Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, October 6th 2017

Publications:

CLAS 2016-10
Determination of the proton spin structure functions for $0.05 < Q^2 < 5.0$ GeV^2 using CLAS
R. Fersch, submitted to Phys Rev C

CLAS 2017-06
Semi-inclusive π^0 target and beam-target asymmetries from 6 GeV electron scattering with CLAS
S. Jawalker, submitted to Phys. Lett. B

CLAS 2017-09
Measurement of Unpolarized6 Cross Sections and Polarized Cross Section Differences for Deeply Virtual Compton Scattering (DVCS) on the proton at the Jefferson Laboratory with CLAS, at $0.1 < x_B < 0.58$, $1.0 < Q2 < 4.8$ GeV^2, and $0.09 < -t < 2.0$ GeV^2,
H. Saylor, submitted to Phys. Rev. C

Ad Hoc Review

Analysis	Data	Lead Author	In progress
Beam spin asymmetries of ep->epη in the deep inelastic regime	**e1f**	**A. Kim**	Done Sep 17
Hard exclusive backward-angled single charged pion electronproduction from the proton at CLAS	**e16**	**K. Park**	2nd round in September

Analysis Review

Analysis	Data	Author	In progress
Measurement of the spin structure g_1^d of the deuteron and its moments at low Q^2	**eg4**	**K. Adihari**	Done Sep 17
Beam asymmetries in exclusive π^+ electro production for W> 1.7 GeV from e16	**e16**	**P. Bosted**	Ongoing
Exploring the structure of the proton via semi-inclusive pion electroproduction	**e1f**	**N. Harrison** **K. Joo**	Ongoing

Analysis Review

Analysis	Data	Author	In progress
Exclusive electroproduction of the f0(980) and f2(1270) on the proton with CLAS	**e1f**	**B. Garillon** **S. Niccolai**	Brice busy with other project, V2 in one month
Di-hadron beam spin asymmetry in SIDIS electro production	**eg1-dvcs**	**S. Pisano**	Silvia busy with other project Last version in one month
Deep-virtual production of the ρ^+ meson off the proton	**e1-dvcs**	**A. Fradi**	Ahmed busy with other projects. Slow progress
Semi-inclusive pion production	**e16**	**M. Osipenko**	Working on a better alignment
Time-like Compton scattering	**g12**	**I. Abayrak**	Last record 2015

DPWG Meeting, 5th October 2017

Future plans and opportunities (morning)

CLAS6 Analysis (afternoon)

Studies and developments for CLAS12 (afternoon)

Common WG session (11:00 − 12:30):

- a possible analysis framework common to the whole Collaboration
- the role of the WGs in CLAS12 to help
  strengthening the analysis quality and shortening the review time

Positron beam opportunities with CLAS12*)

Volker Burkert

High Impact Science Program for Positrons?

- Deeply Virtual Compton Scattering (DVCS) with e^+/e^-
  - Extraction of leading twist Compton Form Factors (CFF) and GPDs
- Two-photon contributions to electron-proton elastic scattering
  - How well do we know the fundamental electromagnetic elastic proton form factors?

- Prepare Letter of Intent for PAC46 ?

For positron source & injector/machine options:

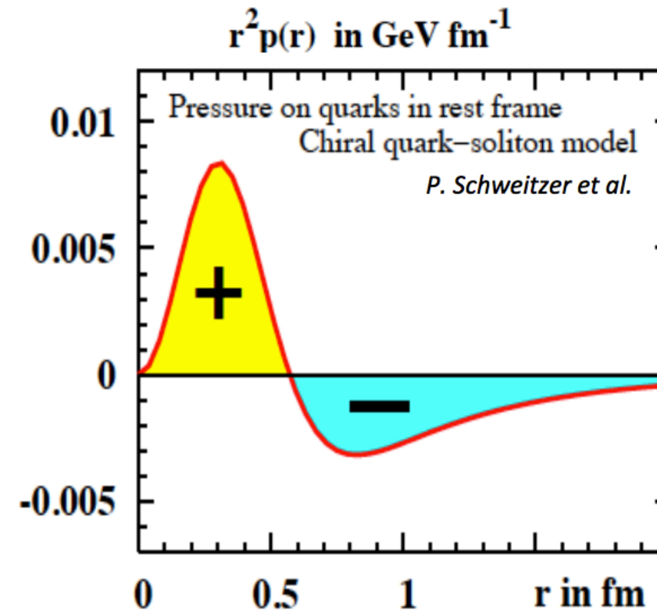
www.jlab.org/conferences/JPos2017

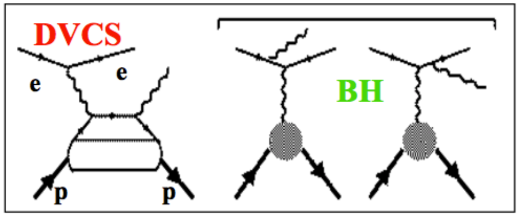
Accessing the forces & pressure on quarks

$$M_2^q(t) + \frac{4}{5} d_1(t)\xi^2 = \frac{1}{2}\int_{-1}^{1} dx\, x H^q(x,\xi,t)$$

To determine $d_1(t)$ we need $\mathcal{Re}\{H^q\}$ and $\mathcal{Im}\{H^q\}$

Measuring $d_1(t)$ will access the pressure distribution and shear forces on quarks in protons => how is confinement realized.

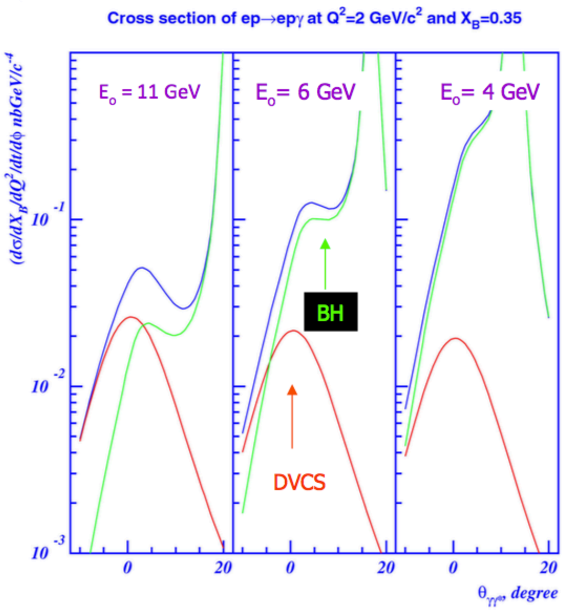




$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} \sim |\mathcal{A}^{DVCS} + \mathcal{A}^{BH}|^2$$

$\mathcal{A}^{BH}$: given by elastic form factors F_1, F_2

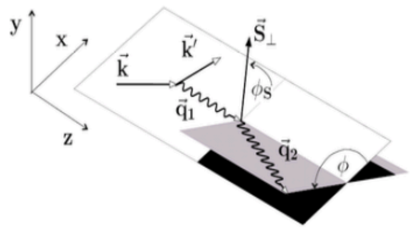
$\mathcal{A}^{DVCS}$: determined by GPDs



$$I \sim 2(\mathcal{A}^{BH})\mathrm{Im}(\mathcal{A}^{DVCS})$$

Accessing the forces & pressure on quarks

Polarized Beam, unpolarized Target:

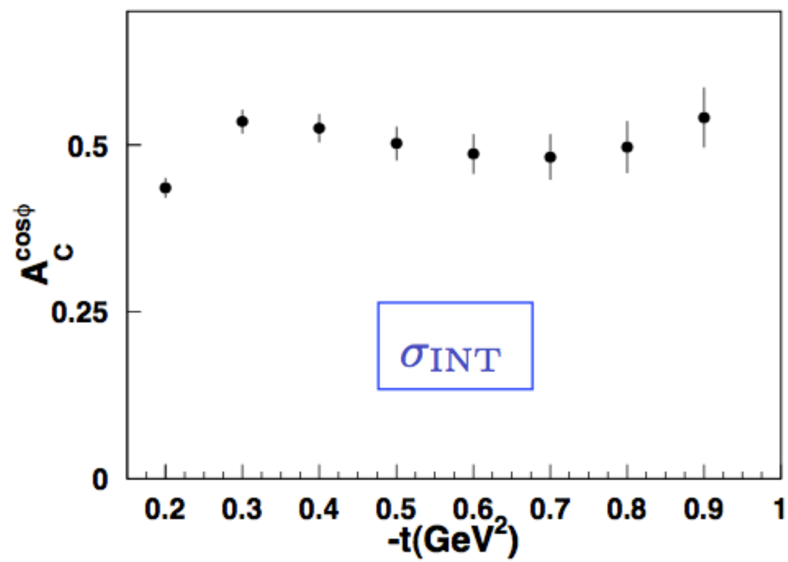


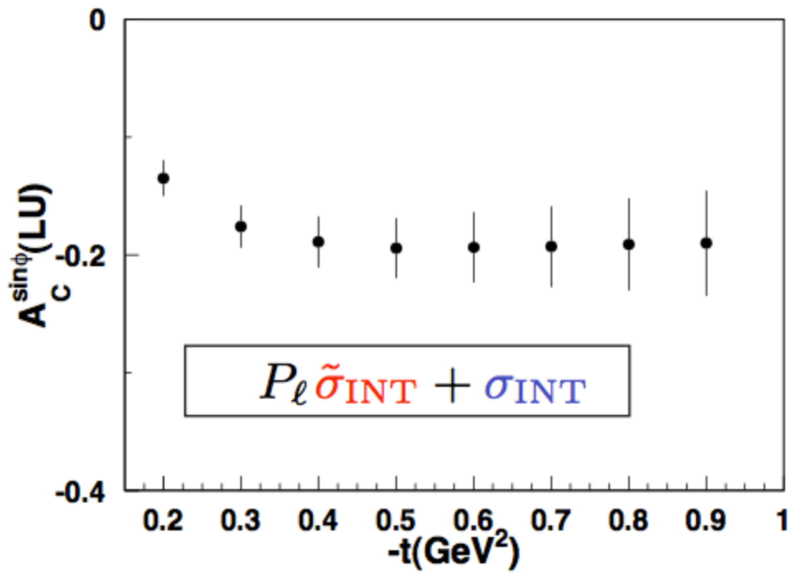
$$\sigma_{ep\to e\gamma p} = \sigma_{\rm BH} + e_\ell\,\sigma_{\rm INT} + P_\ell e_\ell\,\tilde{\sigma}_{\rm INT} + \sigma_{\rm VCS} + P_\ell\,\tilde{\sigma}_{\rm VCS}$$

where σ even in ϕ $\quad\sigma_{\rm INT} \propto {\rm Re}\,\mathcal{A}_{\gamma^* N\to\gamma N}$

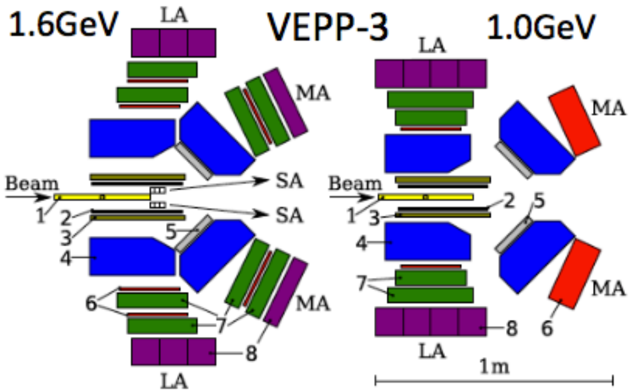
$\tilde{\sigma}$ odd in ϕ $\quad\tilde{\sigma}_{\rm INT} \propto {\rm Im}\,\mathcal{A}_{\gamma^* N\to\gamma N}$

