

# **The Deepest Phi Proposal**

**Charles E. Hyde**

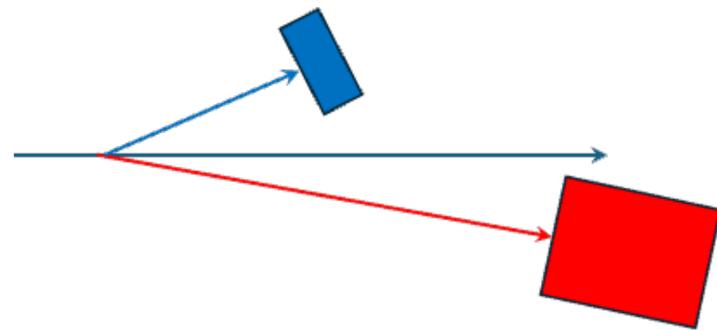
**Eric Fuchey**

**SBS Collaboration Meeting**

**9 Sept 2025**

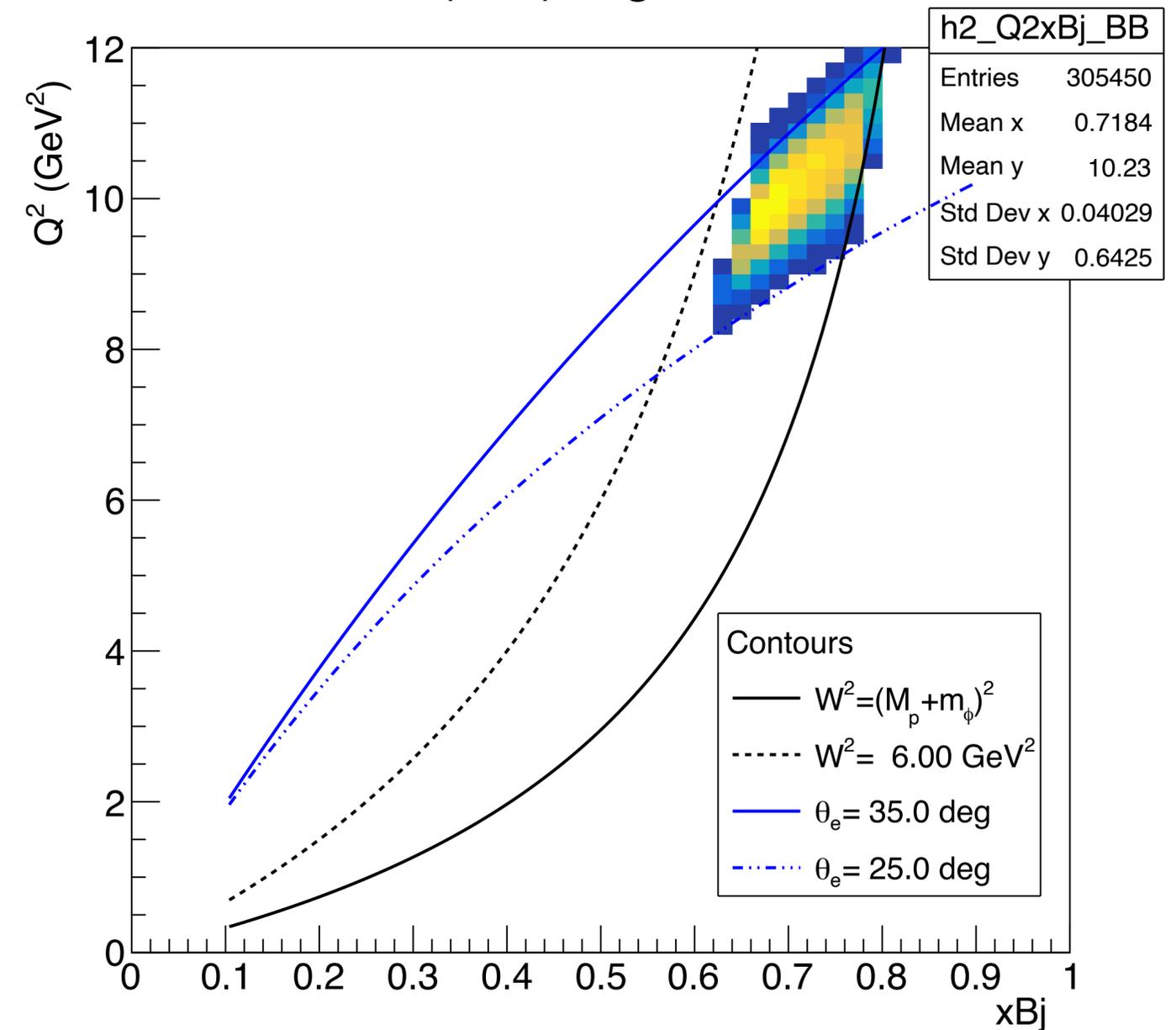
# Threshold $H(e, e'\phi)$ at $Q^2 = 9 \text{ GeV}^2$

**SBS** at 14 deg, **BB** at 30 deg



- The 11 GeV Window of Opportunity
  - Near threshold, proton and phi ~co-linear
  - Large  $Q^2$ :  $\phi$  is boosted forward,  $K^+K^-$  are in small decay cone.
  - Detect scattered electron in BigBite, at least 2 out of three hadrons in SBS.
  - SBS HCal energy sum for triggering
  - SBS PID with HERMES RICH?

