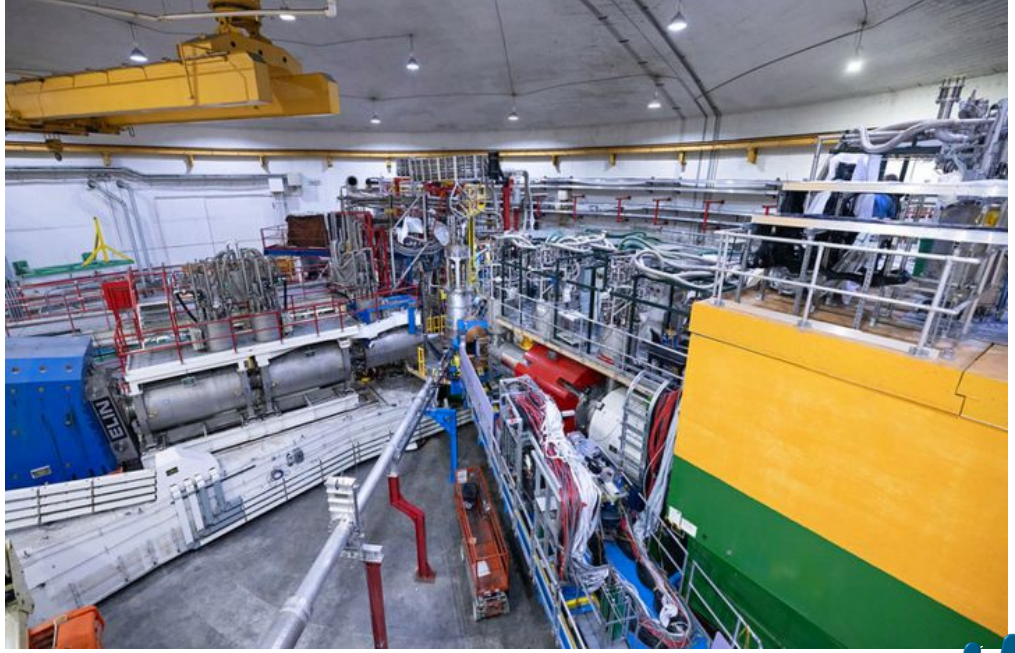


NPS RG1-a Overview

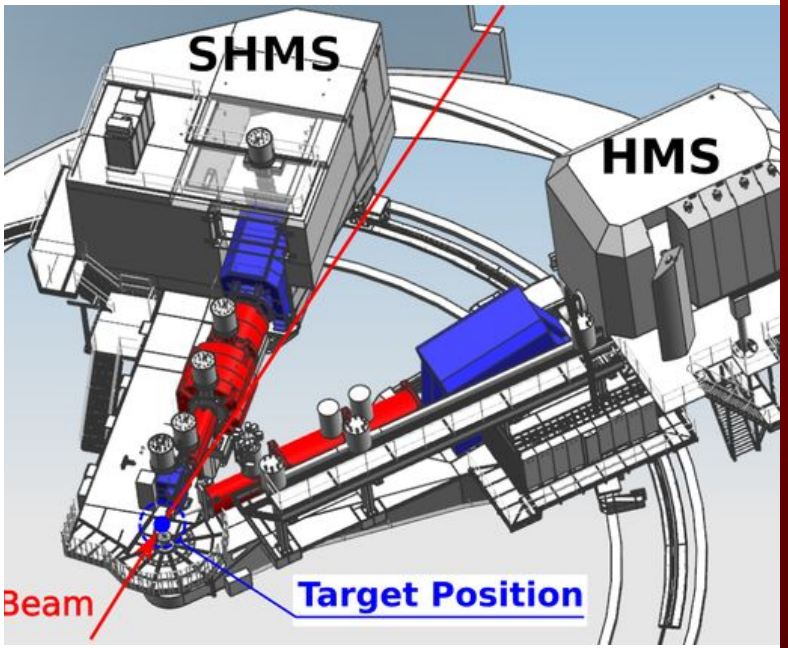
Supported by NSF grant PHY2309976

Casey Morean

1/13/2024

Hall C and the Neutral Particle Spectrometer

- Hall C is for precision measurements
- Removal of HB on SHMS carriage, straight shot into NPS
- Coincidence between NPS and well-characterized HMS
- Small angle, precision cross-sections, LT separation, high luminosity