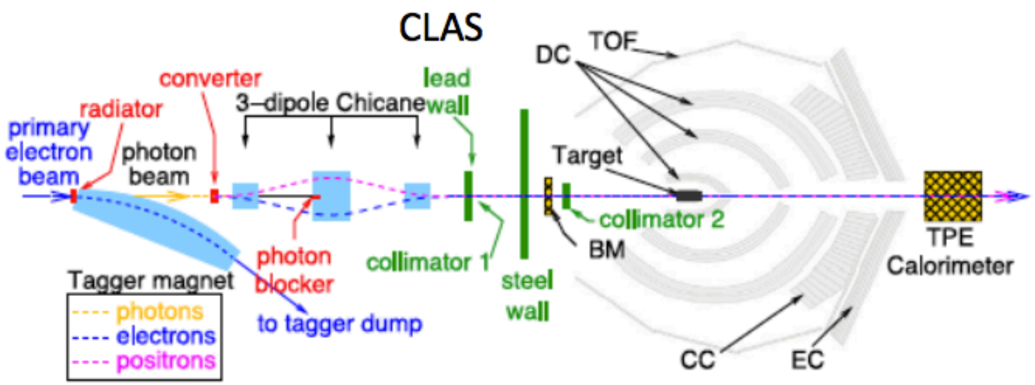
	beam charge	beam pol.	combination
	e^-	difference	$-\tilde{\sigma}_{\rm INT} + \tilde{\sigma}_{\rm VCS}$
e^+	difference	none	$\sigma_{\rm INT}$
$\vec{e}^{\,+}$	difference	fixed	$P_\ell\tilde{\sigma}_{\rm INT} + \sigma_{\rm INT}$

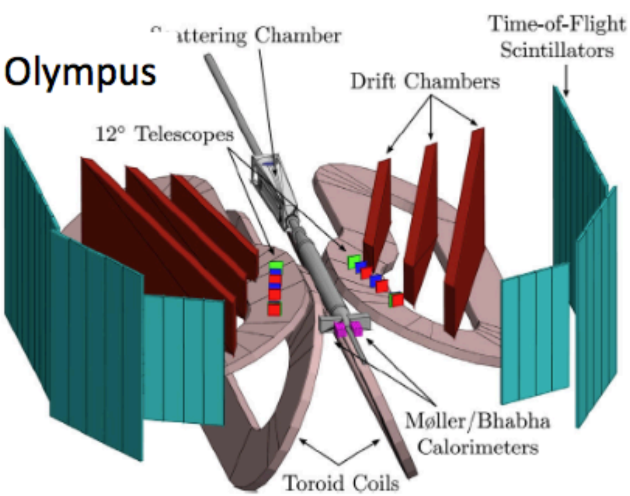


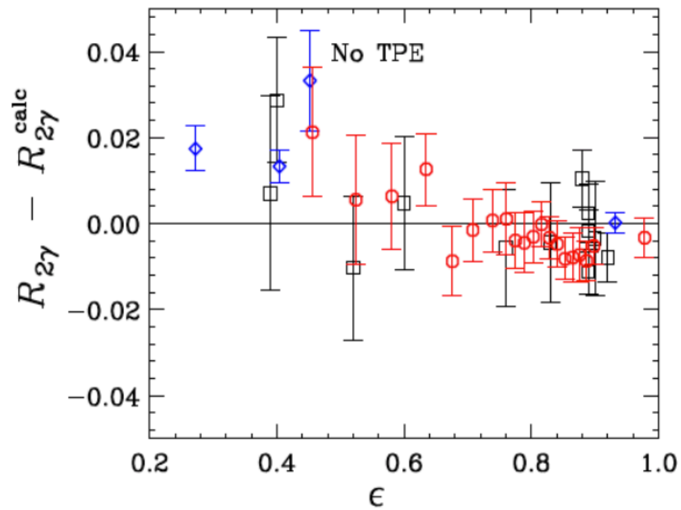


Review article *"Two-photon exchange in elastic electron-proton scattering"*, *A.Afanasev, P.G. Blunden, D. Hassel, B.A. Raue, PPNP 95 (2017) 245-278*





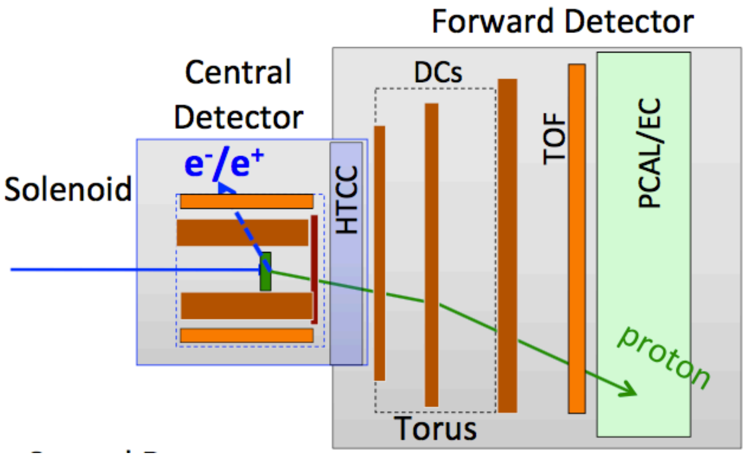


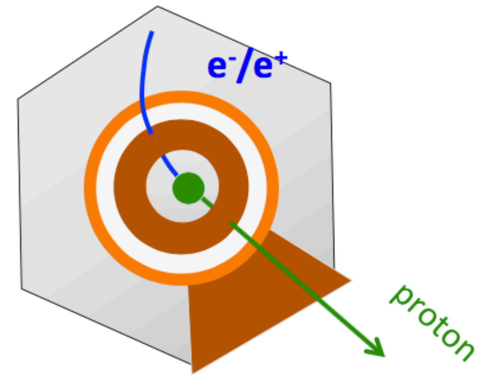


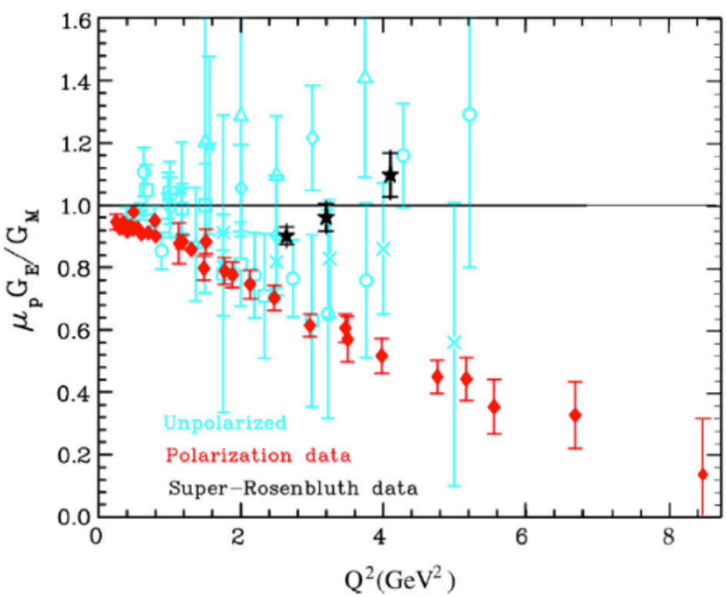
"The results of these experiments are ***by no means definitive***. Most of the data are well below where the form factor discrepancy is significant ($Q^2 > 2GeV^2$). Questions regarding the sources of the discrepancy remain largely unanswered"

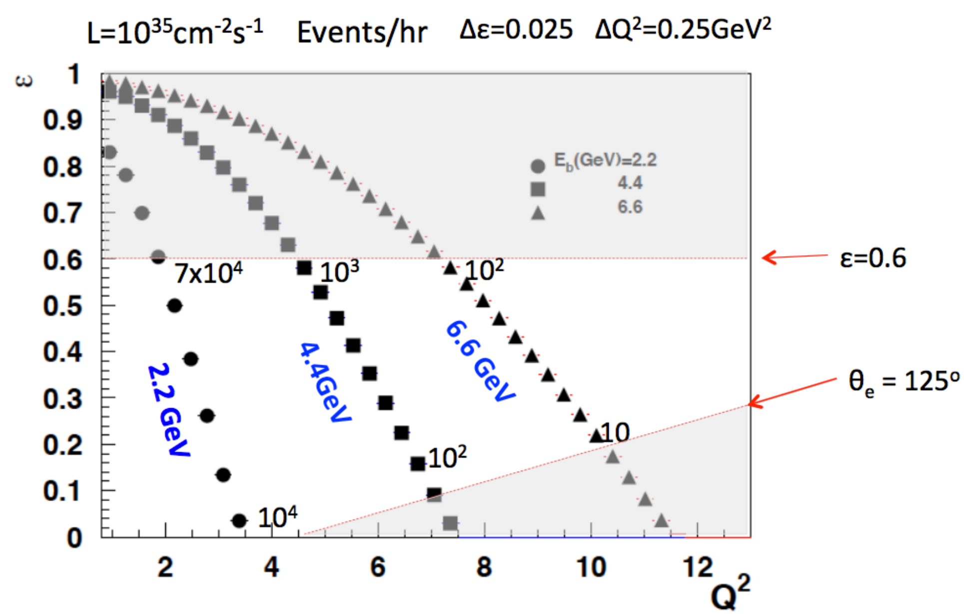
"There is a clear need for similar experiments at larger Q^2 and at ε <0.5".

CLAS12 e+/-p/e+/-p experiment (generic)