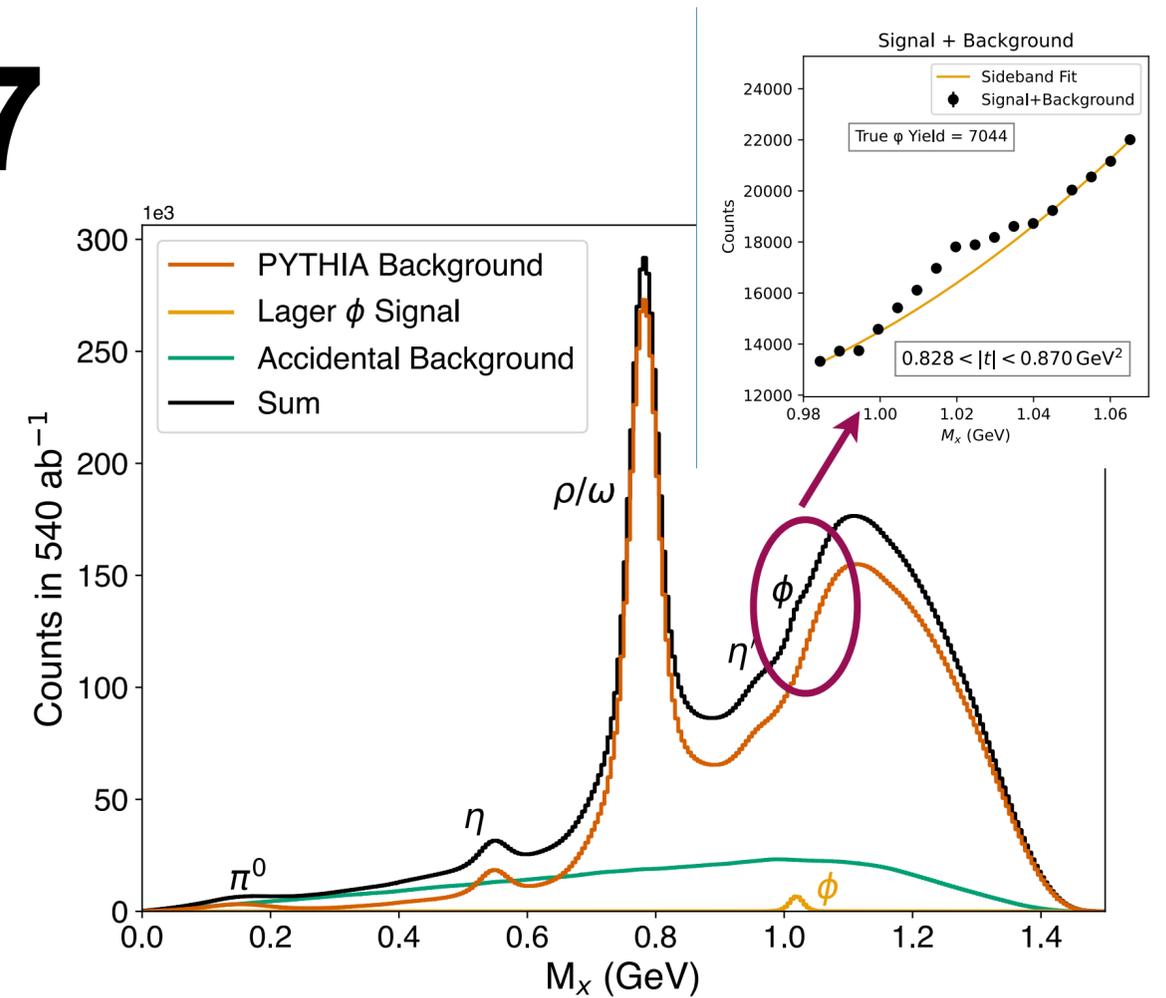
(e,e') Big Bite



# Comparison with E12-25-007

## Contrast: technique and kinematic range

- E12-25-007, H. Klest, et al
  - $H(e, e'p)X$ ,  $Q^2 = 3.4 \text{ GeV}^2$ , High Luminosity!
- This concept:
  - Explicitly identify  $ep \rightarrow ep\phi$  by detection of  $\phi \rightarrow K^+K^-$  decay channel.
  - Analyze the hadronic-final-state phase space to extract the spin-density-matrix-elements.
    - The isotropic term gives  $R = d\sigma_L/d\sigma_T$ , up to corrections from measurable violations of SCHC and Natural Parity Exchange (NPE).



