton energy loss correction

FD

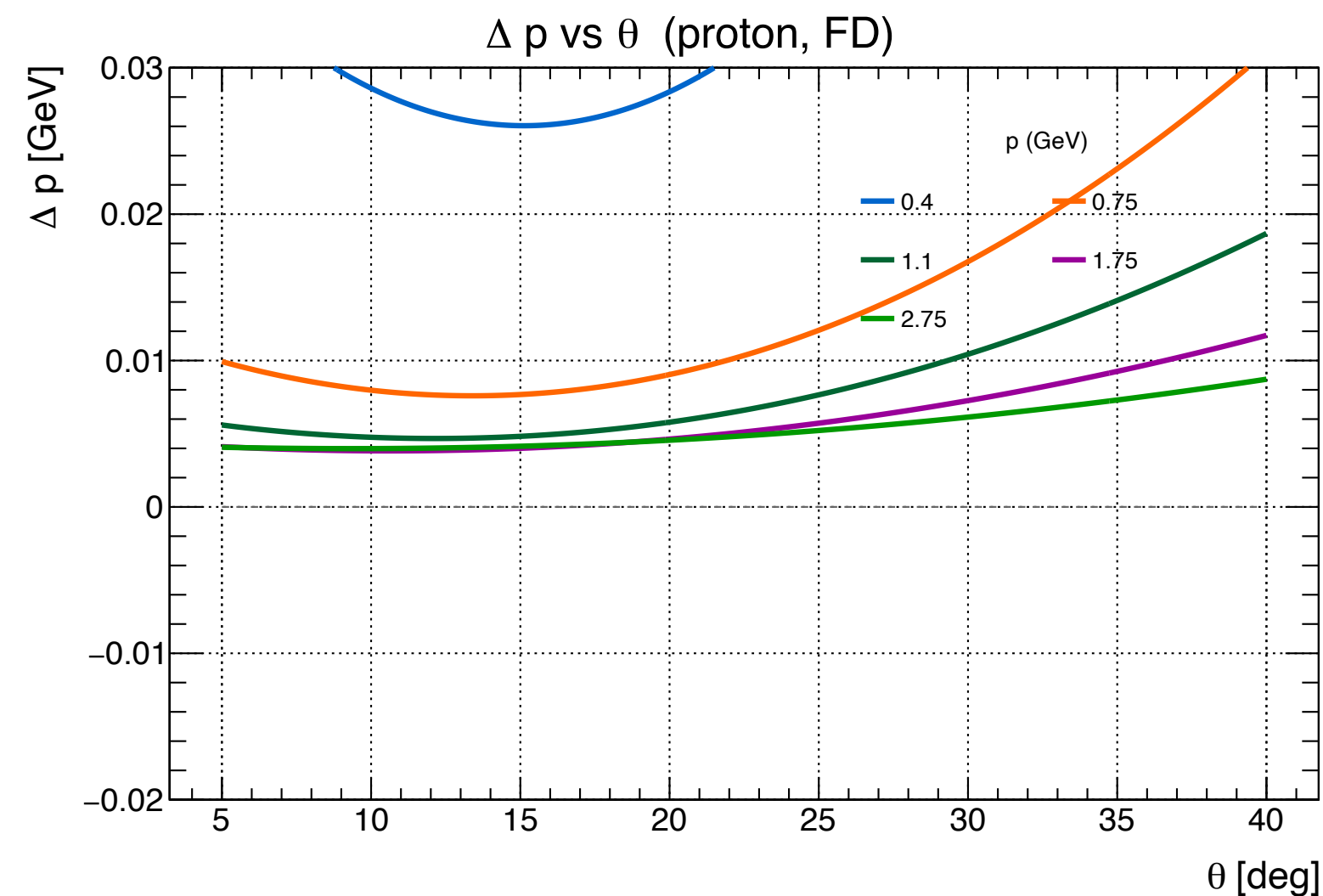
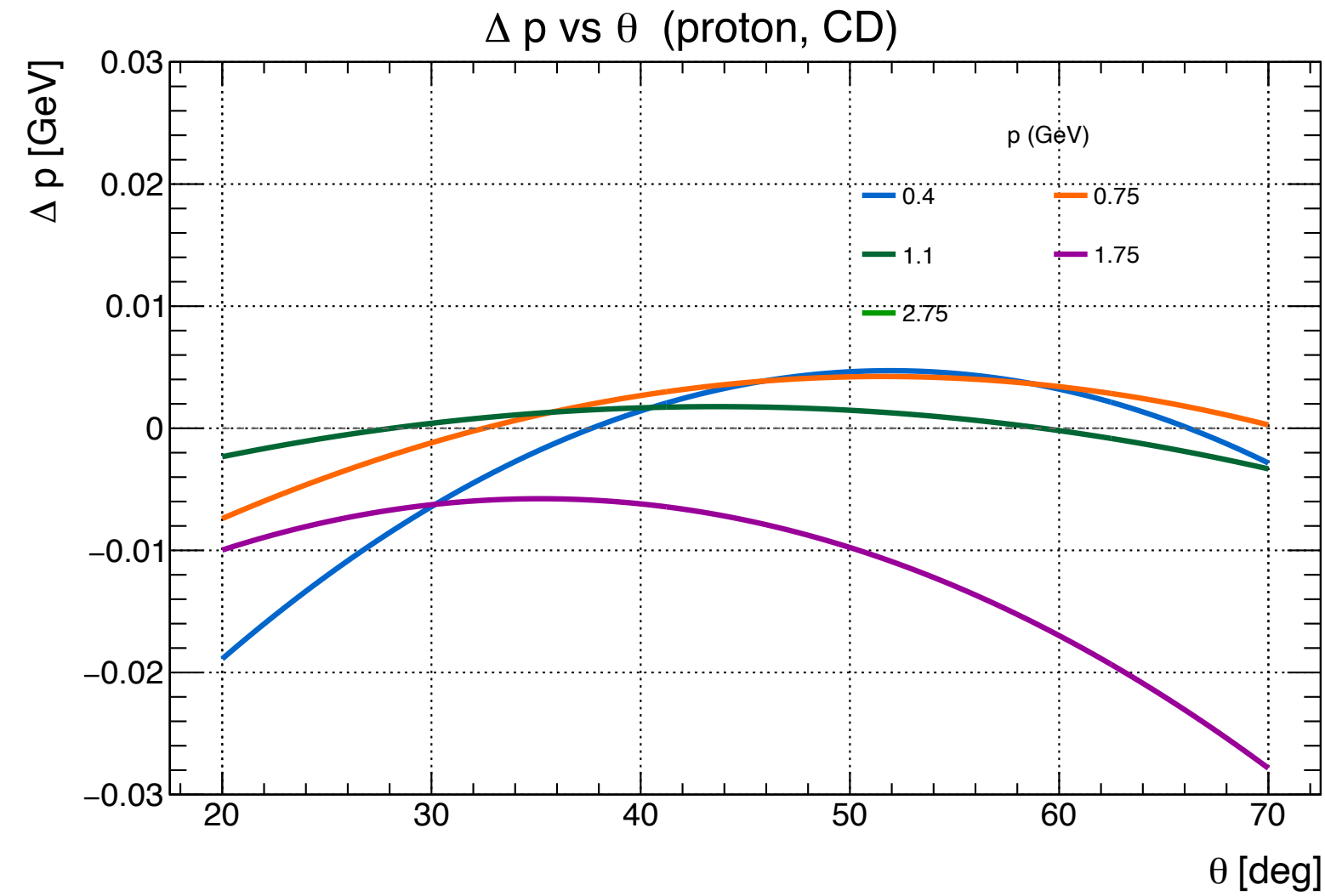
From Timothy

$$p \rightarrow p + A_p^{\text{FD}}(\theta) + B_p^{\text{FD}}(\theta)/p + C_p^{\text{FD}}(\theta)/p^2$$