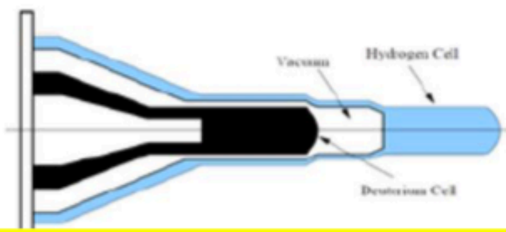




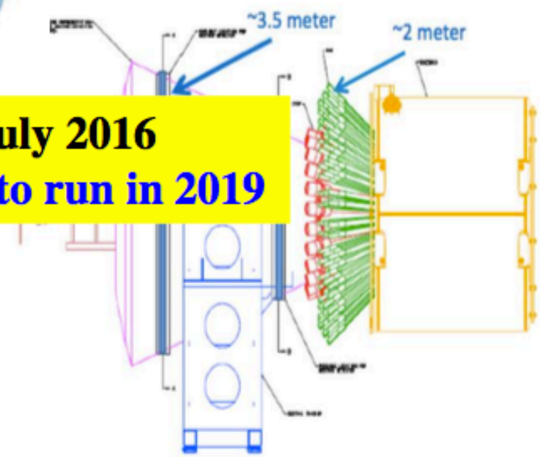
Run-Group B: physics and setup

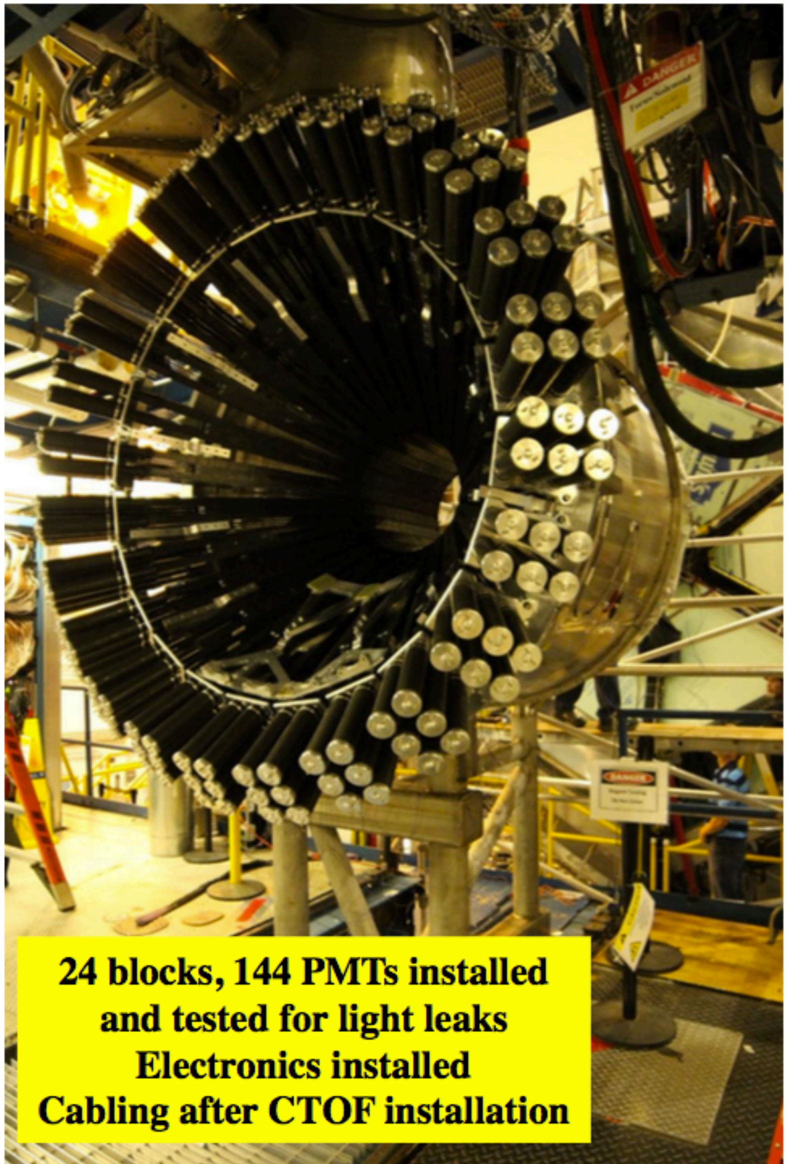
- **RG-B**: measurements of **FFs, PDFs, GPDs, and TMDs** using **deuteron as a neutron target**
→ **quark-flavor separation**, combining with proton results
- Common features to all experiments of RG-B: **liquid deuterium** target, **11-GeV** beam
- Approved PAC days: **146**; days in the run-groups table: **90**

Neutron magnetic form factor	Dual target	A-	30
Study of partonic distributions in SIDIS kaon production	*Dual target*, RICH	A-	56
Boer-Mulders asymmetry in K SIDIS	*Dual target*, RICH, two field settings	A-	56
Deeply virtual Compton scattering on the neutron	Single-cell target, CND, FT	A (HI)	90
Collinear nucleon structure at twist-3	*Dual target*, RICH	--	
In medium structure functions, SRC, and the EMC effect	Single-cell target, BAND	--	



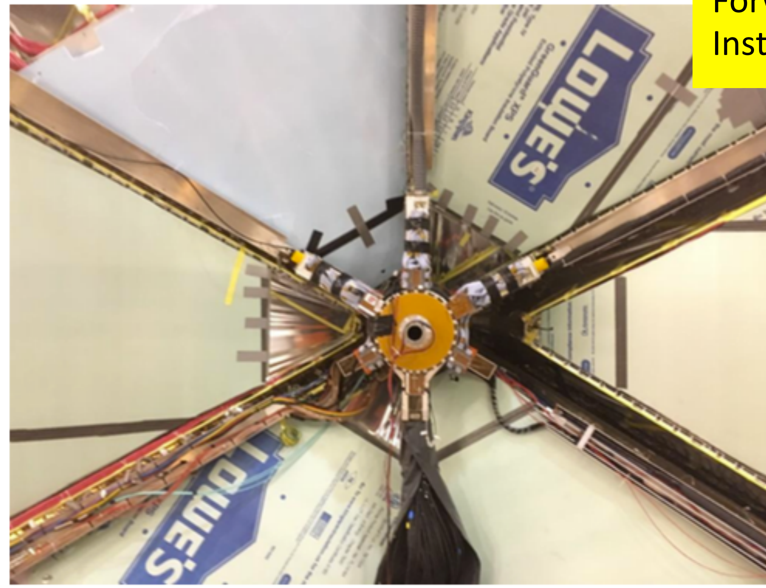
A scheduling request for 2018 was submitted in July 2016
Given the current accelerator schedule, RG-B is likely to run in 2019



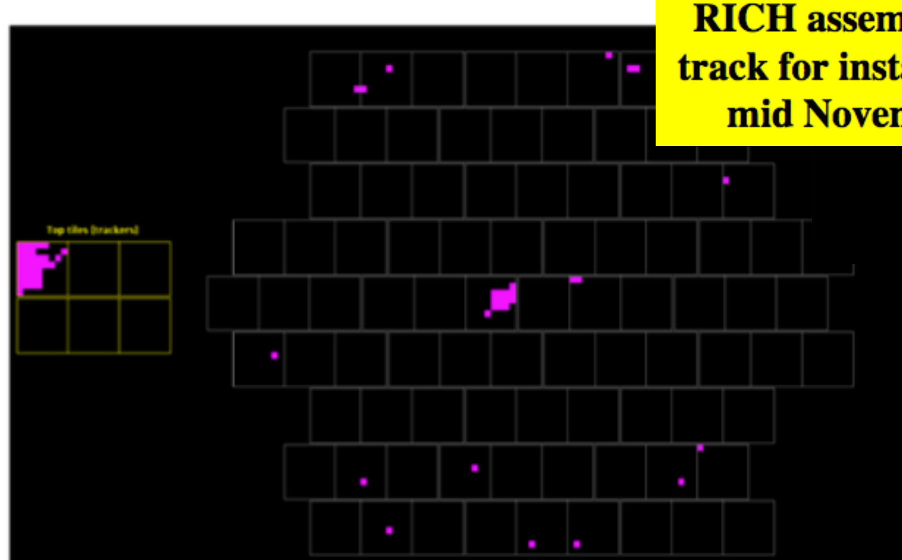


24 blocks, 144 PMTs installed
and tested for light leaks
Electronics installed
Cabling after CTOF installation

Forward Tagger
Installed



RICH assembly on
track for installation
mid November

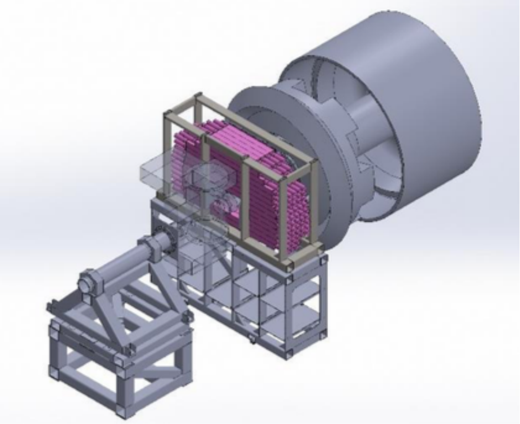


Status of BAND

« In medium structure functions, short-range correlations, and the EMC effect », O. Hen et al.

BAND: new scintillator-based **back angle neutron detector**

- 160-170°
- ~ 35% neutron detection efficiency
- ~ 7x7 cm^2 scintillators
- MRI applied for 2017



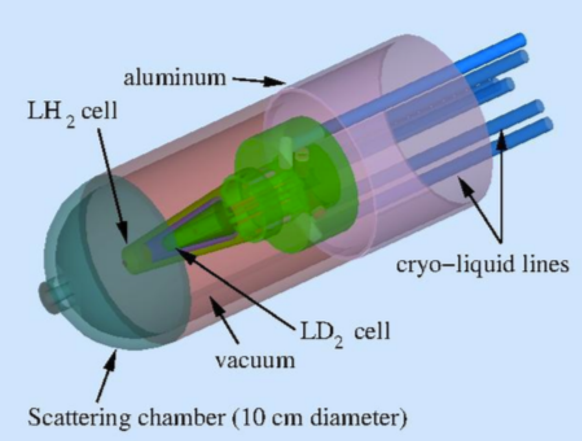
- ✓ Construction and tests starting in these days, to be completed by early summer, then shipping to JLab
- ✓ Discussion of ERR with the lab resulted in a general agreement to hold the BAND ERR as part of the general RG-B ERR, in early 2018 (?). BAND will NOT be a condition for RG-B to pass the ERR

Status of Dual Target

August 2017: as an ERR would be needed, soon, and the dual target is not ready for that, it is agreed to run the first part of RG-B with an ordinary deuterium target

Alternative idea: using deuterium data for NDE

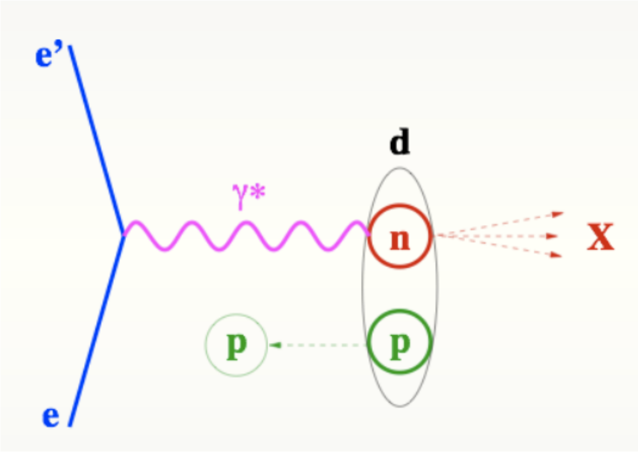
reaction $\gamma d \rightarrow p n \pi^+ \pi^-$