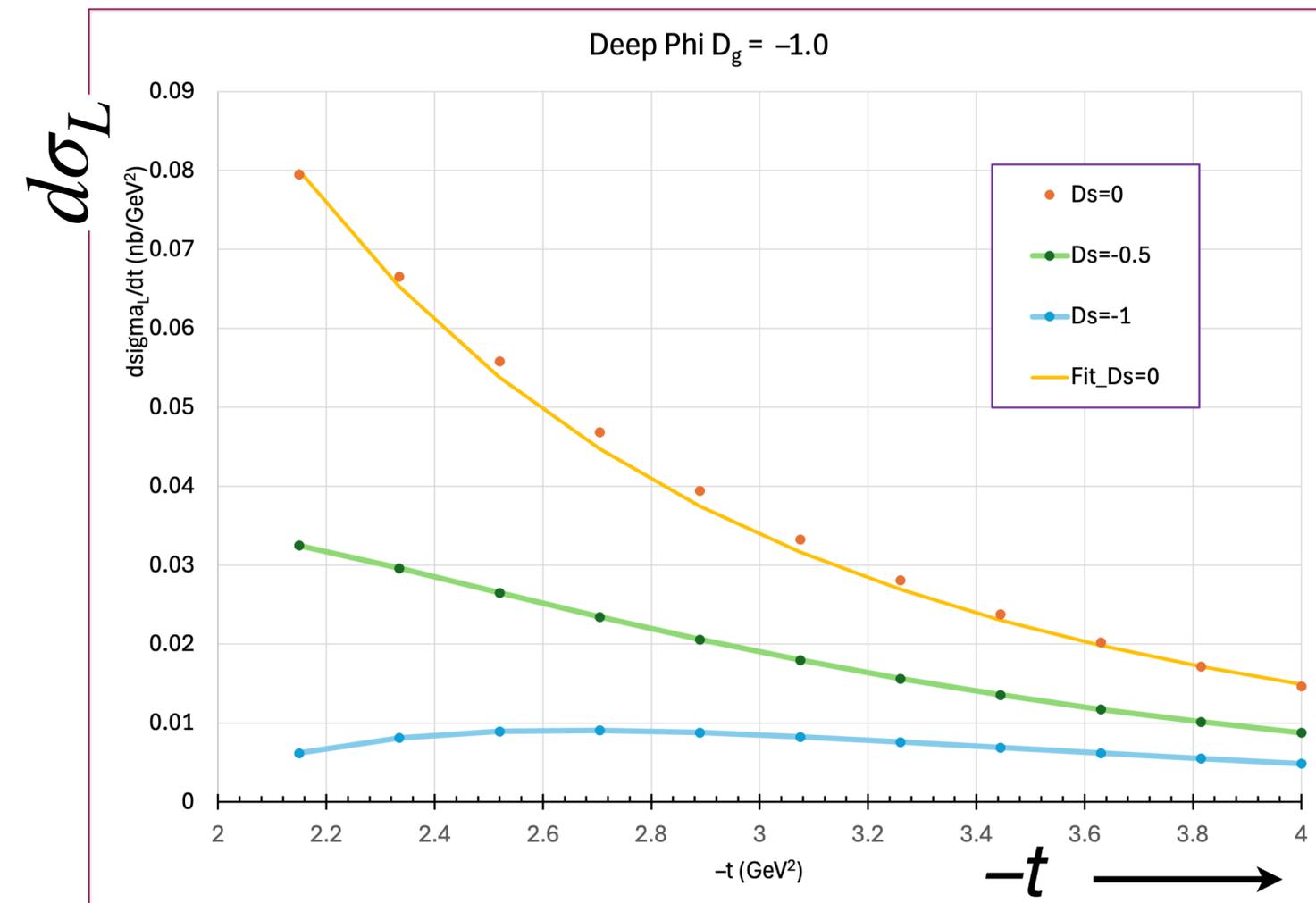
# Why High- $Q^2$ Measurement of Threshold Electroproduction of $\phi$ -Meson?

## Complementarity to threshold exclusive $J/\Psi$ production

- Perturbative scale in exclusive threshold  $J/\Psi$  production:  
 $Q^2 + M_{J/\Psi}^2 \geq 9.6 \text{ GeV}^2$ 
  - Data from GlueX and Hall C 007 collaboration
  - Proton gluonic  $d$ -term
- Threshold  $\phi$ -electroproduction at  $Q^2 \geq 9 \text{ GeV}^2$ :  $Q^2 + M_{\phi}^2 \geq 10 \text{ GeV}^2$ 
  - $\phi$ -production on same theoretical footing as  $J/\Psi$  production
  - Sensitive to combination of gluon and strange-quark  $d$ -terms