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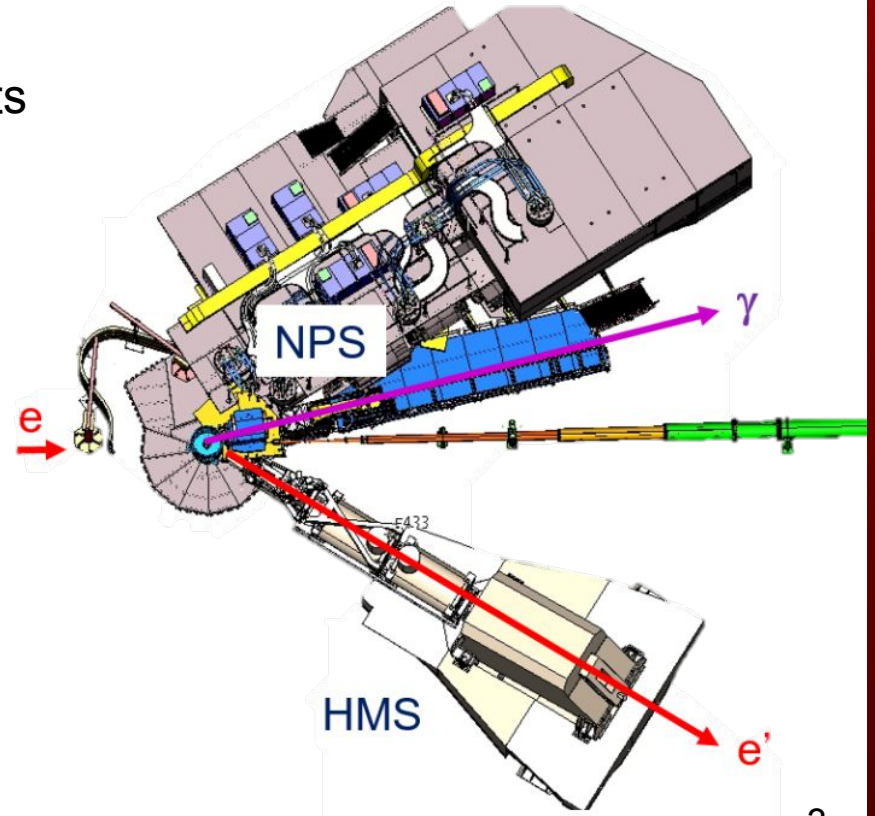


Small Angle Program of NPS Collaboration (RG1a)

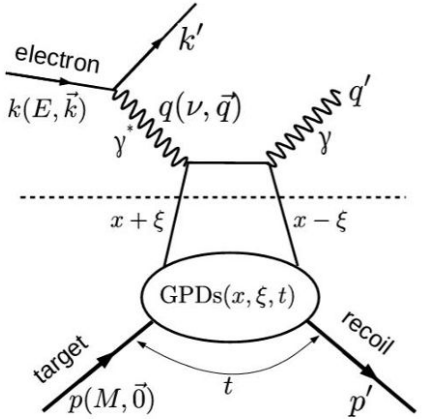
- Deeply Virtual Compton Scattering off the proton
- DVCS off the neutron
- Deeply Virtual Meson Production (neutral pions)
- Semi-Inclusive Deep Inelastic Scattering (SIDIS) with neutral pions