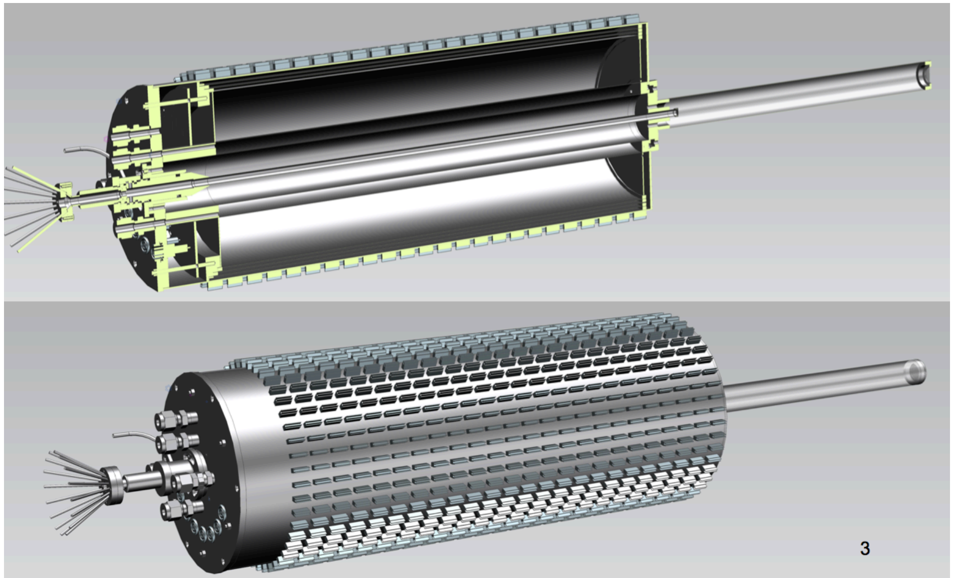


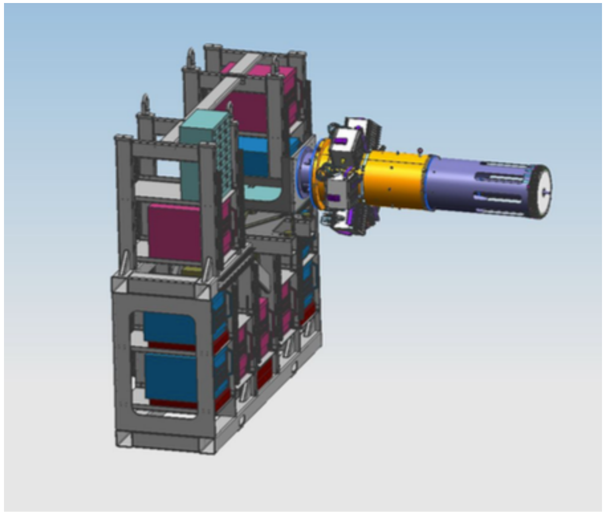
Sebastian Kuhn, *Old Dominion University*

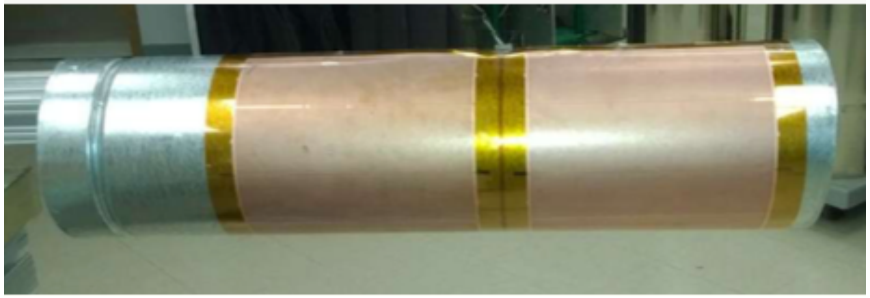
Status Report

BONuS12 (E12-06-113, CLAS12 Run Group F)



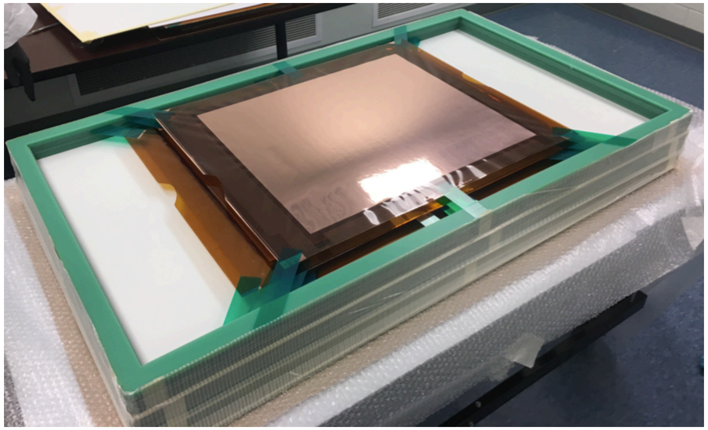




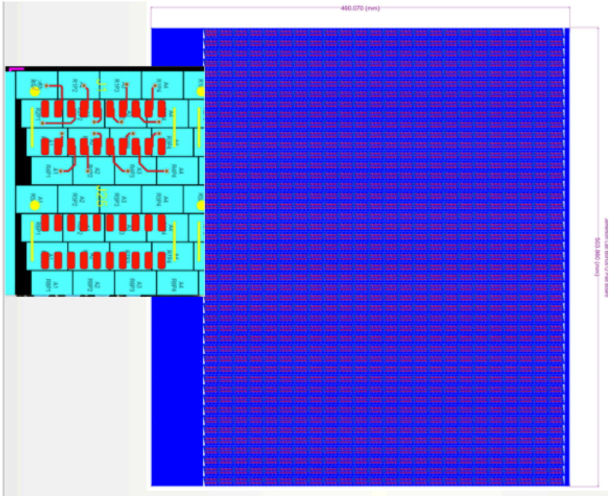


Scheduled to be ready by the end of FY2018

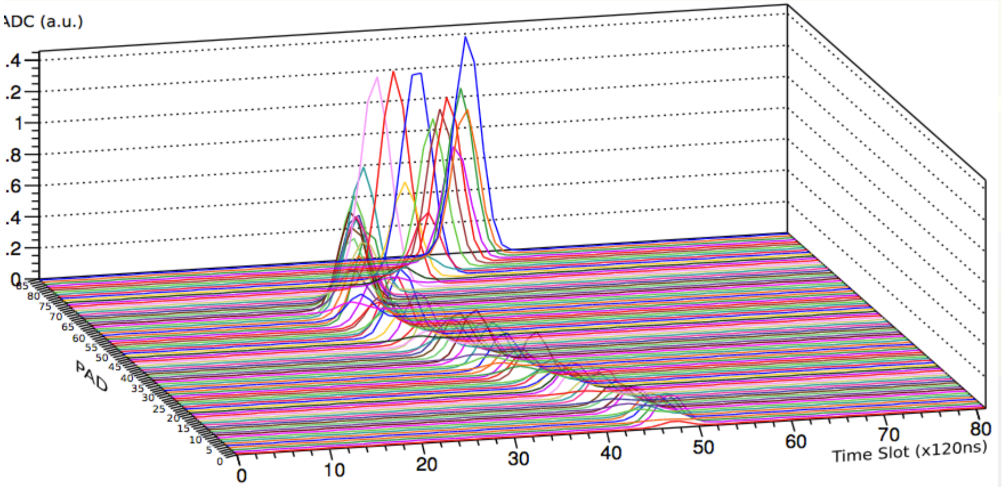
GEM foils

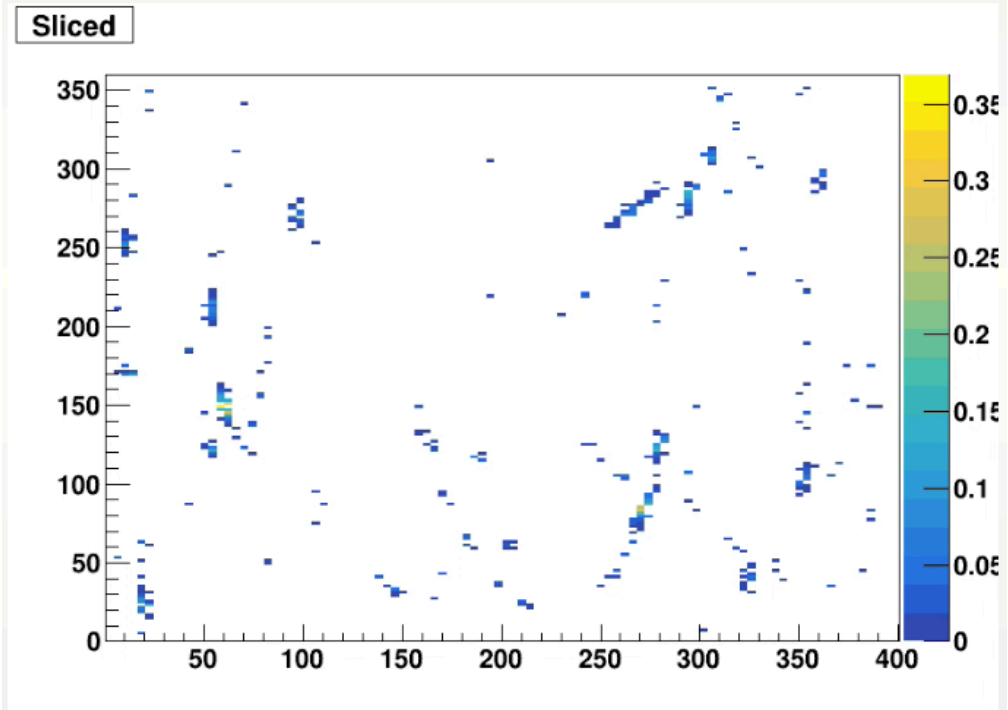


DREAM based Readout

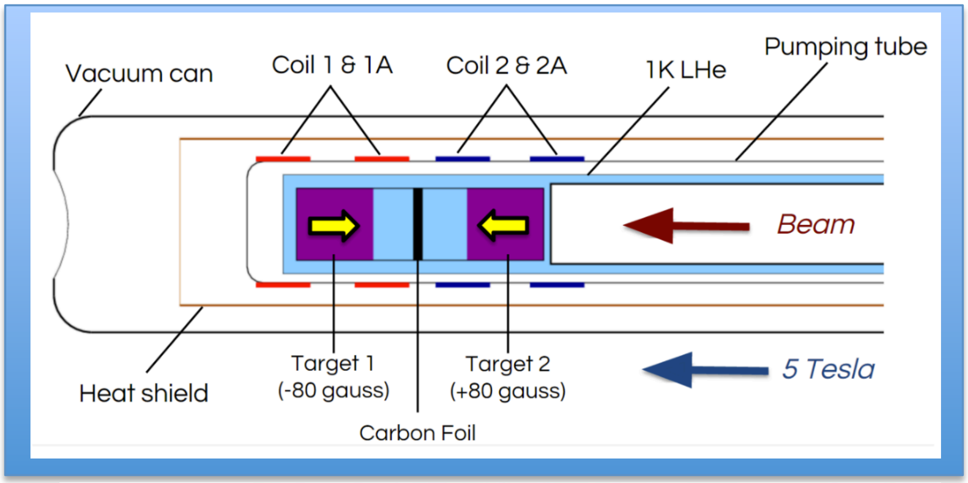


- Full simulation with signal shape in DREAM
- GEMC, Coatjava, track finder, Kalman filter,···