# Theory of Exclusive $\phi$ -Electroproduction

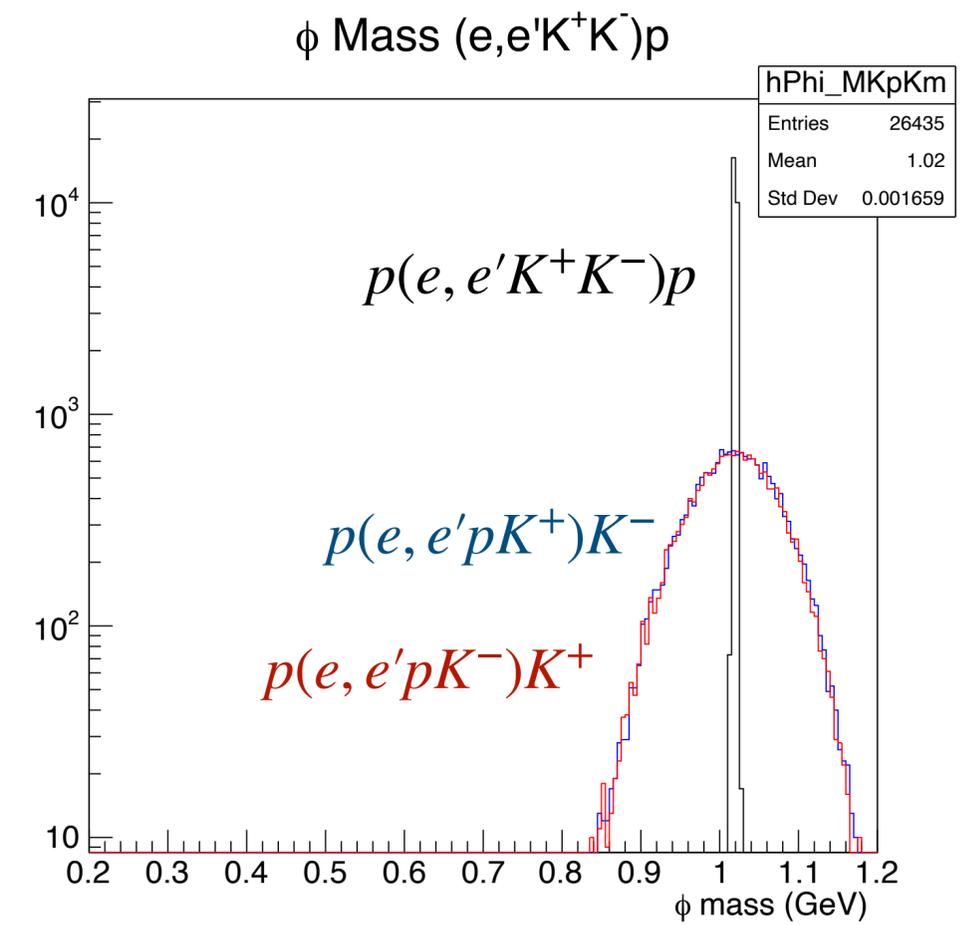
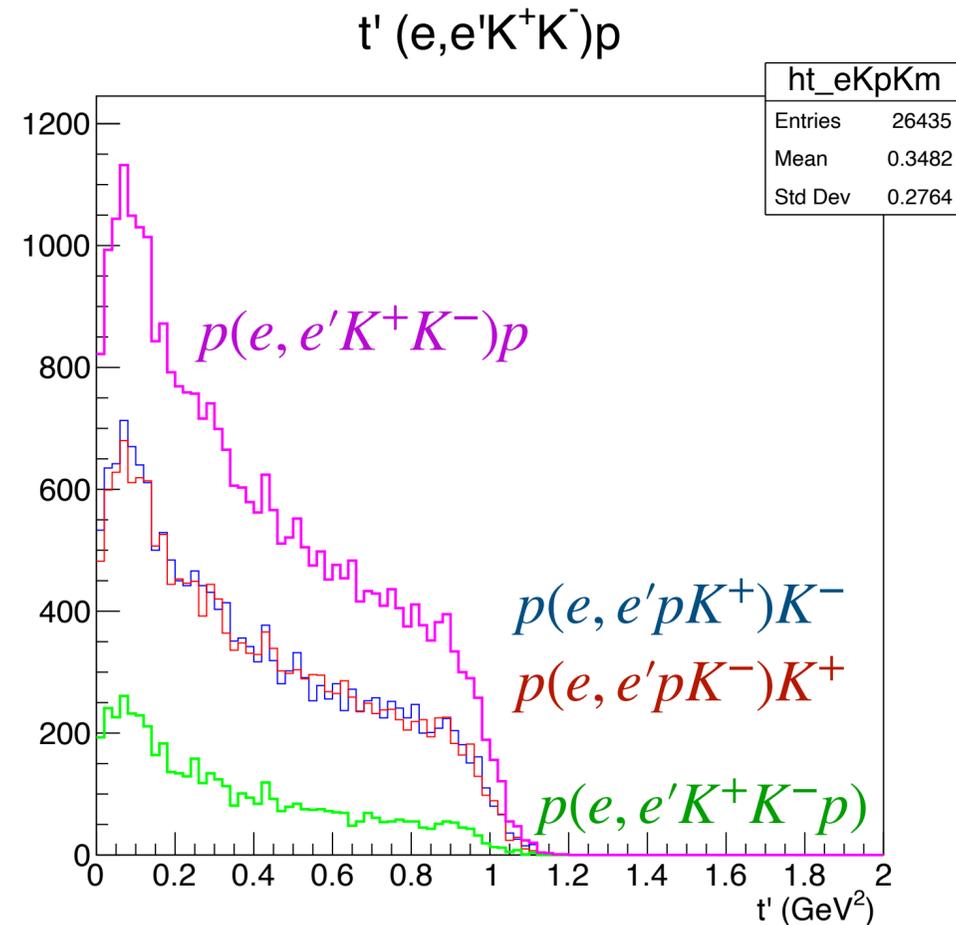
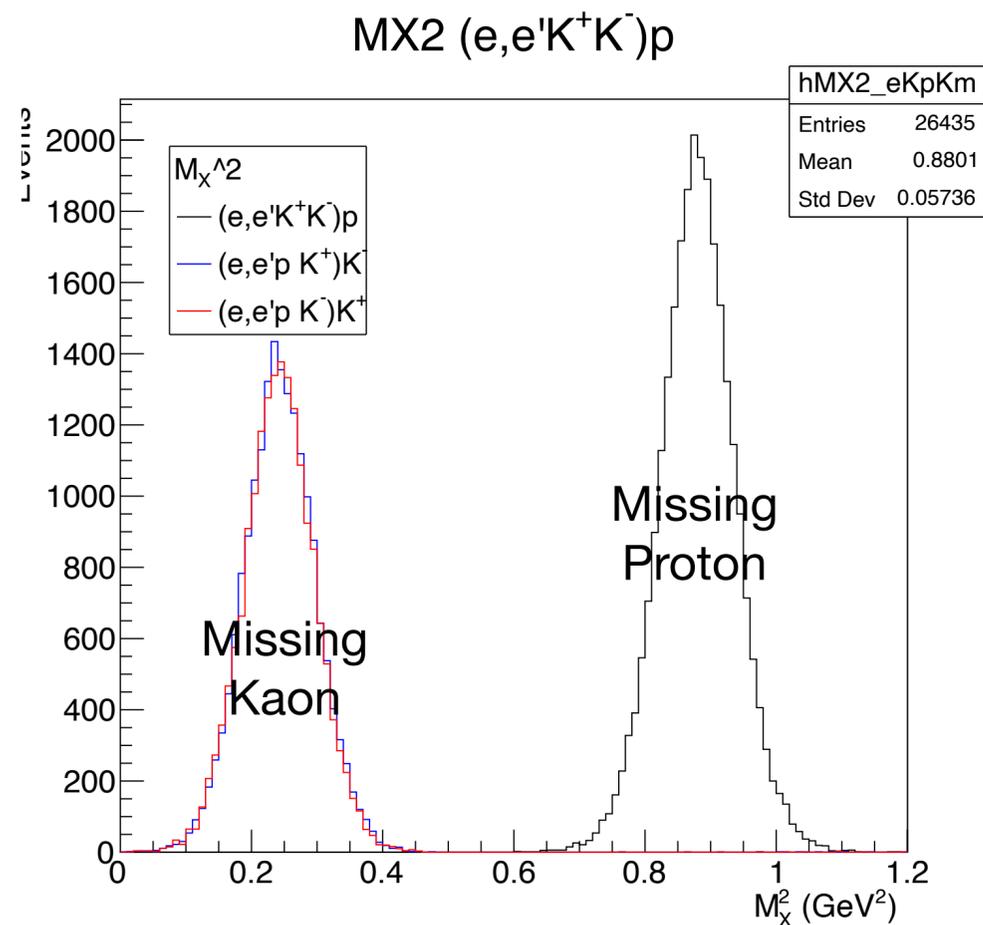
- S.Goloskokov, P.Kroll, EurPhysJ C **50**, 829–842 (2007)
  - In DVES kinematics (well above threshold)  $d\sigma_L$  dominated by gluon GPDs
  - Important contributions from  $d\sigma_T$  in JLab kinematics
- Y.Hatta, H.T.Klest, *et al*, “Deeply virtual  $\phi$ -meson production near threshold,”  
 Progress of Theoretical and Experimental Physics, (2025)  
 ptaf076, <https://doi.org/10.1093/ptep/ptaf076>
  - Calculation of contributions of both gluon and strange  $d$ -terms to  $d\sigma_L$
  - $Q^2 = 9 \text{ GeV}^2$ ,  $W = 2.2 \text{ GeV}$