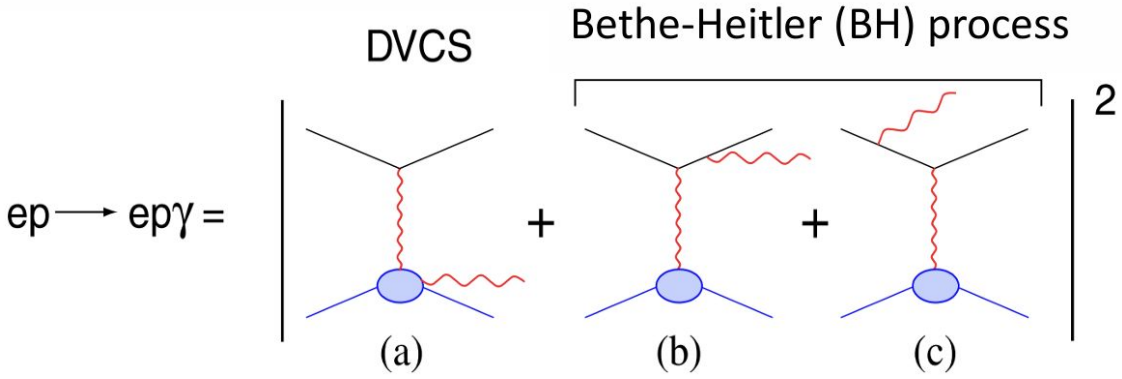
E12-13-010	E12-13-007	E12-22-006	E12-23-014
65 PAC days	25 PAC days*	44 PAC days	+7 PAC days

- 94 PAC days total!
- Large acceptance of the NPS and unique trigger allows multiple processes to be measured simultaneously

Proton Structure and DVCS

- Nucleon form factors accessed via elastic scattering
- Parton distribution functions accessed via DIS
- DVCS is the simplest probe of GPDs
- LT Separation



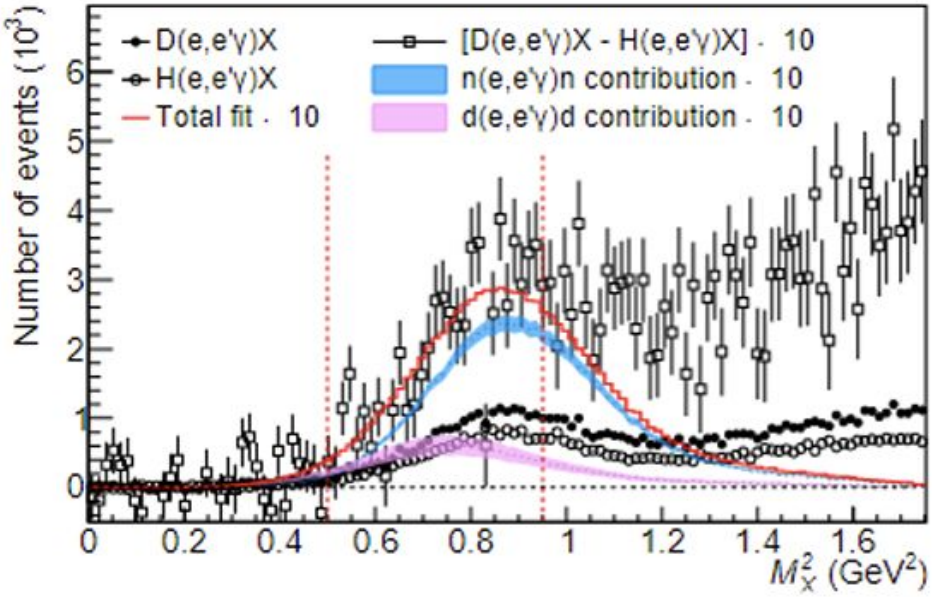


$$\sigma(ep \to ep\gamma) = |DVCS|^2 + |BH|^2 + interference$$

DVCS off the Neutron

Results from E08-025

- Subtraction of pi0 background
- ~2-12x better separation of nDVCS and dDVCS
- Flavor dependence of nucleon GPDs
- Azimuthal, beam, and helicity dependence of cross-section