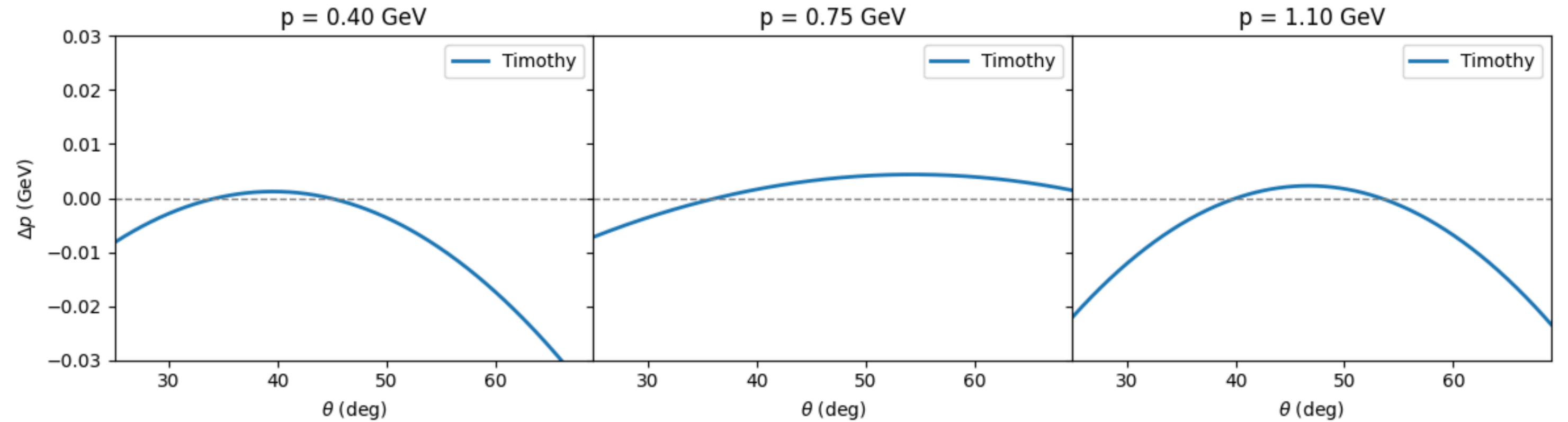
Corrections as function of theta (inb fall 2018)