# g4sbs, Acceptance, Resolution

$$Q^2 \in [8,12] \text{ GeV}^2, \quad W^2 \in [(M_p + m_\phi)^2, 6 \text{ GeV}^2], \quad t' = t_0 - t < 1 \text{ GeV}^2$$

- Uniform phase space generation
- Resolution  $\delta p/p = 1\%$   $\delta\theta = 1.5 \text{ mr}$

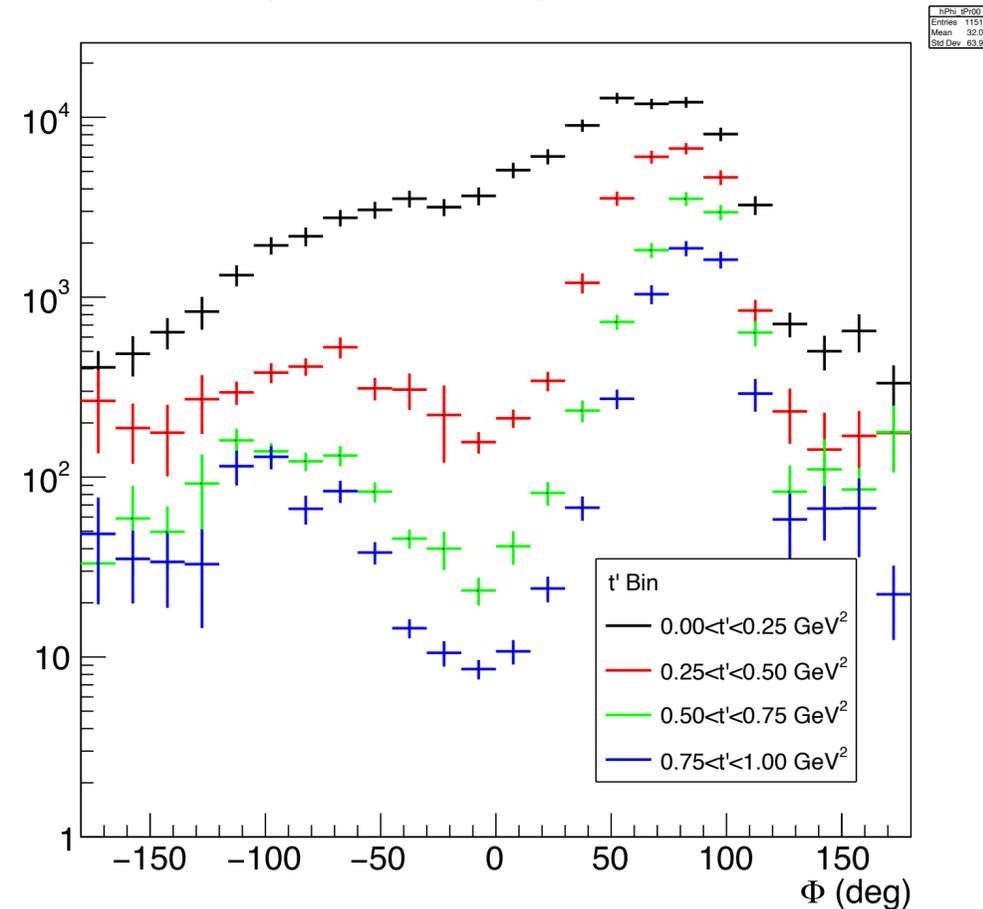


# g4sbs simulations:

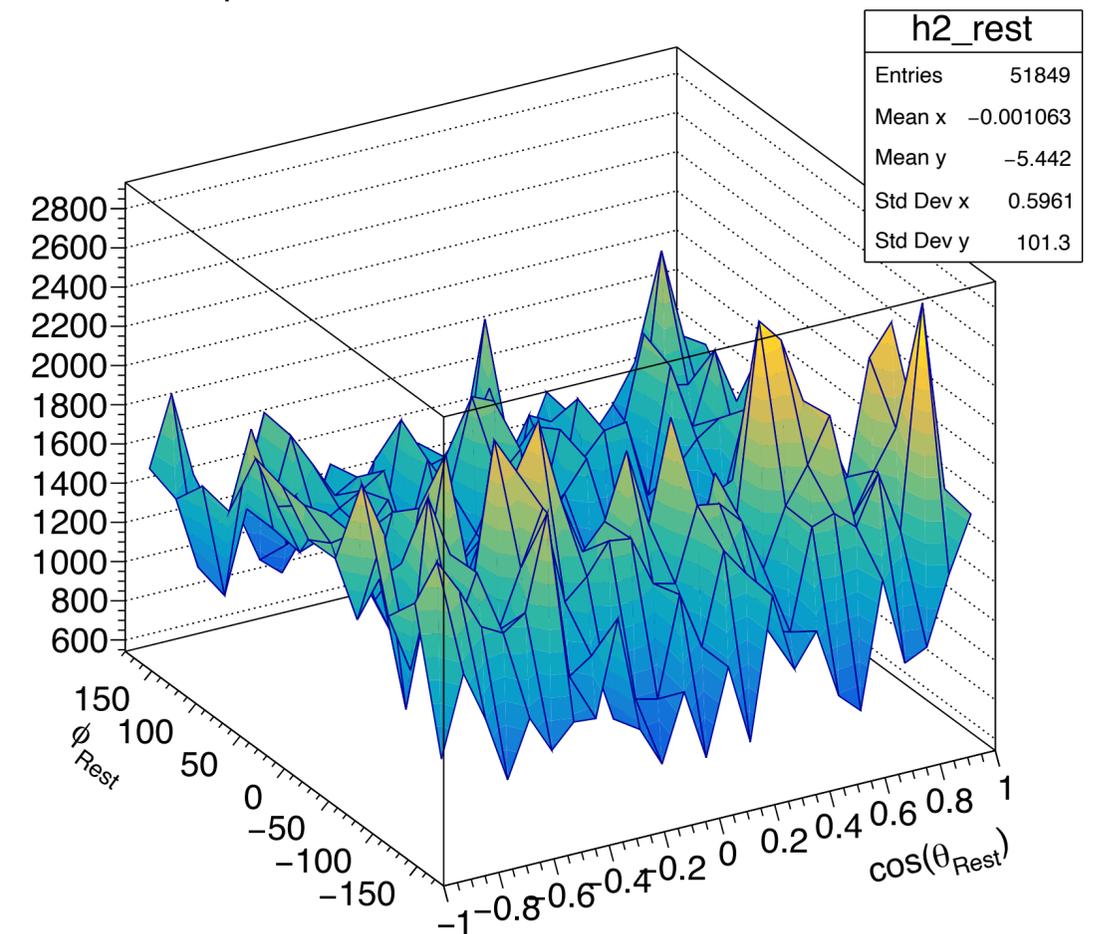
- $ep \rightarrow ep\phi$  event generator with the four leading  $\phi$ -decay channels
- SBS and BB GEANT4 acceptance simulation including resolution smearing
- Cross section weighted yield interpolated from Y. Hatta code.