M. Benali et al., Nature Phys. 16 (2020) 2, 191-198

$$D(e,e'\gamma)X = d(e,e'\gamma)d + n(e,e'\gamma)n + p(e,e'\gamma)p,$$

Separated by missing mass — E12-13-010

$$\left(\Delta M_X^2 = t(1 - M_N/M_d) \approx t/2 \right)$$

Proton Structure and DVCS

- Nucleon form factors accessed via elastic scattering
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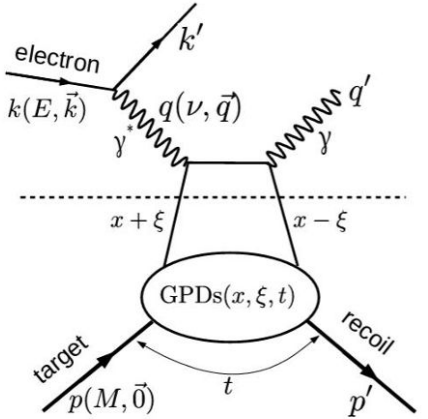
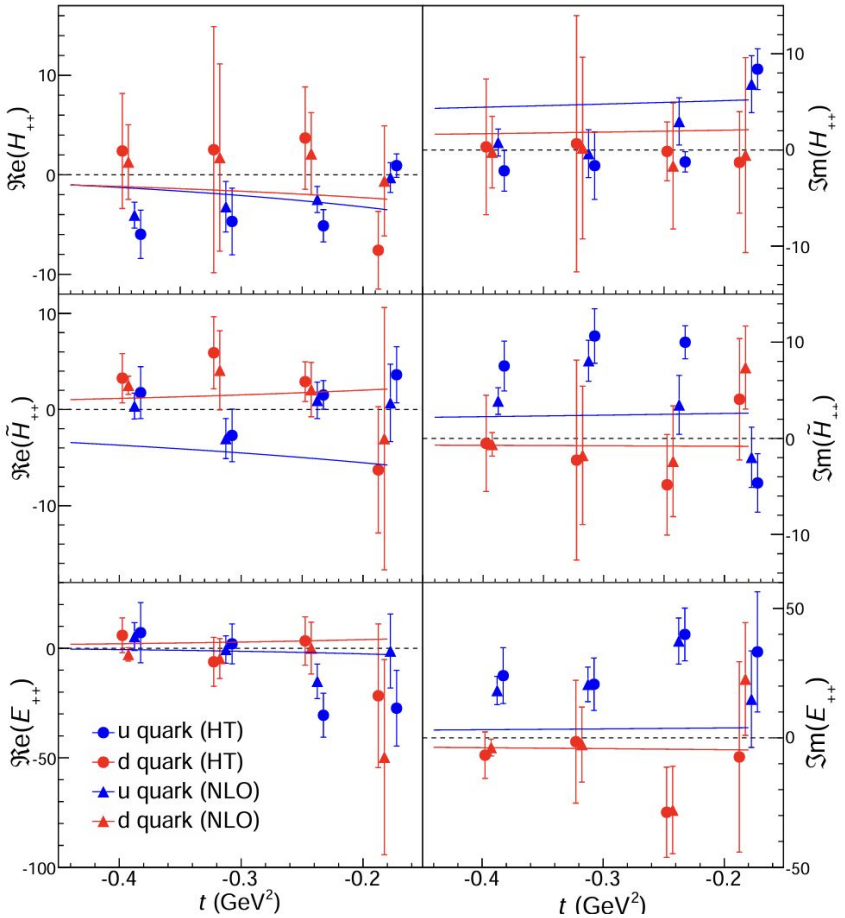