- Final corrections for different momenta

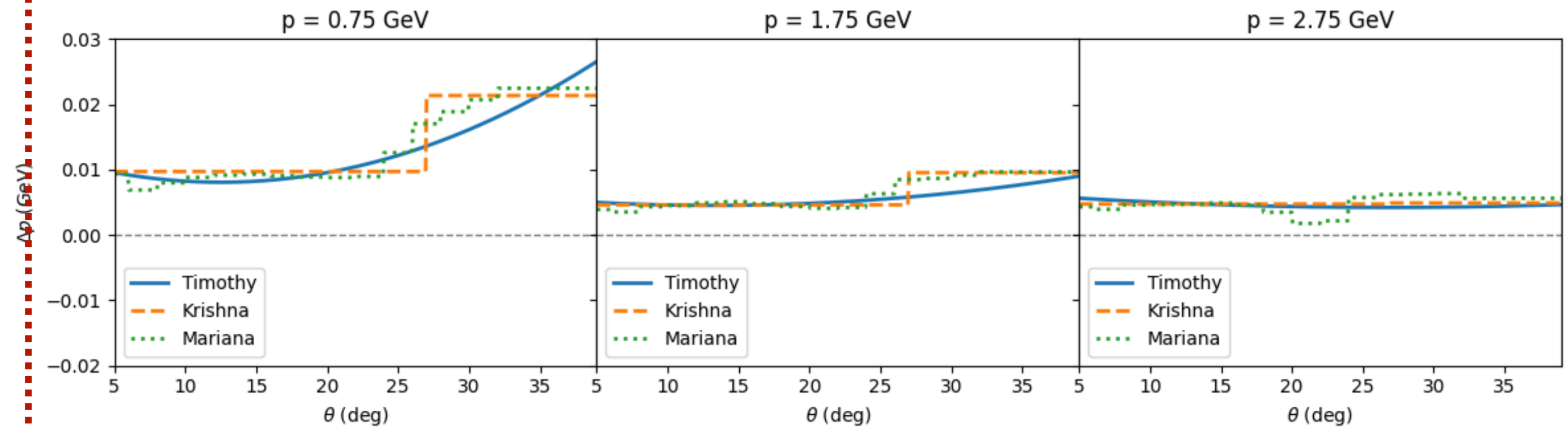


From Timothy

Central Detector Energy Loss Corrections

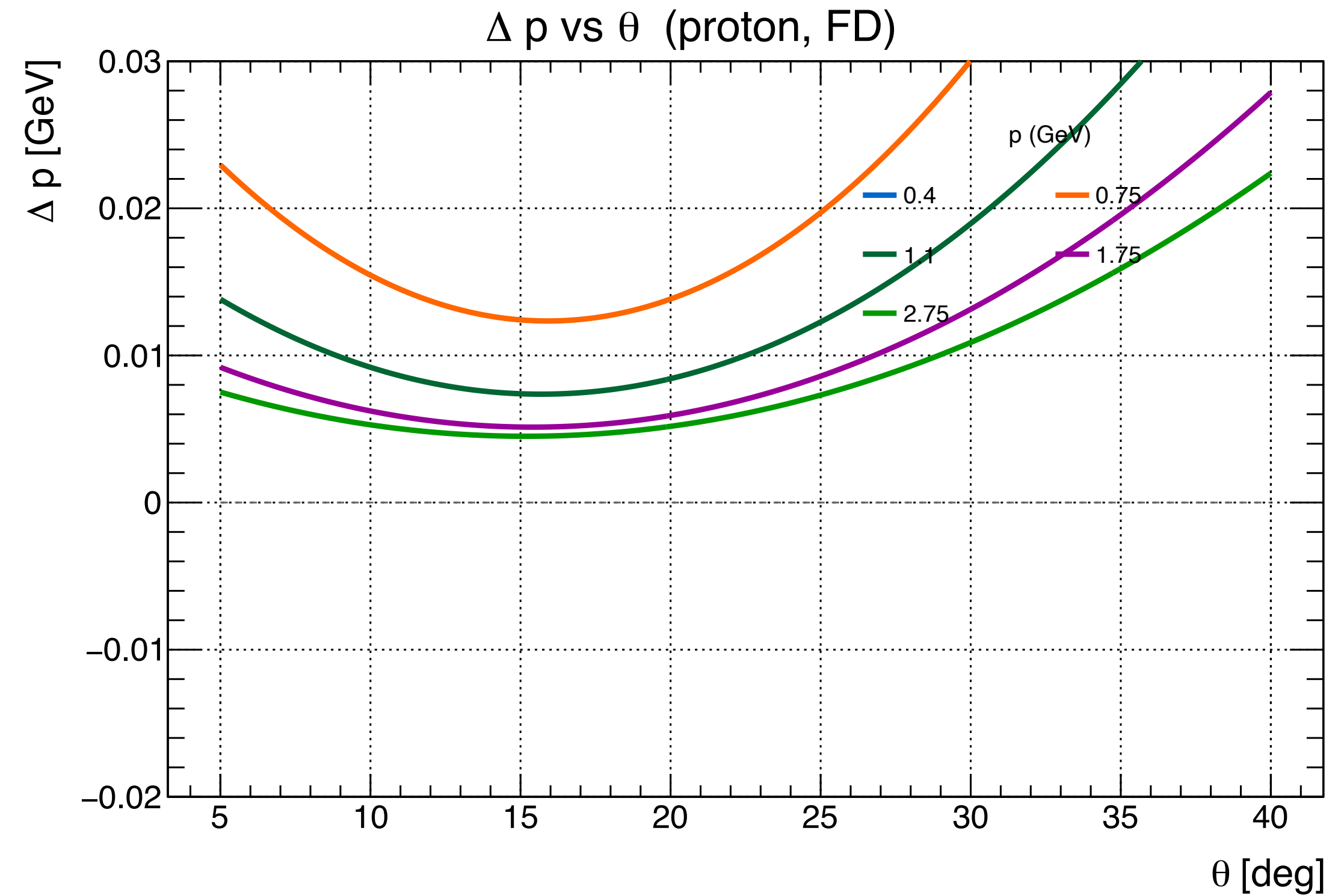
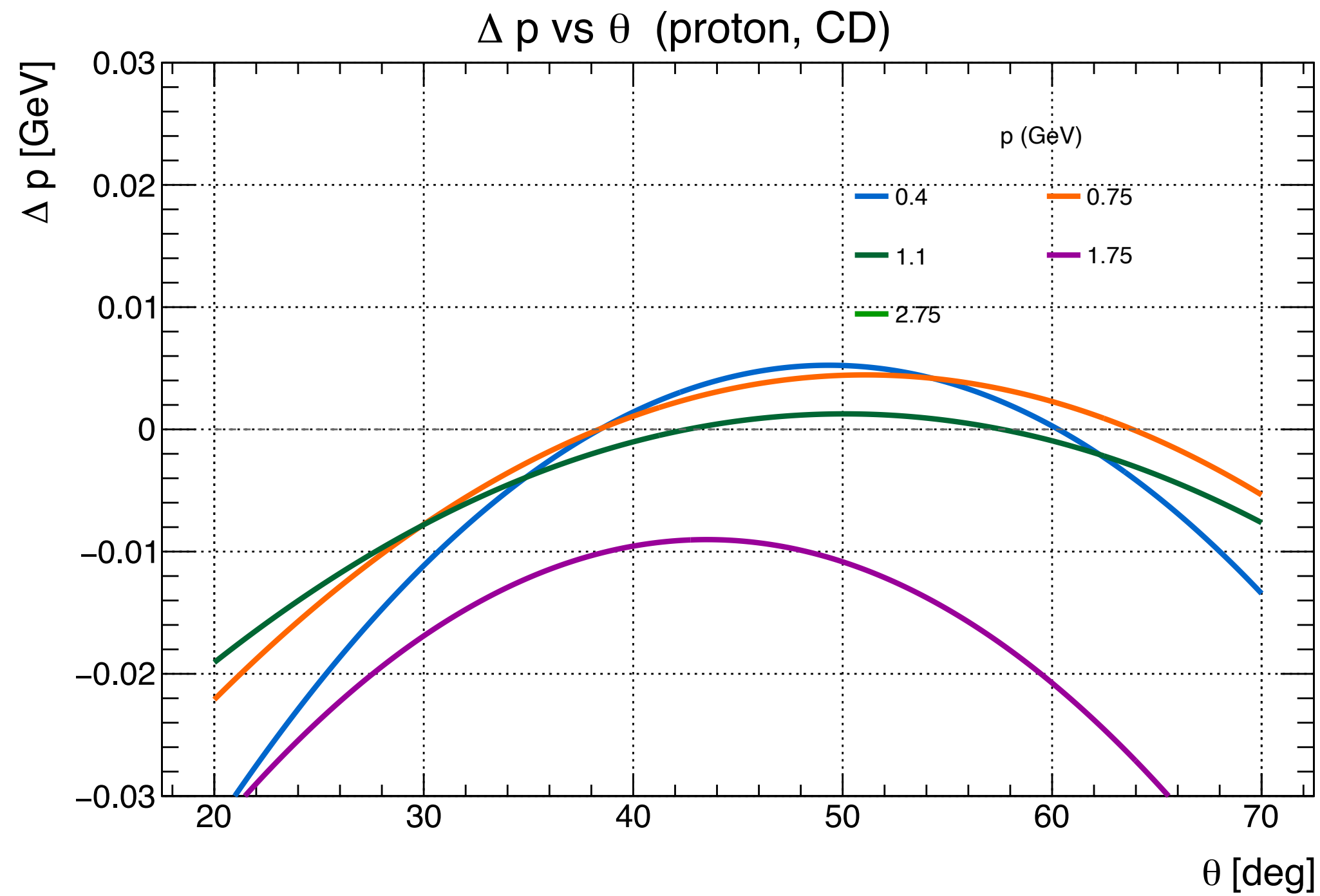


Forward Detector Energy Loss Corrections



Corrections as function of theta (inb sp2018)