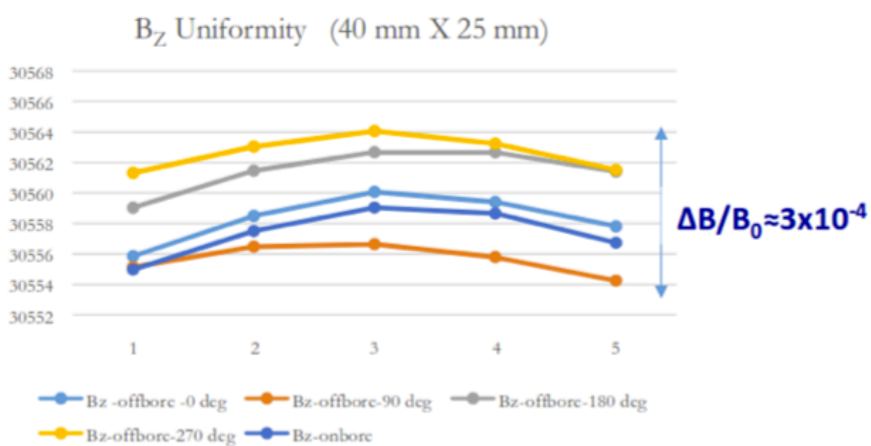


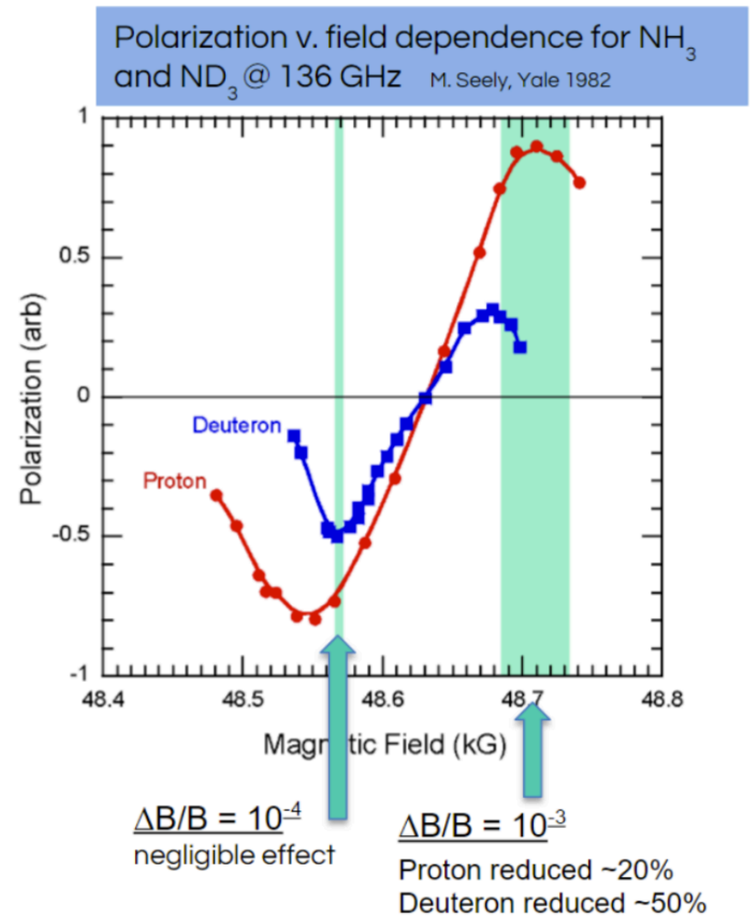


Update on the Longitudinally Polarized Target for CLAS12 Run Group C



Azimuthal variation off-bore (12.5 mm)

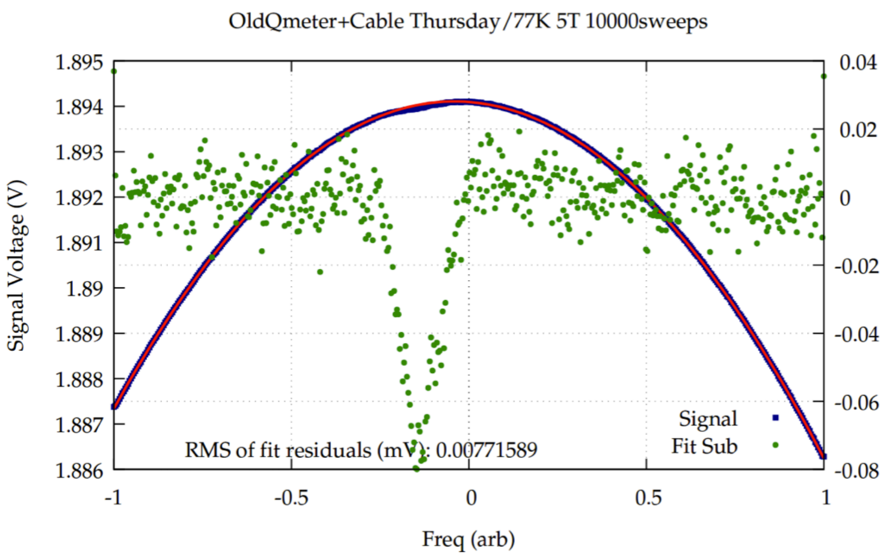


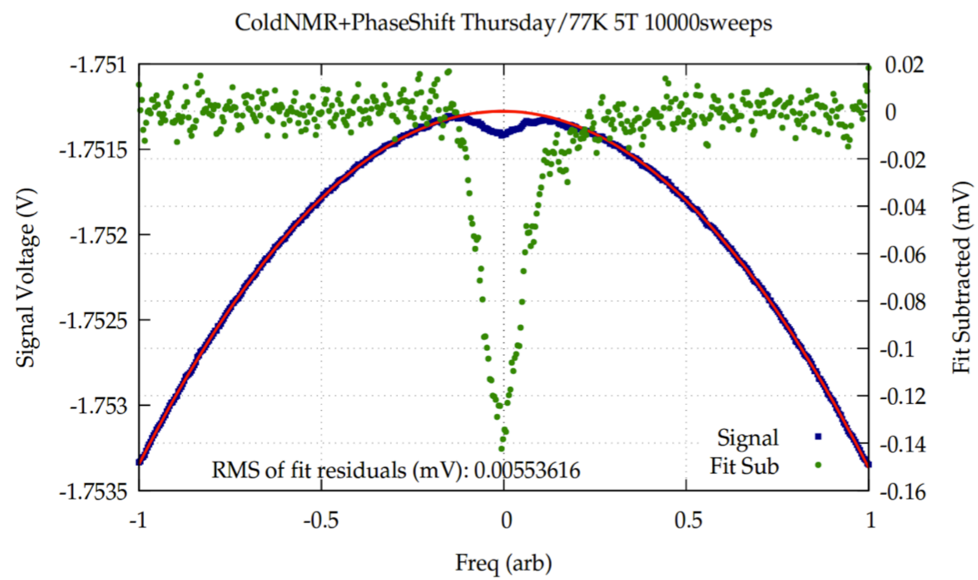


NMR

OLD

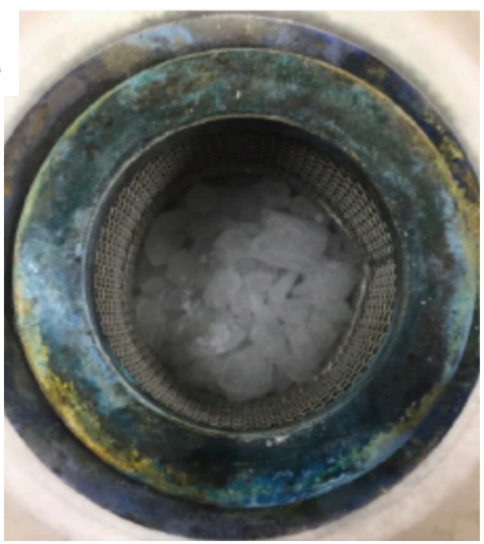
NEW



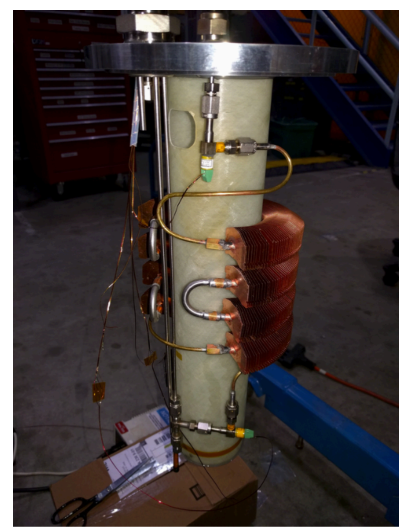


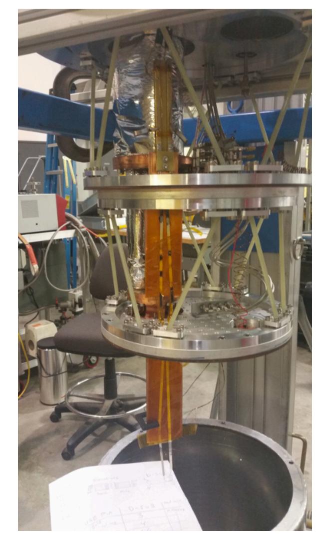
Chile - UVA

Crystallized Ammonia



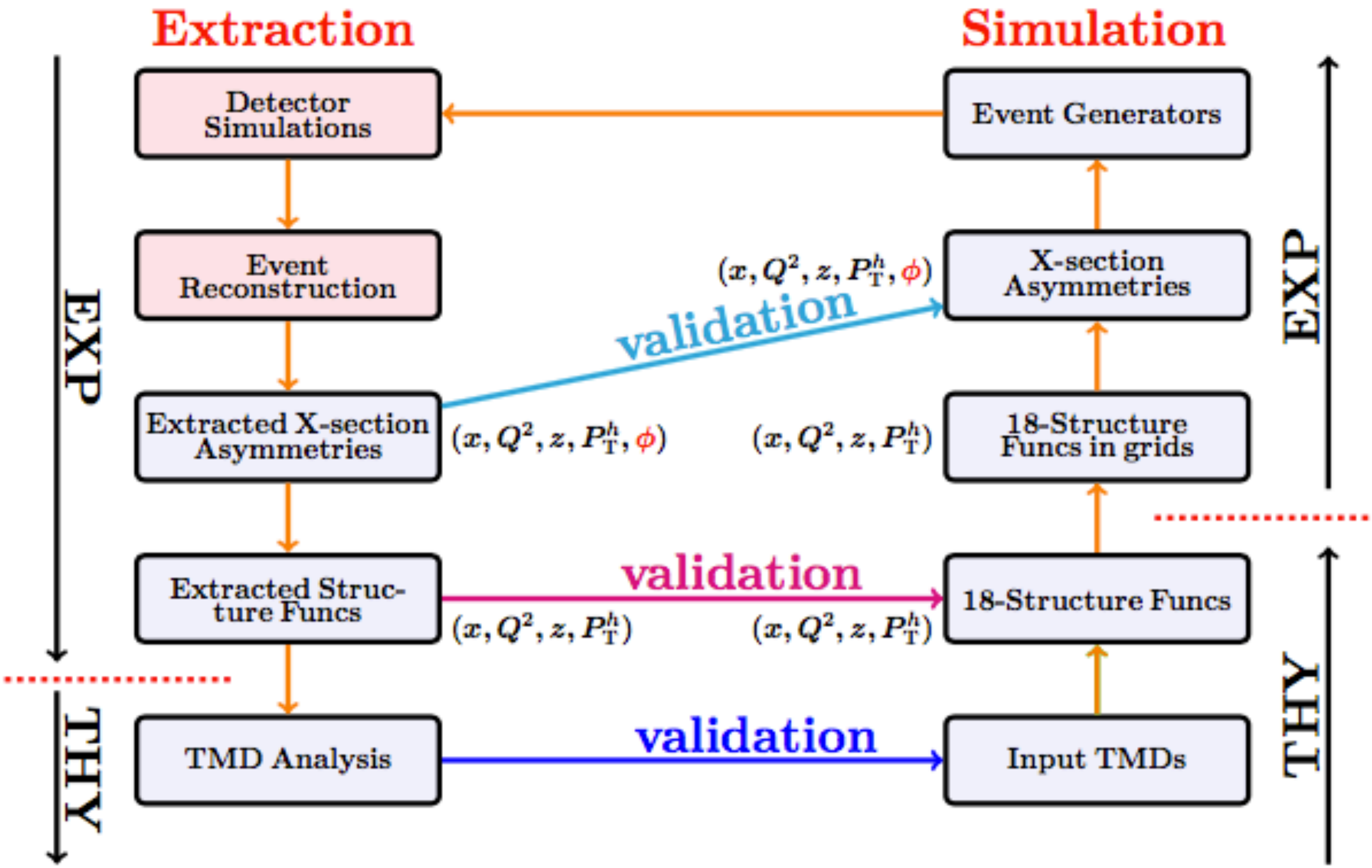
Heat Exchanger Test Leads





EVA workflow

Nobuo Sato
University of Connecticut



Questions to be solved:

- Is the input and output "physics" consistent?
- "physics" does not need to be perfect, only approximated version is required

type	Name	$\mathcal{K}_q$	$\mathcal{C}_q$
$\mathcal{F}_q$	upol. PDF	1	f_1^q
$\mathcal{F}_q$	pol. PDF	1	g_1^q
$\mathcal{F}_q$	Transversity	1	h_1^q
$\mathcal{F}_q$	Sivers	$\frac{2M^2}{\omega_q}$	$f_{1T}^{\perp(1)q}$
$\mathcal{F}_q$	Boer-Mulders	$\frac{2M^2}{\omega_q}$	$h_1^{\perp(1)q}$
$\mathcal{F}_q$	Pretzelosity	$\frac{2M^2}{\omega_q}$	$h_{1T}^{\perp(1)q}$
$\mathcal{C}_q$	FF	1	D_1^q
$\mathcal{C}_q$	Collins	$\frac{2z^2m_h^2}{\omega_q}$	$H_1^{\perp(1)q}$

ready, in progress, TODO

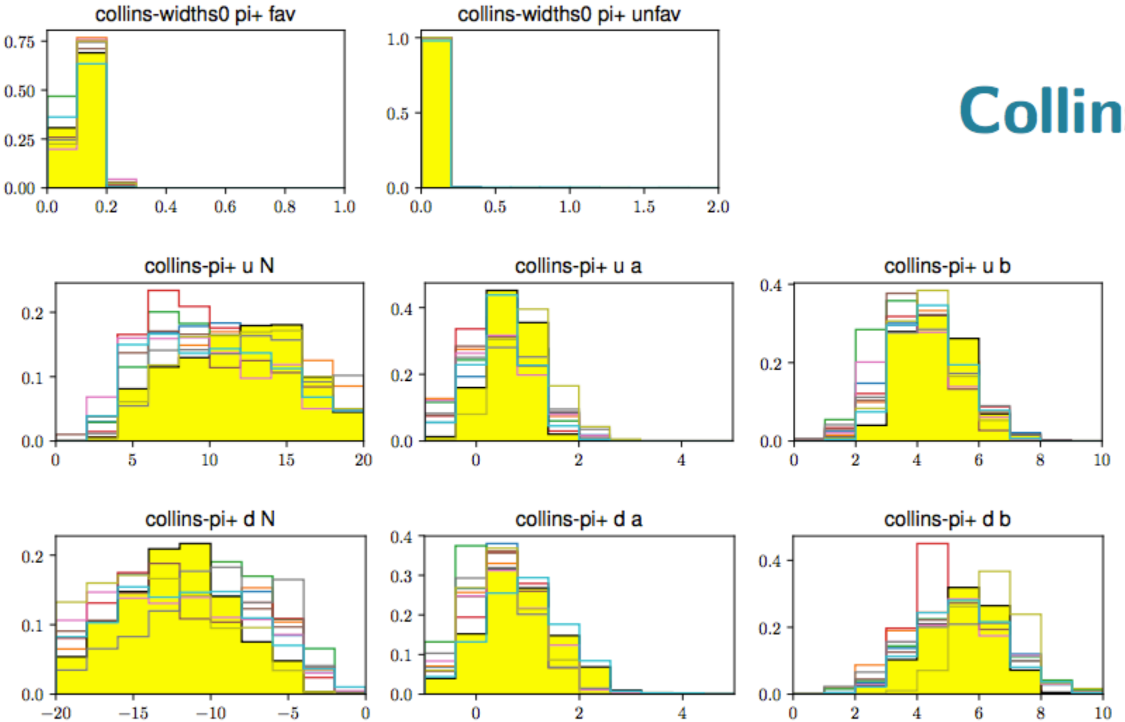
- Use the approximated "physics" to interpret P_{hT} dependent SIDIS data.

- Factorization ansatz for partons in nucleon

$$\mathcal{F}_q(x,p_\perp) = \mathcal{K}_q\,\mathcal{C}_q(x)\frac{\exp\left(-k_\perp^2/\omega_q\right)}{\pi\omega_q}$$

- Factorization ansatz for partons to hadrons

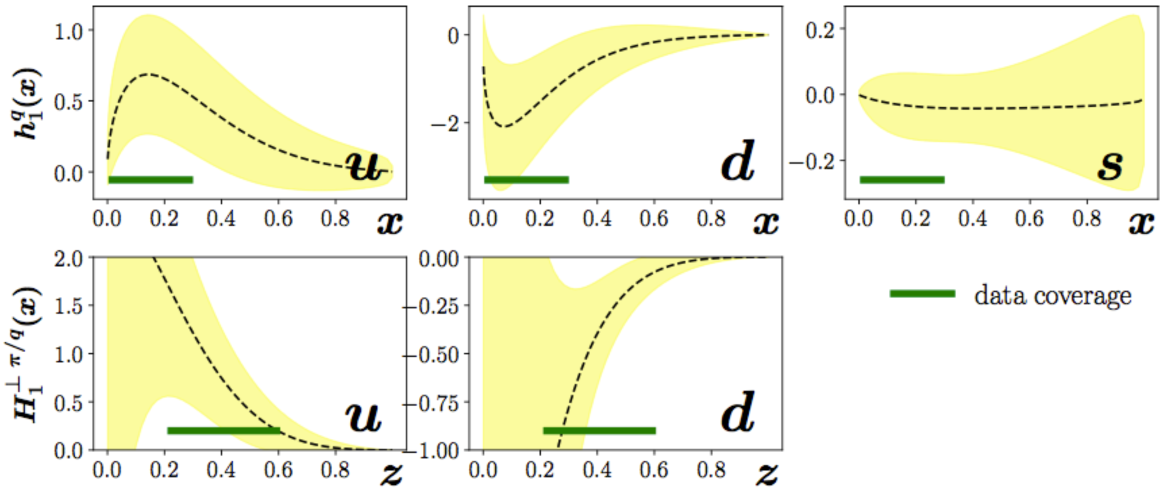
$$\mathcal{D}_q(z,p_\perp) = \mathcal{K}_q\,\mathcal{C}_q(z)\frac{\exp\left(-P_\perp^2/\omega_q\right)}{\pi\omega_q}$$



Collins π parameters

Transversity

Collins function



Wandzura-Wilczek type Approximation in TMDs

Kemal Tezgin

University of Connecticut

1. By using the Equations of Motion (EoM) of a quark field in QCD;

$$(i\not{D} - m)\psi = 0$$

decompose a twist-3 PDF obtained by $< \bar{q}q >$ correlator to a twist-2 PDF and a "pure" twist-3 PDF.

$$g_T^q(x) = \int_x^1 \frac{dy}{y} g_1^q(y) + \tilde{g}_T^q(x) \approx \int_x^1 \frac{dy}{y} g_1^q(y)$$

$$h_L^q(x) = 2x \int_x^1 \frac{dy}{y^2} h_1^q(y) + \tilde{h}_L^q(x) \approx 2x \int_x^1 \frac{dy}{y^2} h_1^q(y).$$

- WW Approximation is supported by Semi-Classical approximations in QCD; like Chiral Quark Soliton Model.
  [Ref:J. Balla, M. V. Polyakov and C. Weiss, Nucl.Phys. B510 (1998)]
- Also supported by data [SLAC, JLAB].

Example: $F_{UU}^{cos\phi_h}$

- Let us apply WW-type approximation to a specific structure function, $F_{UU}^{cos\phi_h}$. The original definition is given by

$$F_{UU}^{\cos\phi_h} = \frac{2M}{Q}\mathcal{C}\Big[\ \frac{\hat{\mathbf{h}}\cdot\mathbf{P}_\perp}{zm_h}\Big(xh\,H_1^\perp + \frac{m_h}{M}\,f_1\frac{\tilde{D}^\perp}{z}\Big) - \frac{\hat{\mathbf{h}}\cdot\mathbf{k}_\perp}{M}\Big(xf^\perp D_1 + \frac{m_h}{M}\,h_1^\perp\frac{\tilde{H}}{z}\Big)\Big]$$

- After neglecting the tilde ("pure" twist-3) terms and applying the following WW-type approximations

$$xf^{\perp q}(x,k_\perp^2) \approx f_1^q(x,k_\perp^2)$$

$$xh^q(x,k_\perp^2) \approx -\frac{k_\perp^2}{M^2}h_1^\perp(x,k_\perp^2)$$

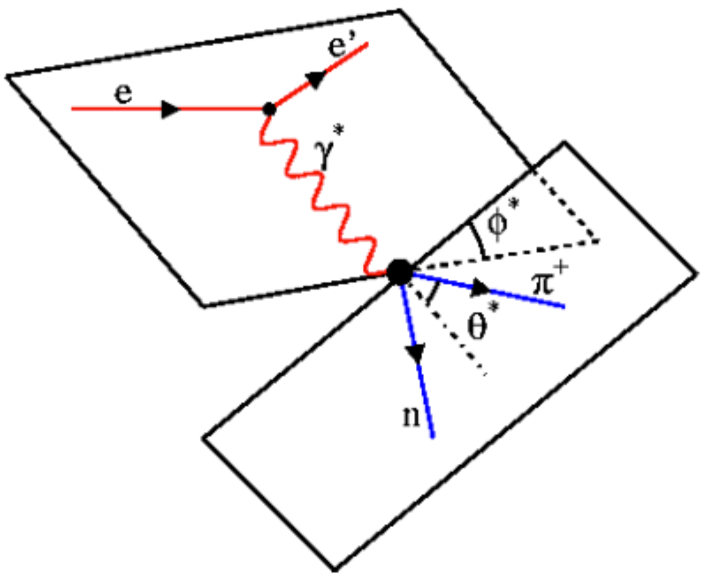
We obtain

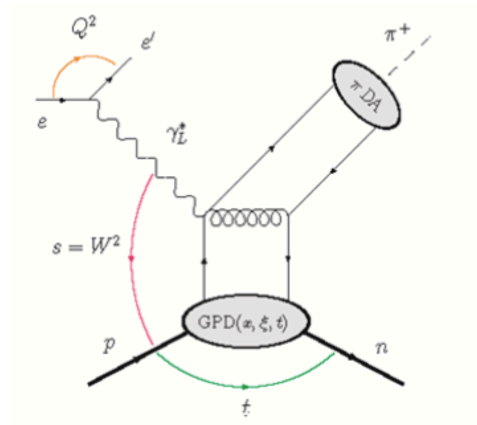
$$F_{UU}^{cos\phi_h} = \frac{2M}{Q}\mathcal{C}\Big[-\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{P}_\perp}{zm_h}\Big(\frac{k_\perp^2}{M^2}h_1^\perp H_1^\perp\Big) - \frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_\perp}{M}\Big(f_1 D_1\Big)\Big]$$