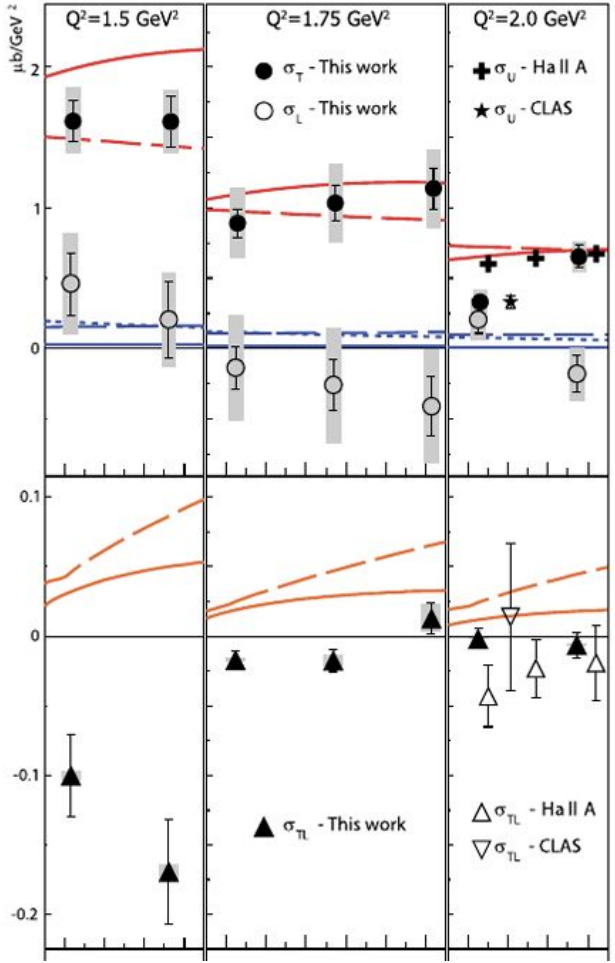


M. Benali et al., Nature Phys. 16 (2020) 2, 191-198

$$\sigma(ep \to ep\gamma) = |DVCS|^2 + |BH|^2 + interference$$

Exclusive neutral pion electroproduction

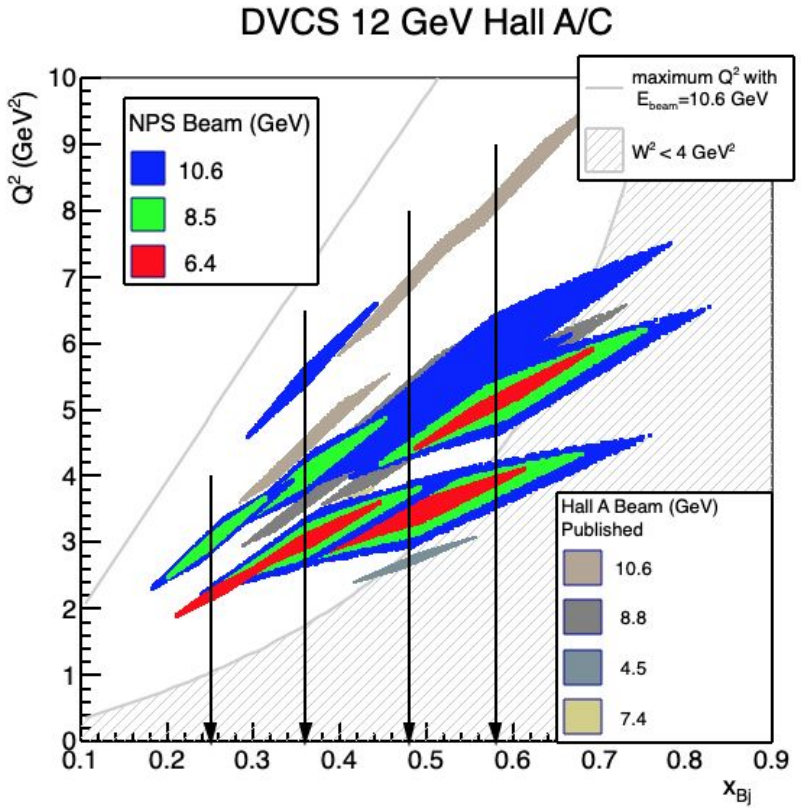
- Previous experiment in Hall A and CLAS show evidence of transversely polarized virtual photons
- LT separation off proton and deuteron with a large separation in epsilon (three epsilon points)
- Handbag factorization tells us the amplitude for transversely polarized virtual photons are suppressed by 1/Q