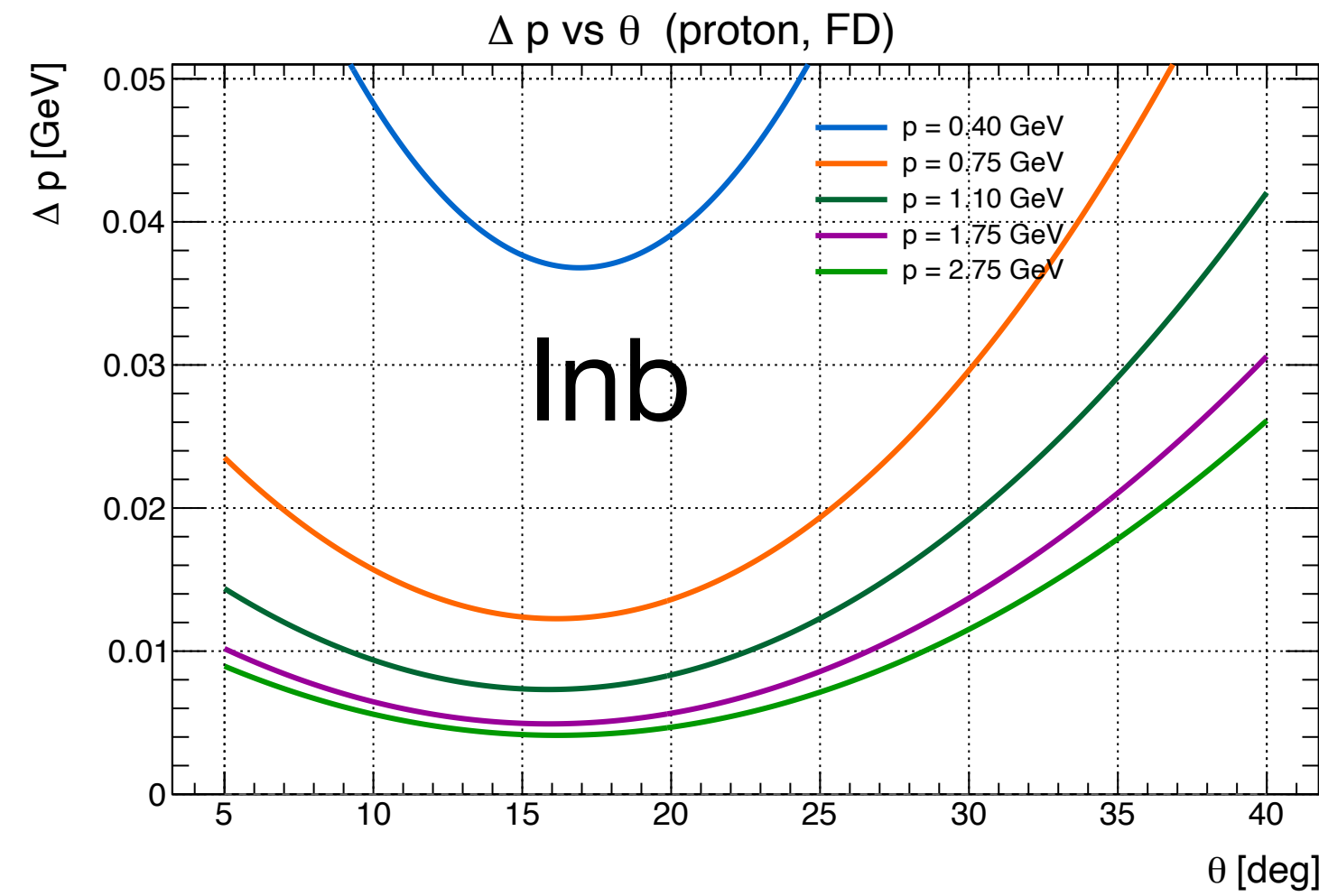
- Final corrections for different momenta



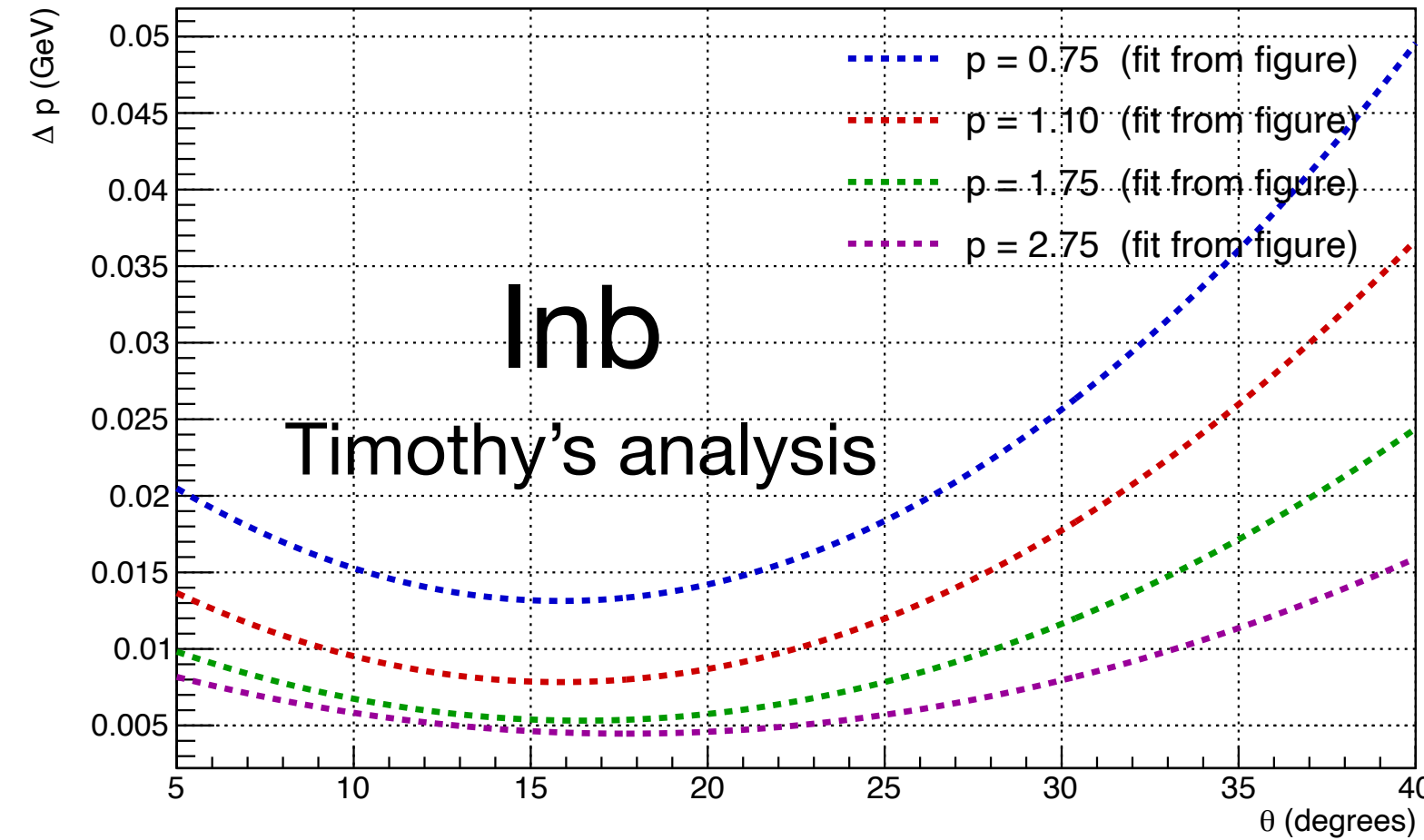
Corrections as function of theta (inb and outb sp2018)