Beam spin asymmetries from hard exclusive π^+ electroproduction

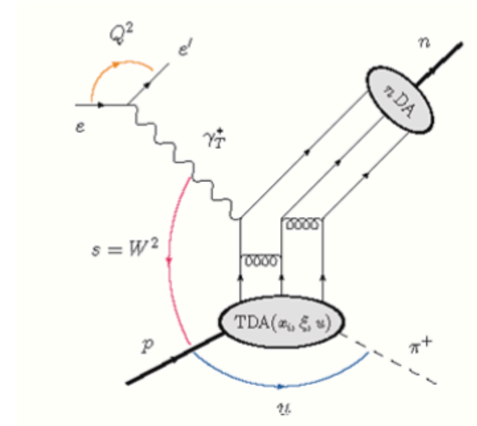
David Riser

University of Connecticut





Near forward
Small t
Large u

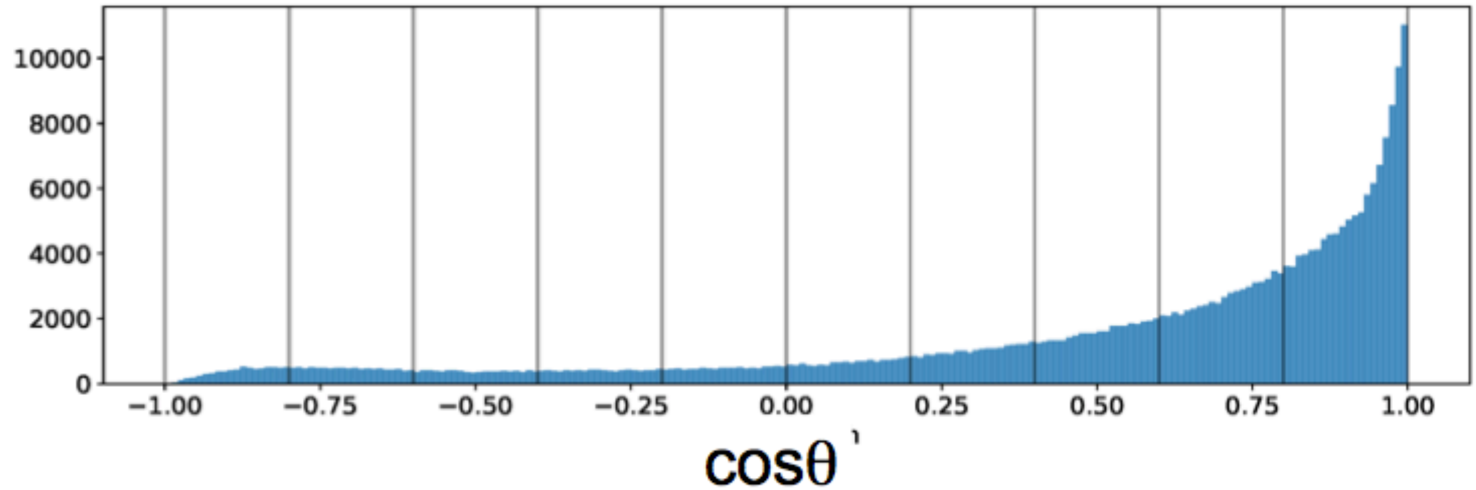


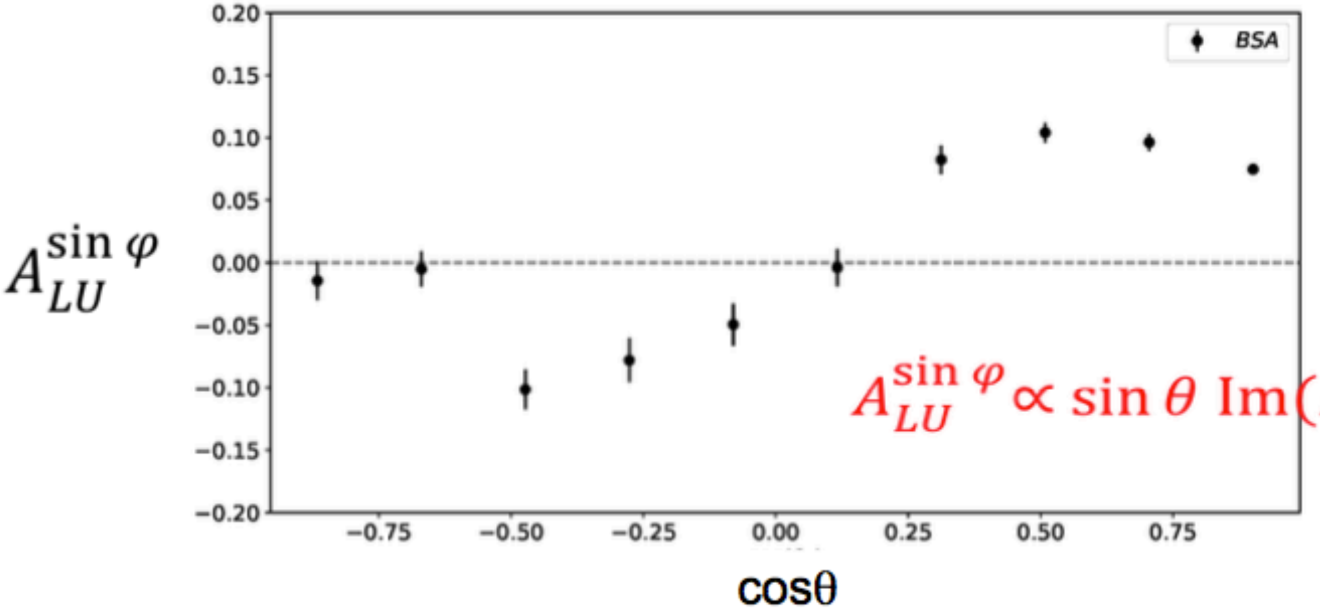
Near backward
Small u
Large t

$$\frac{d^4\sigma}{dQ^2 dx_B d\phi dt} \sim (\sigma_T + \epsilon_L \sigma_L + \epsilon \sigma_{TT} \cos 2\phi + \sqrt{2\epsilon_L(1+\epsilon)}\sigma_{LT} \cos\phi + h\sqrt{2\epsilon_L(1-\epsilon)}\sigma_{LT'} \sin\phi)$$

Beam helicity

$A_{LU}^{\sin\varphi}$ for $ep \rightarrow e\pi^{+}n$



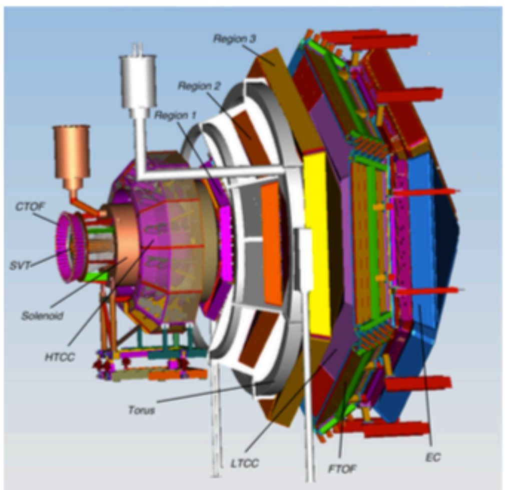


$$A_{LU}^{\sin\varphi} \propto \sin\theta\ \mathrm{Im}\left(F_{+0}^{++} + F_{+0}^{--}\right)$$

CLAS12 Simulation Studies of DVγ and DVϕ

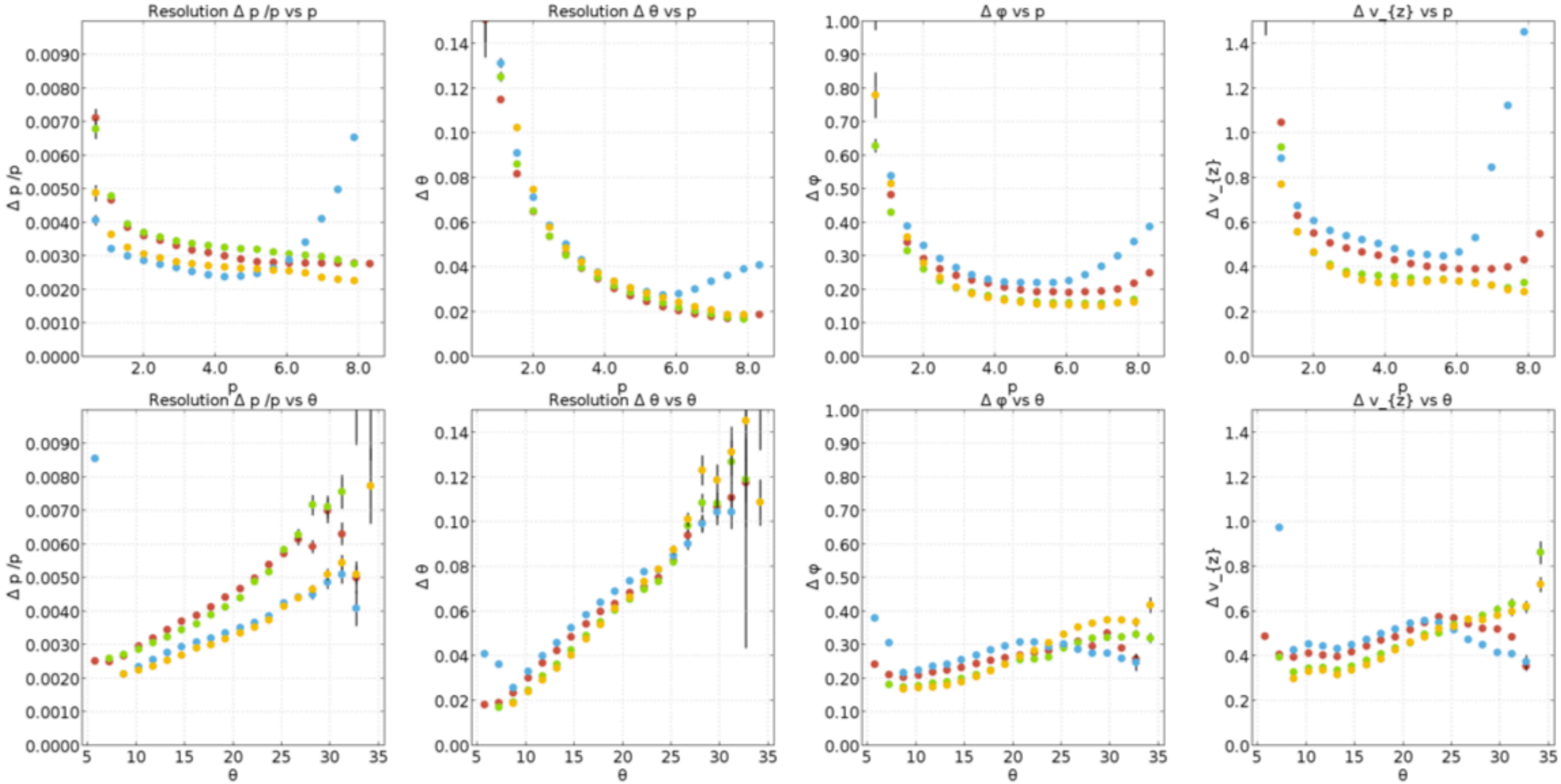
F.-X. Girod

Jefferson Laboratory



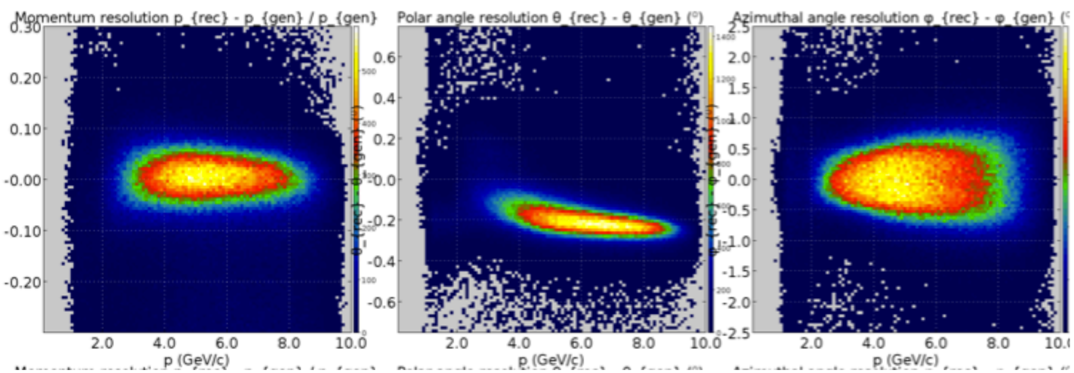
- **CLAS12 Full Chain Simulations works**
- You should use it and check it
- Baseline Specifications are met or exceeded
- Particles Identification, Event Builder
- The PAC approved proposals were obtained with questionable acceptances and resolutions
- Document your study on optimization for your proposal
- Basis for final discussion on the run plan and configuration