- Projected yield: 40 PAC days,  $20 \mu A$  on 20 cm LH2 target
  - 50% of a 25 week run
- Two out of three hadrons from  $ep \rightarrow e'pK^+K^-$  detected in SBS
- HCal > MIP
- $\Phi$ : Azimuth of phi-meson around virtual photon q-vector
- $(\cos \theta_{\text{Rest}}, \phi_{\text{Rest}})$ : Spherical polar angle variables of  $K^+$  in  $\phi$ -meson rest-frame

$\Phi(q,\phi)$  3-Fold Projected Events



$\phi$ -meson Rest-Frame Distribution



# Initial Conclusions from g4sbs

Projected yield: 40 PAC days, 20  $\mu\text{A}$  on 20 cm LH2 target, cross section weighted

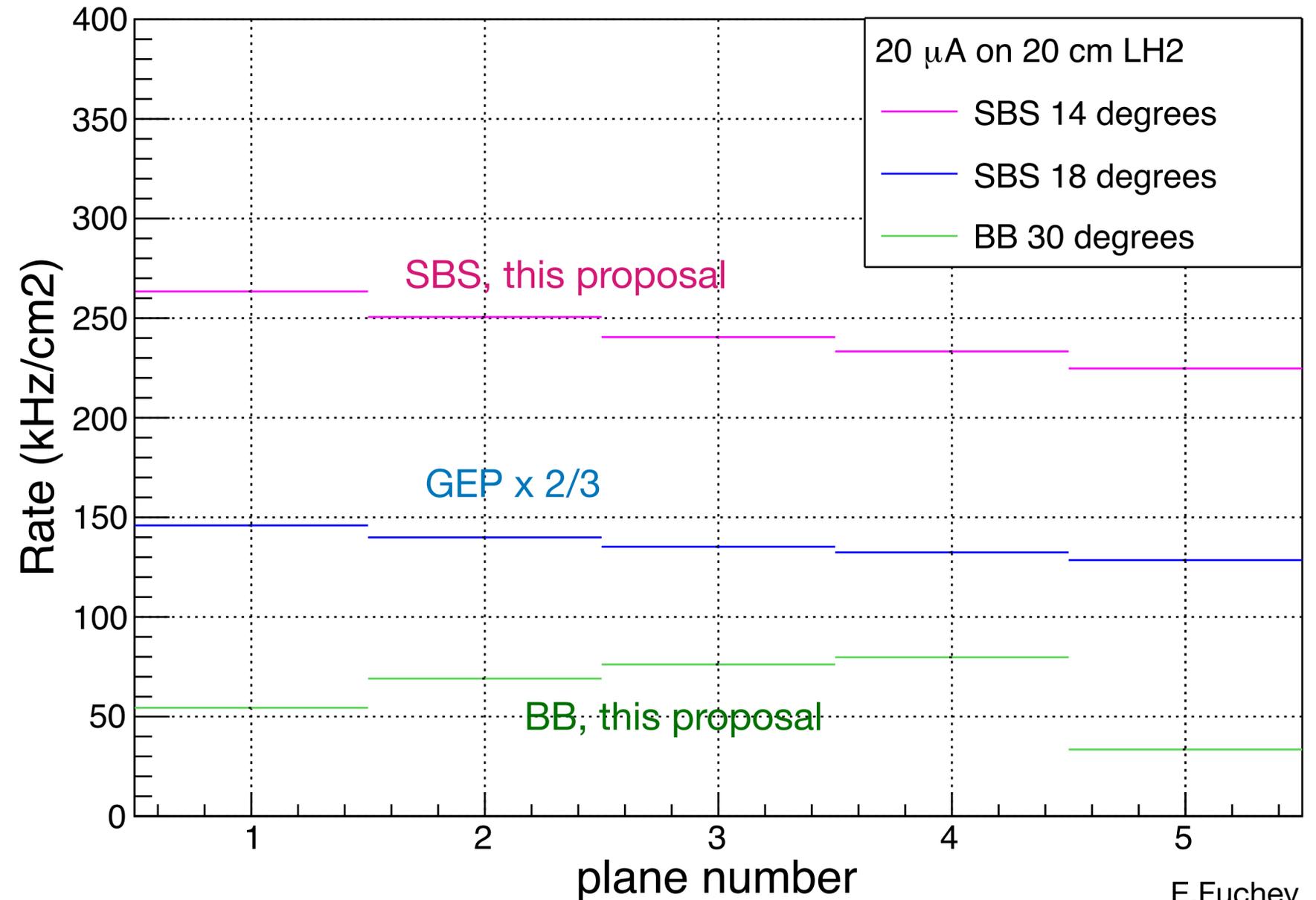
- 433,000 projected 3-fold coincidence events  $H(e, e'_{BB}[hh]_{SBS})X$ 
  - Subset of 21,000 4-fold  $H(e, e'pK^+K^-)$
- Phase space reconstruction  $(\Phi, \phi_{\text{Rest}}, \cos \theta_{\text{Rest}})$  non-uniform.
  - Sufficiently comprehensive to reconstruct spin density matrix elements (sdme).
  - $r_{00}^{04}$ : Isotropic term
  - $R^{04} = \frac{1}{\epsilon} \frac{r_{00}^{04}}{1 - r_{00}^{04}} \rightarrow R = \frac{d\sigma_L}{d\sigma_T}$  if SCHC and NPE validated by other sdme