- Final corrections for different momenta

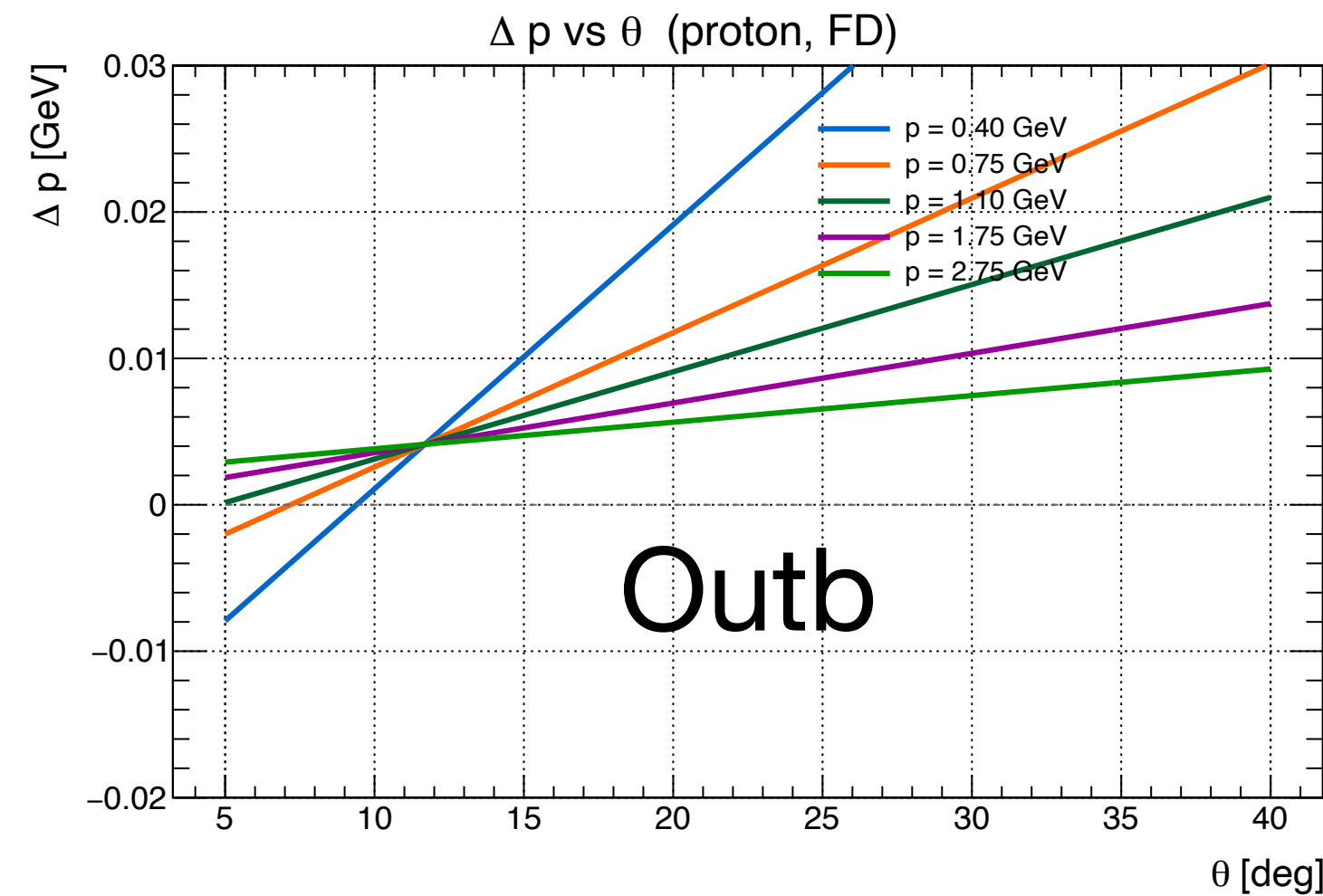
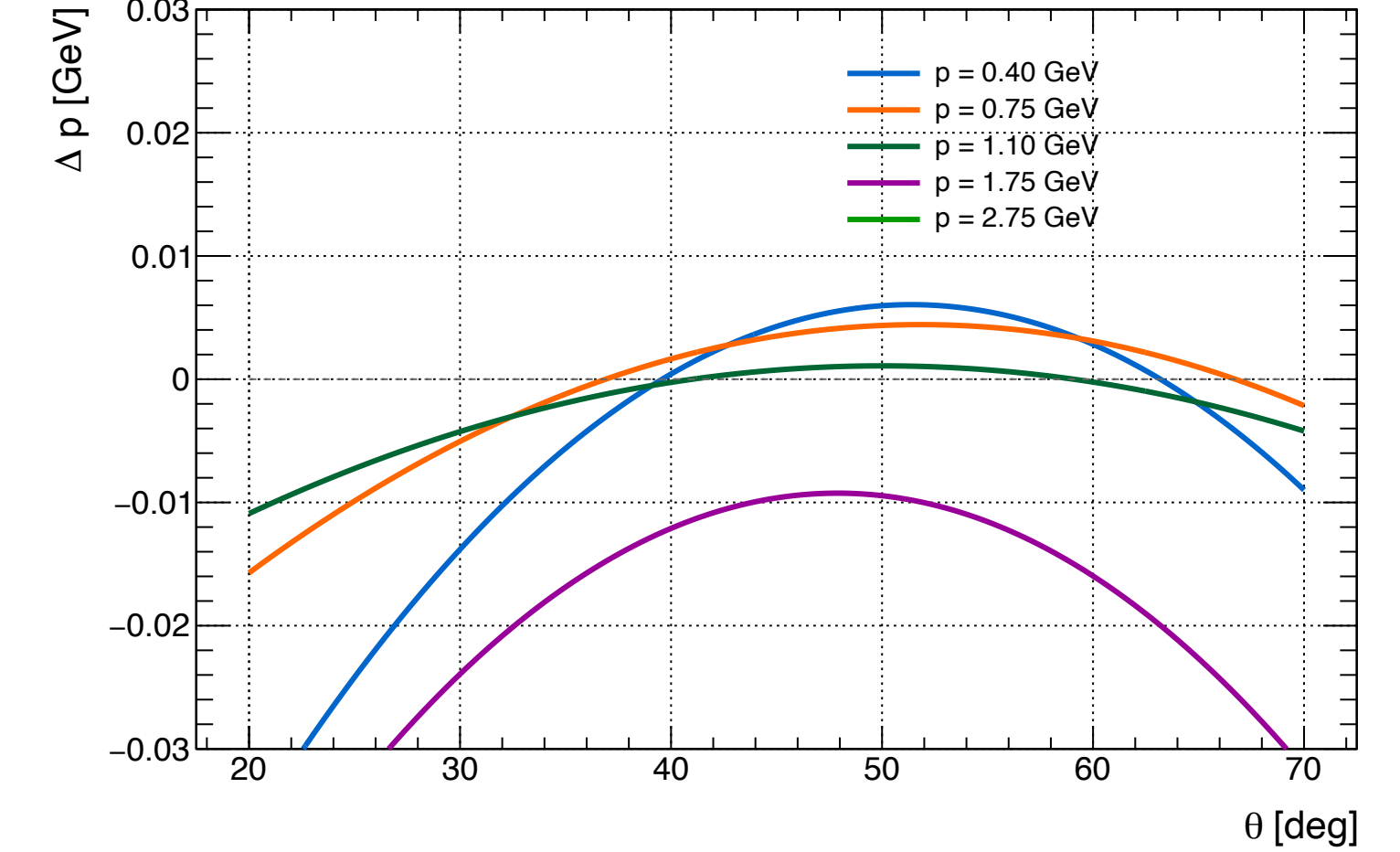
Inb