M. Defurne Phys. Rev. Lett. 117, 262001 (2016)

Small Angle Program of NPS Collaboration (RG1a)

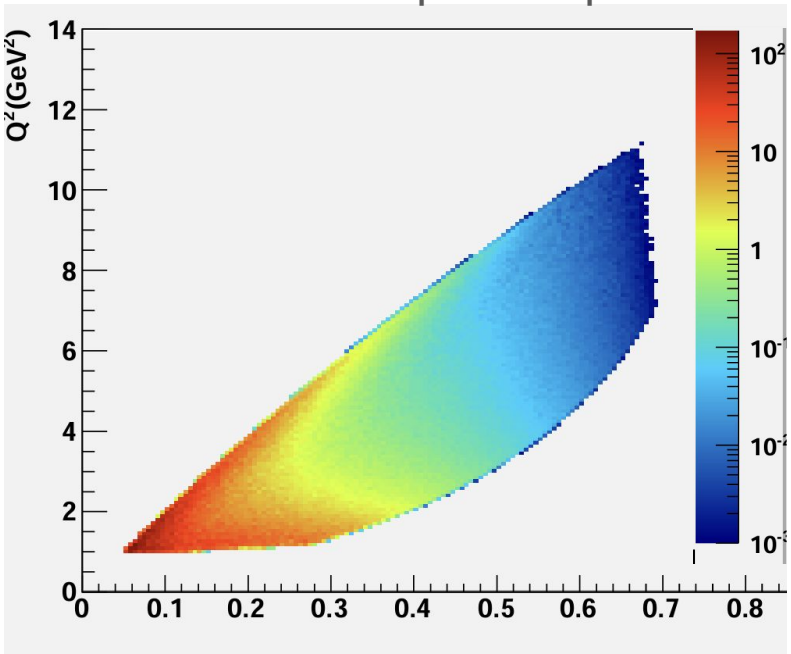
Kinematic Setting	Beam Pass	Coulomb Goal Per Target	LH2 % of Goal	LD2 % of Goal
KinC_x36_1	3	1.2	119.33%	134.08%
KinC_x36_2	4	1.1	37.12%	20.67%
KinC_x36_2'	4	1.1	44.78%	25.22%
KinC_x36_2''	4	1.1	34.77%	25.17%
KinC_x36_3	5	0.6	107.21%	119.06%
KinC_x36_4	4	2.7	36.67%	19.16%
KinC_x36_5	5	1.4	121.88%	88.58%
KinC_x36_5'	5	0.5	137.28%	106.98%
KinC_x36_6	5	4.3	43.95%	36.85%
KinC_x50_0a	3	2	55.18%	48.35%
KinC_x50_0b	3	2	40.73%	47.39%
KinC_x50_1	4	1.9	100.14%	81.01%
KinC_x50_1'	4	1.9	94.84%	80.17%
KinC_x50_2	5	2.05	121.33%	89.67%
KinC_x50_2'	5	0.57	109.81%	90.19%
KinC_x50_2''	5	0.61	94.90%	104.86%
KinC_x50_3	5	4.85	117.56%	86.04%
KinC_x50_3'	5	0.68	80.86%	119.14%
KinC_x50_3''	5	0.7	88.31%	111.69%
KinC_x60_1	3	10	32.48%	29.36%
KinC_x60_2	4	4.75	24.59%	22.70%
KinC_x60_2'	4	4.75	18.67%	20.05%
KinC_x60_3	5	3.17	112.50%	99.41%
KinC_x60_3'	5	1.26	85.76%	114.24%
KinC_x60_3a	5	1.83	57.62%	82.17%
KinC_x60_3b	5	1.83	83.94%	72.65%
KinC_x60_4a	5	3.88	85.56%	77.40%
KinC_x60_4b	5	3.88	83.39%	77.13%
KinC_x25_1	3	0.5	53.14%	34.10%
KinC_x25_3	4	2.6	27.73%	18.02%
KinC_x25_4	5	2.6	41.78%	33.59%