# Recent Progress

## 1) Detector Background

- Random projected hit rates in BB, SBS
- G4sbs
  - SBS rates for this experiment would be comparable to GEp (20  $\mu\text{A}$  on 30 cm)
- Upgraded GEM DAQ could push luminosity higher

SBS GEM background

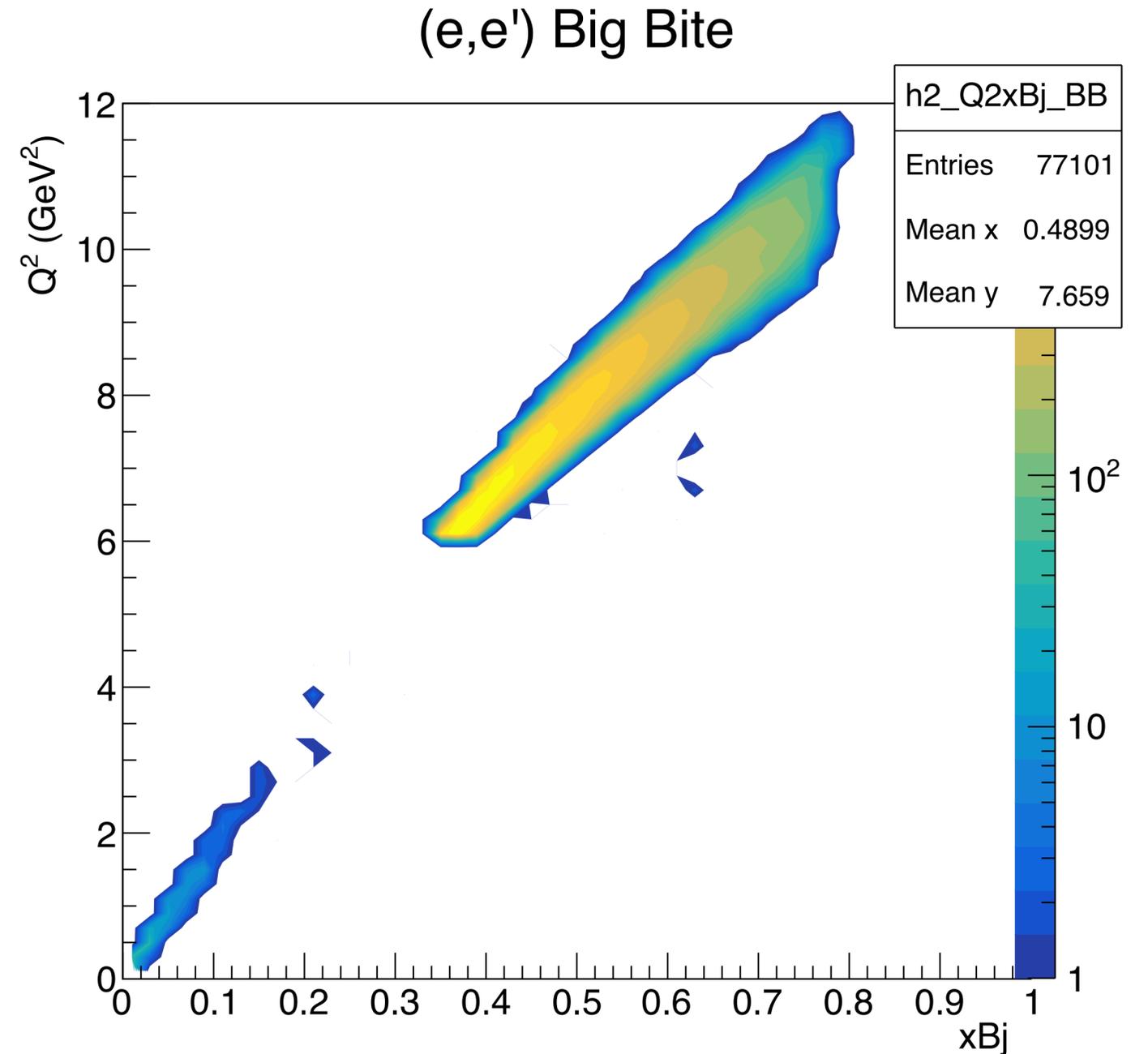


E.Fuchey

# Recent progress

## 2. Physics Backgrounds

- E. Fuchey: Pythia ensemble, 8M events at  $Q^2 \geq 6 \text{ GeV}^2$ ,  $W^2 \geq 4 \text{ GeV}^2$ 
  - Analysis in progress
    - For e.g.  $H(e, e'_{BB}[K^+K^-]_{SBS})X$  events:
      - What is inclusive background to the exclusive  $X=p$  channel?
      - What is the impact of pions mis-identified as kaons (RICH performance requirements)?



~1/4 of Pythia statistics

# Much More Work for a May 2026 Proposal

- PID simulation: HERMES RICH performance requirements
- Complete PYTHIA background study
  - $H(e, e'pK^+)X$
  - $H(e, e'pK^-)X$
  - $H(e, e'K^+K^-)X$
- Model  $d\sigma_T$  and spind-density matrix elements (some) in cross section weighting (use estimates from HERMES, HERA)?
- Systematic errors on extraction of  $r_{00}^{04}$  and other sdme
- Suggestions? Collaborators?