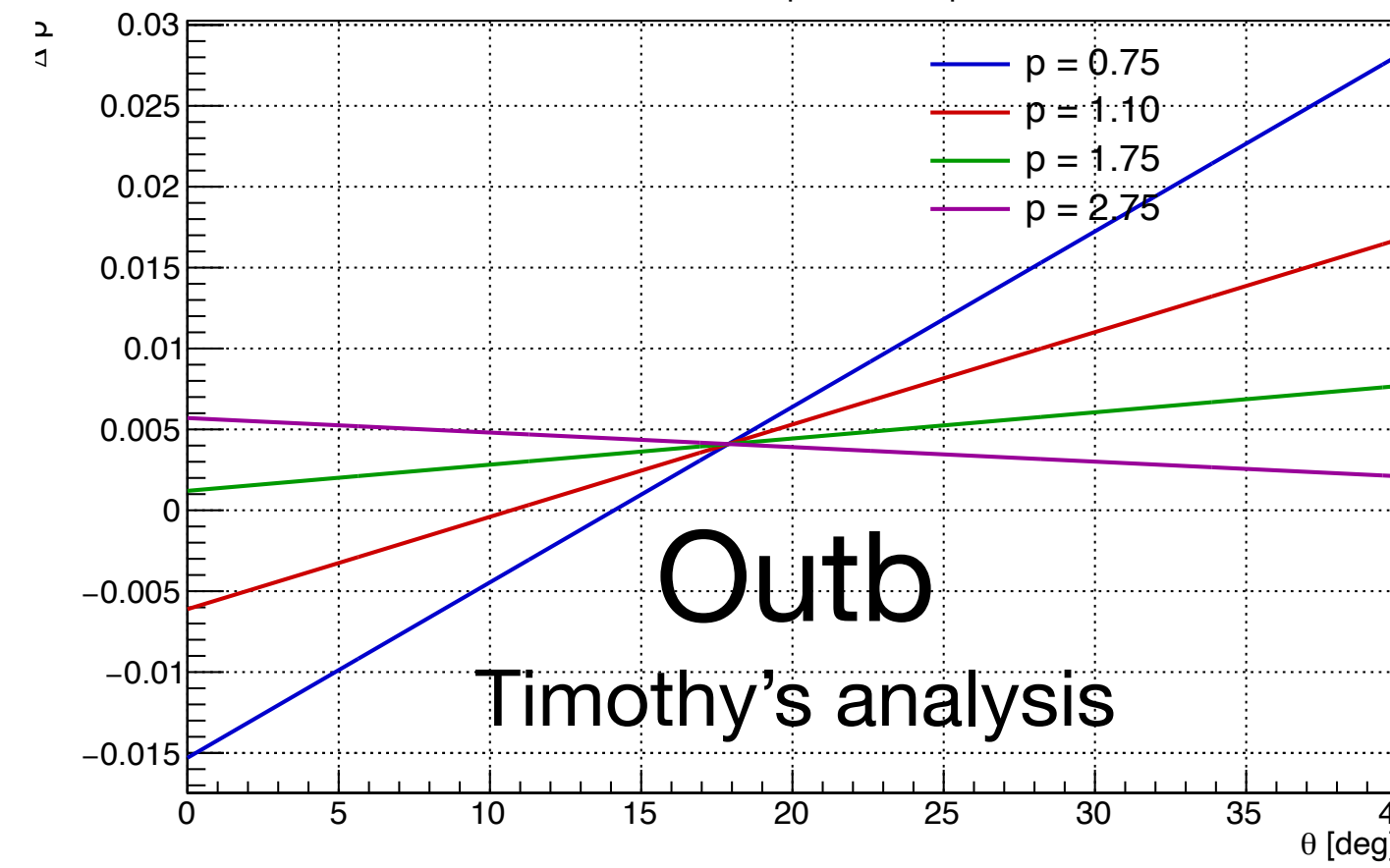
$\Delta p(\theta, p)$ FD, sp2018 inb)