Plot courtesy of Charles Hyde and Julie Roche

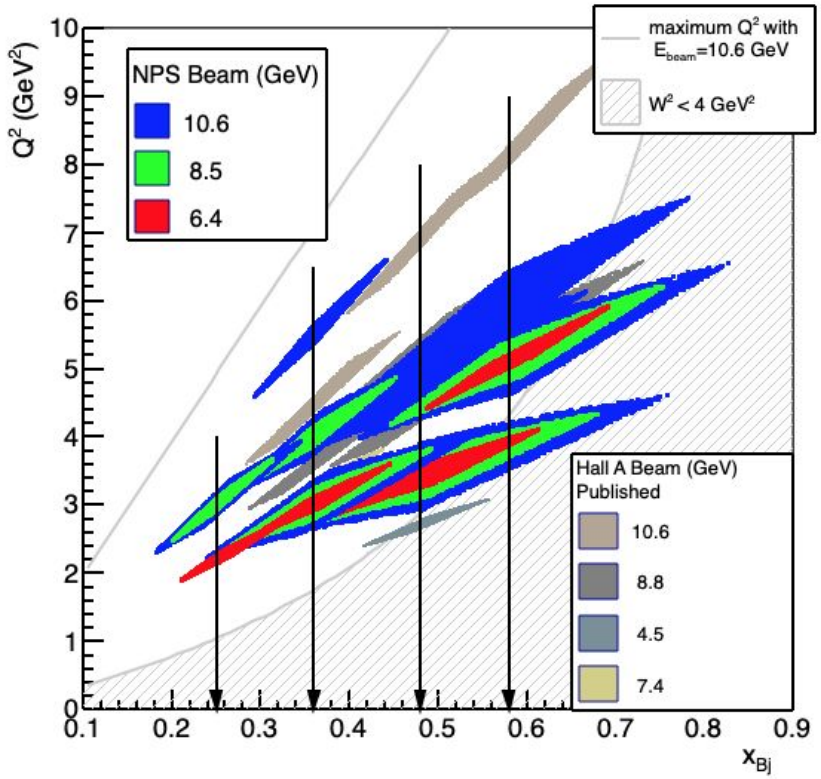
Small Angle Program of NPS Collaboration (RG1a)