Electron Resolutions vs Magnetic Field

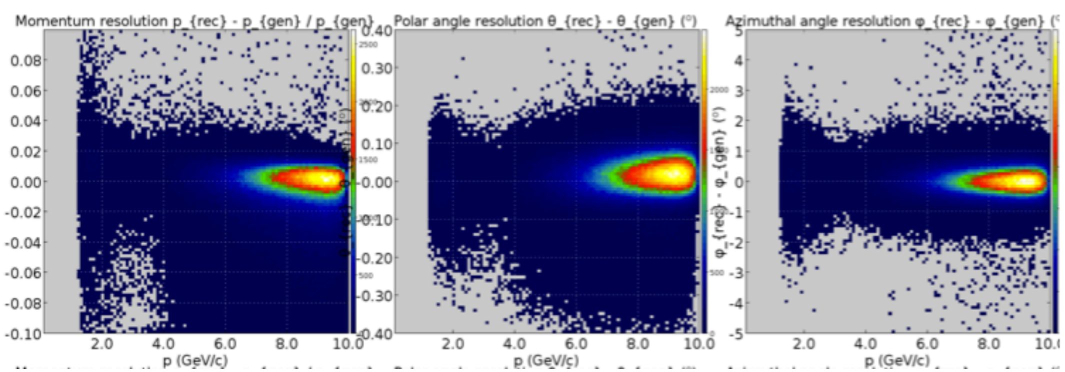


TORUS -1.0 / SOL. 1.0 TORUS -0.75 / SOL. 0.7
TORUS +1.0 / SOL. 1.0 TORUS 0.75 / SOL. 0.7

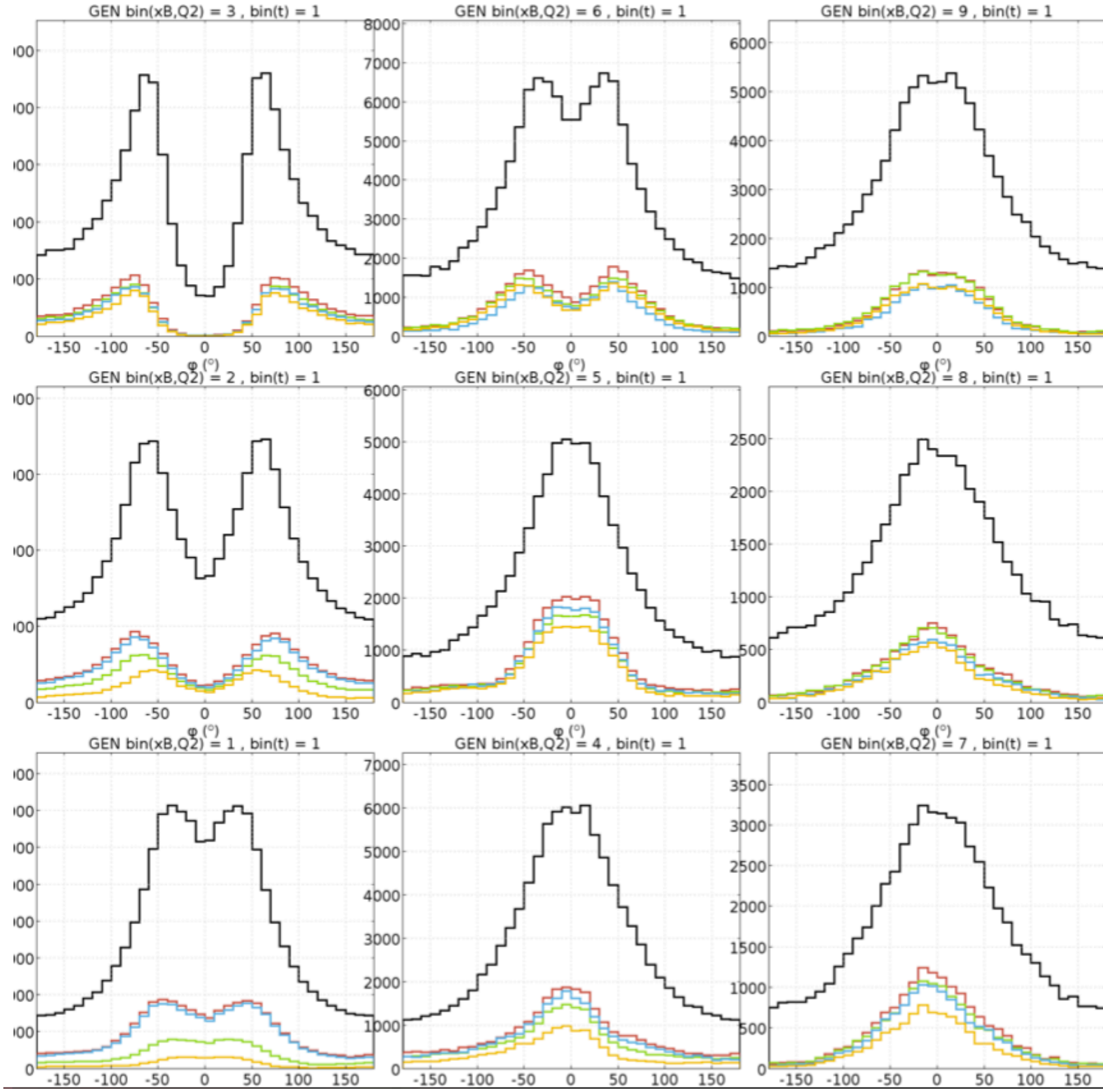
ECAL Photon Resolutions

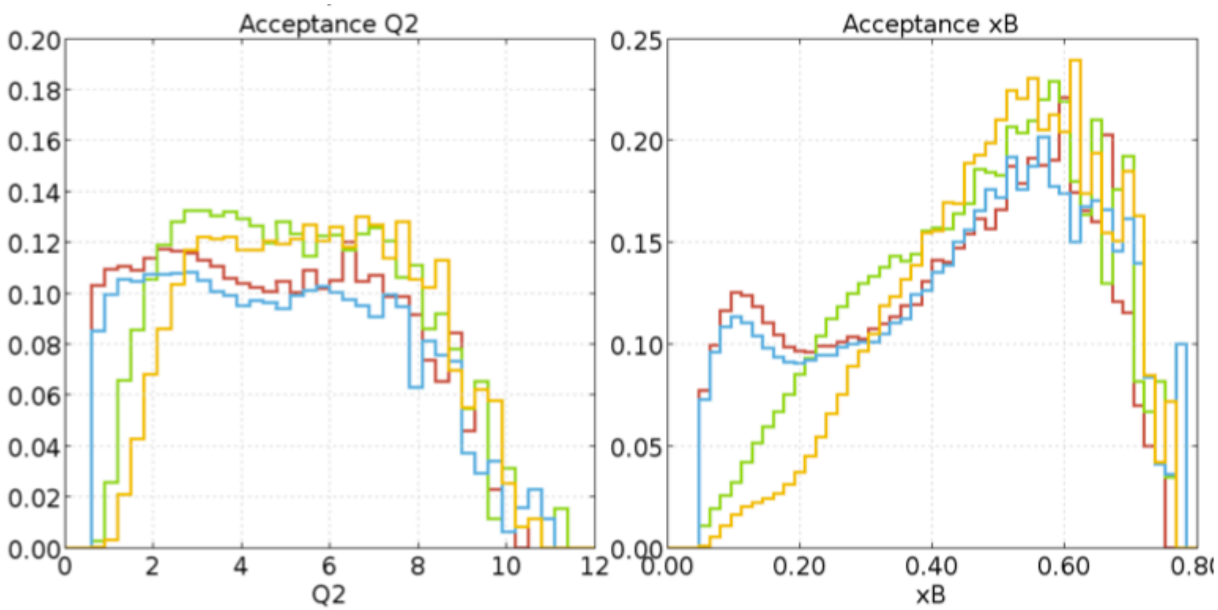


FTCAL Photon Resolutions



DVγ


GEN bin(xB,Q2) = 3 , bin(t) = 1
GEN bin(xB,Q2) = 6 , bin(t) = 1
GEN bin(xB,Q2) = 9 , bin(t) = 1
GEN bin(xB,Q2) = 2 , bin(t) = 1
GEN bin(xB,Q2) = 5 , bin(t) = 1
GEN bin(xB,Q2) = 8 , bin(t) = 1
GEN bin(xB,Q2) = 1 , bin(t) = 1
GEN bin(xB,Q2) = 4 , bin(t) = 1
GEN bin(xB,Q2) = 7 , bin(t) = 1
φ (°)

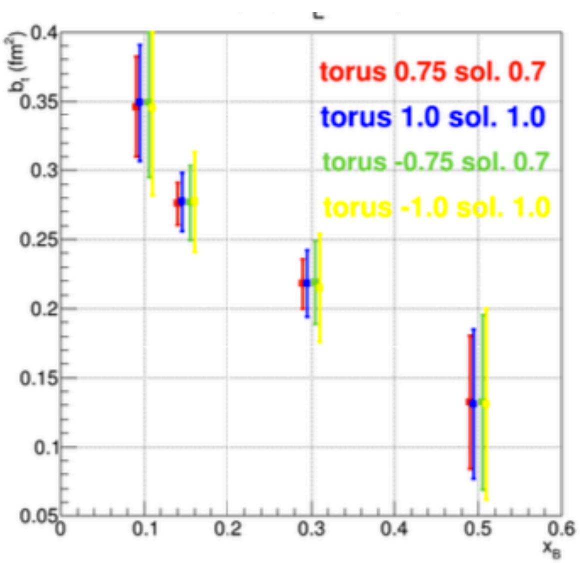


Torus 0.75 / Sol 0.7

Torus 1 / Sol 1

Torus -0.75 / Sol 0.7

Torus -1 / Sol 1



DVϕ

σ_L t-slopes extracted for different magnetic fields

Lower field and negative outbending torus are prefered