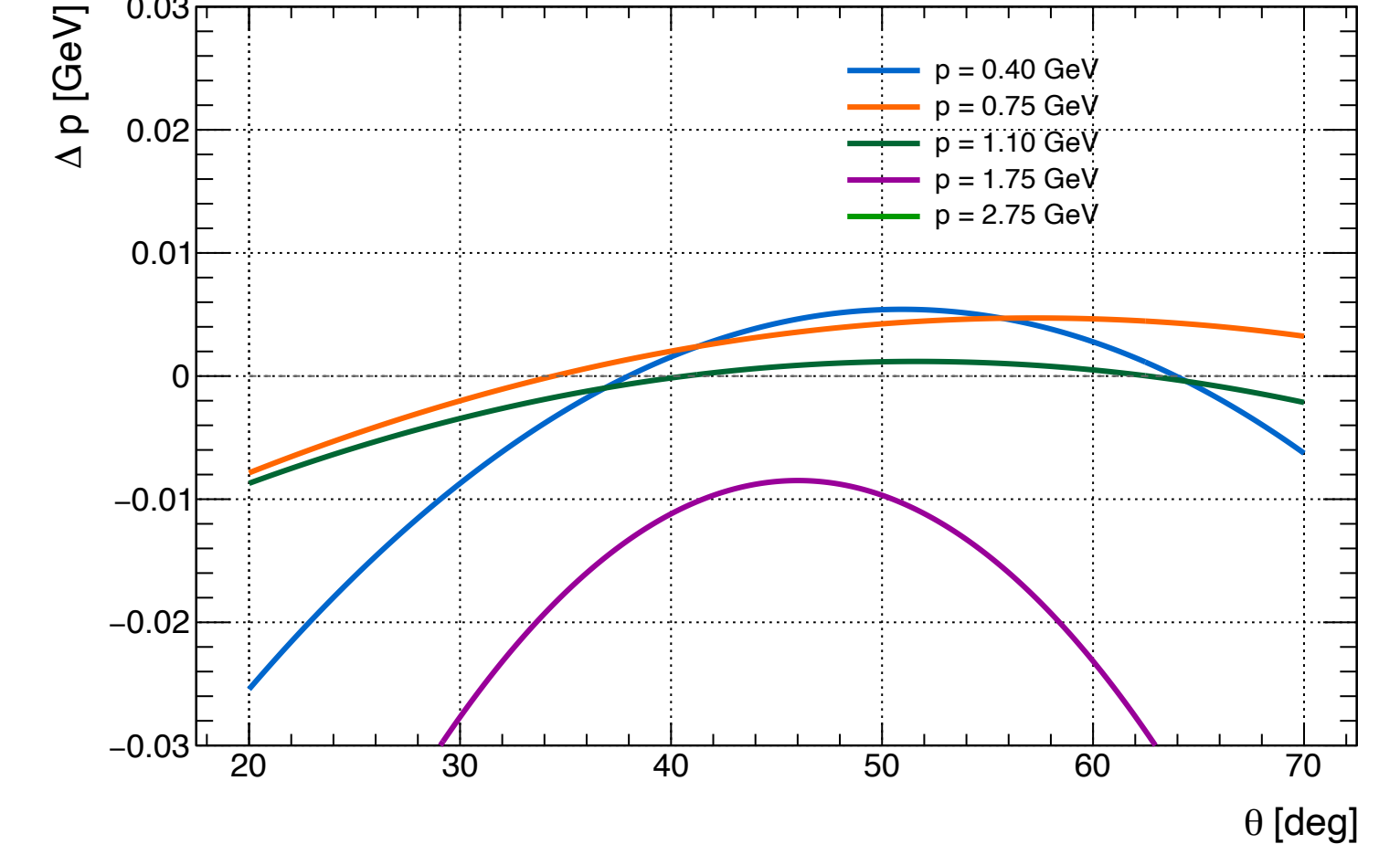
Δp vs θ (proton, CD)



$\Delta p(\theta, p) = A_p(\theta) + B_p(\theta)/p$



Δp vs θ (proton, CD)

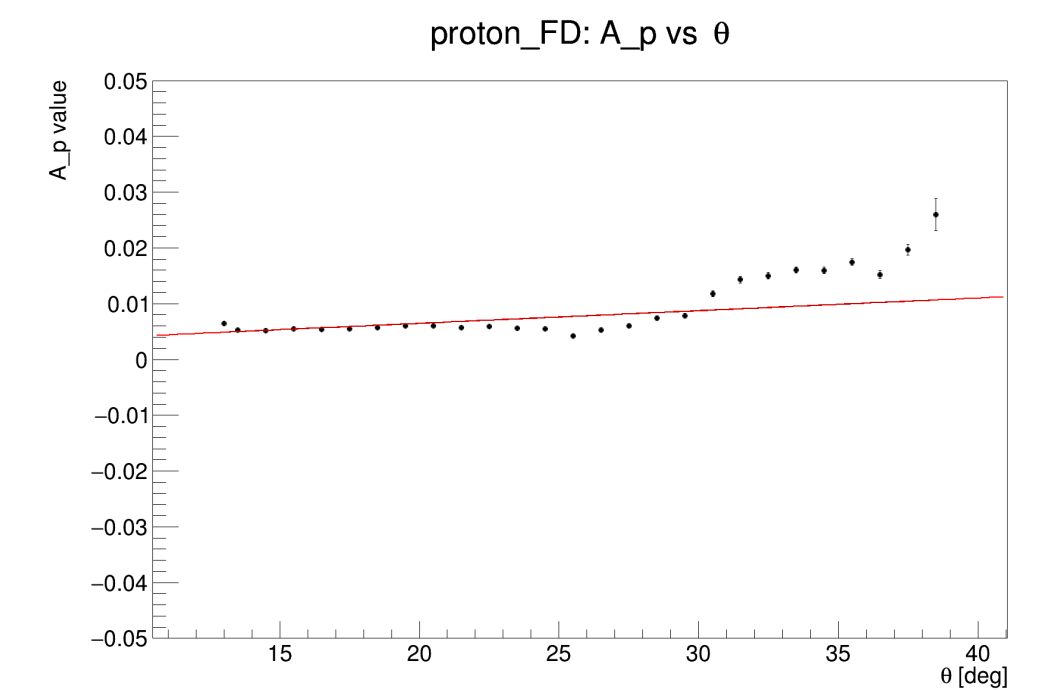
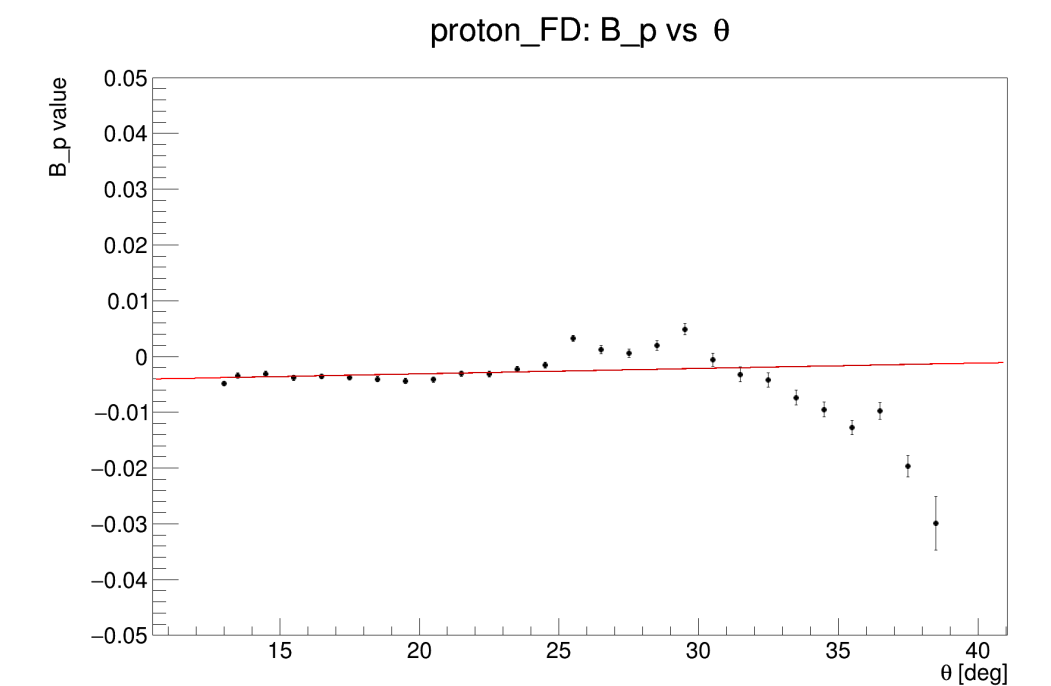
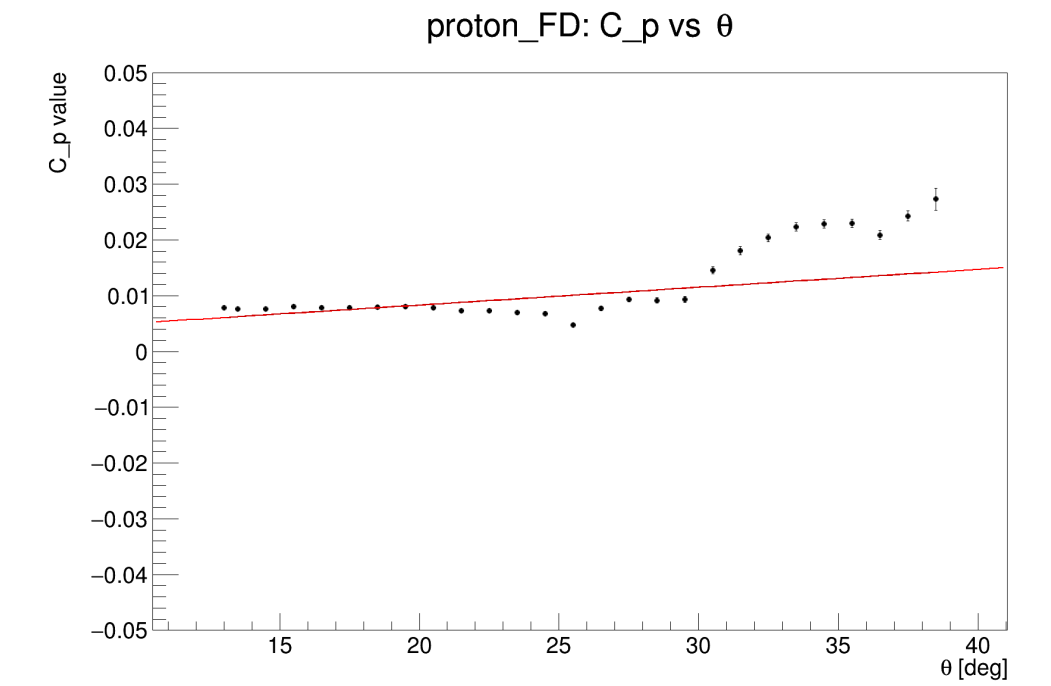
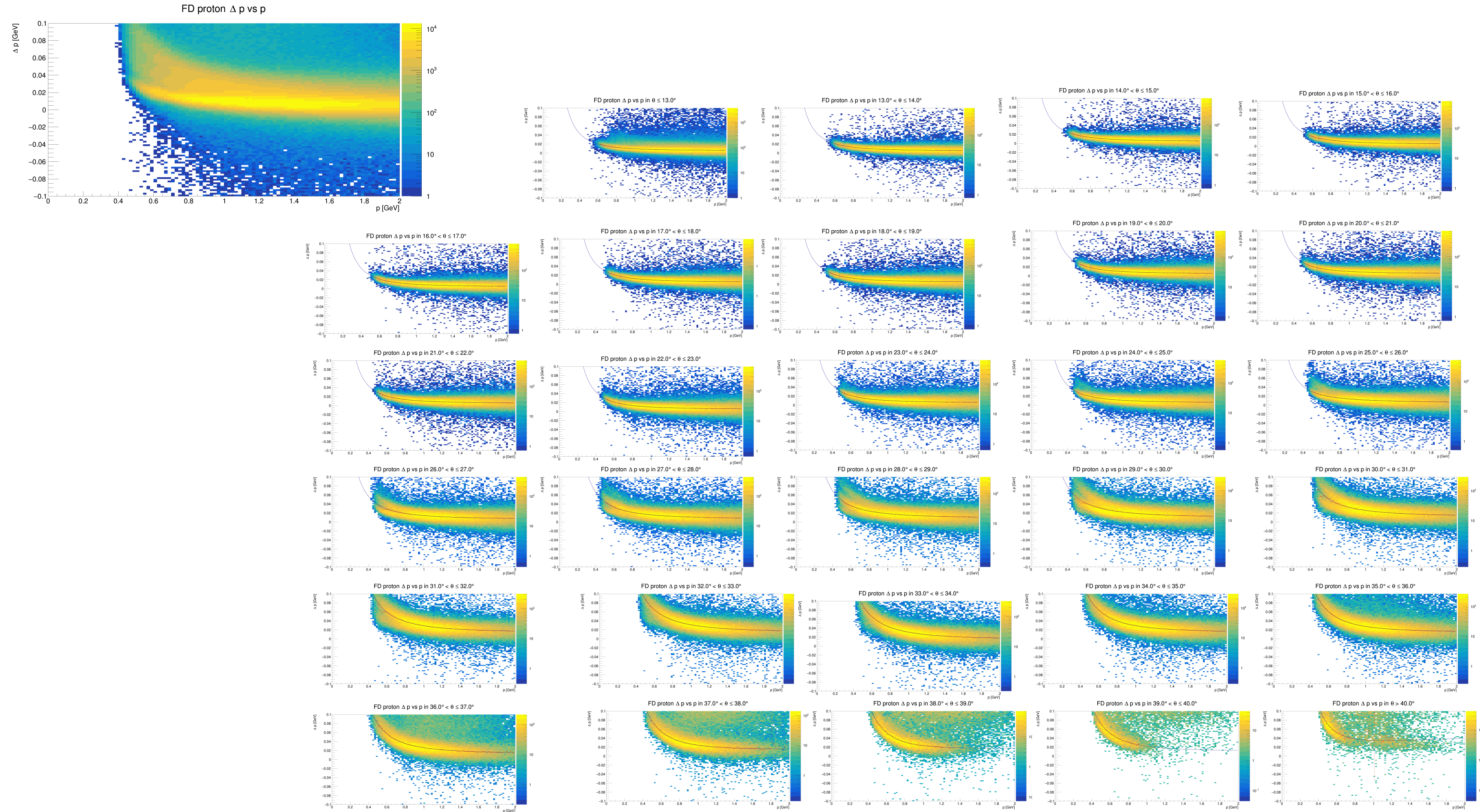


Energy Loss Correction: RGA Spring2018 inb

FD

Proton

$$\Delta p = A + B/p + C/p^2$$



Energy Loss Correction: RGA Spring2018 inb

CD Proton $\Delta p = A + B \cdot p + C \cdot p^2$