CLAS12 DVCS phase space



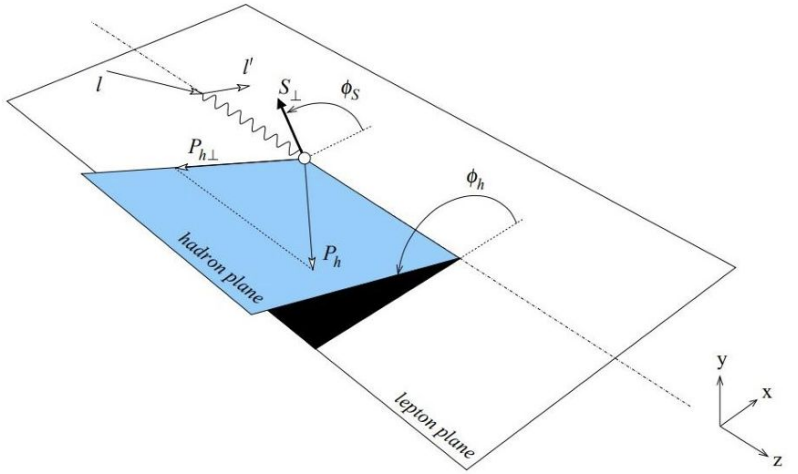
S. Niccolai E12-11-003 proposal

DVCS 12 GeV Hall A/C

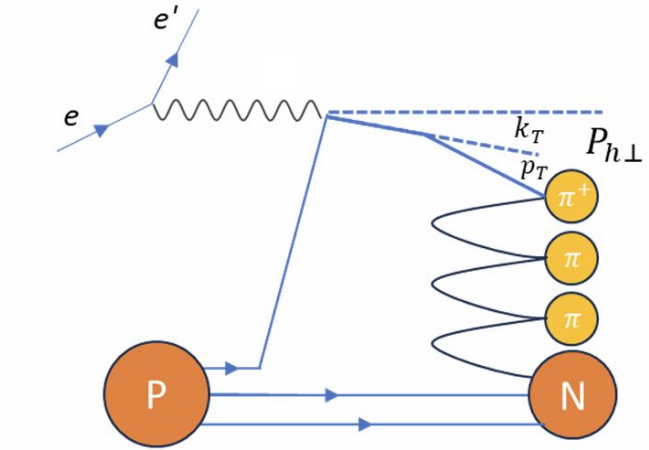


Semi-inclusive deep inelastic scattering

- SIDIS cross sections depend on the transverse momentum of the hadron $P\hbar\perp$.
  - Arises from intrinsic transverse momentum (kT) of the parton and the transverse momentum (pT) of the fragmentation process
- Neutral pions are a good test and consistency check of flavor assumptions in extraction of TMDs with TM fragmentation
  - With a pT and kT dependence, a convolution is necessary to obtain $P\hbar\perp$



Bacchetta et al. JHEP 0702 (2007) 093



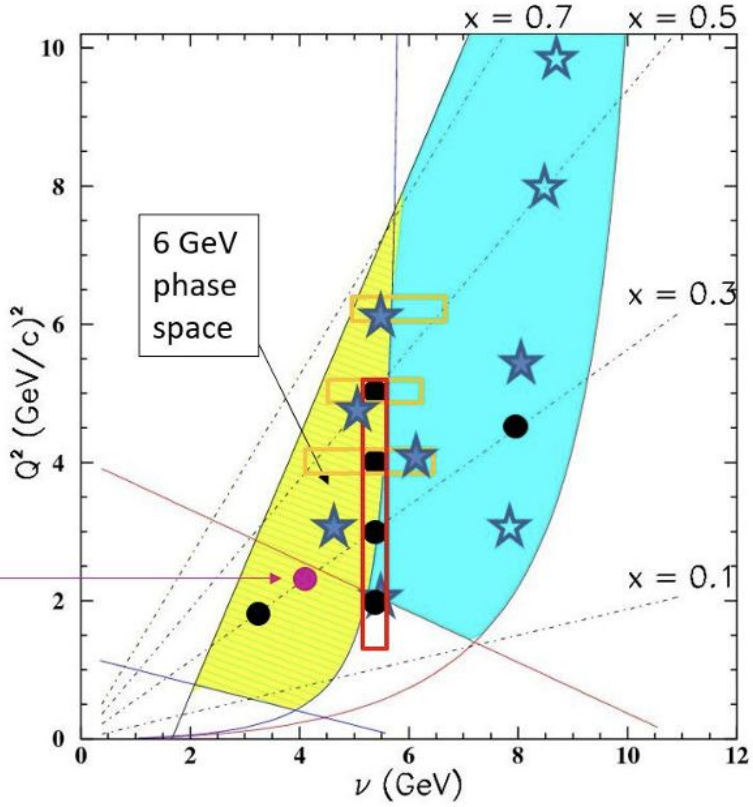
12 GeV Hall C SIDIS Program – HMS+SHMS+NPS

Accurate cross sections for validation of SIDIS factorization framework and for L/T separations

E12-13-007

★ Neutral pions: Scan in (x,z,P_T) Overlap with E12-09-017 & E12-09-002

☆ Parasitic with E12-13-010



Charged pions:

E12-06-104
L/T scan in (z,P_T)
No scan in Q^2 at fixed x: $R_{DIS}(Q^2)$ known

E12-09-017
Scan in (x,z,P_T) + scan in Q^2 at fixed x

E12-09-002
+ scans in z

Courtesy R. Ent

Jefferson Lab

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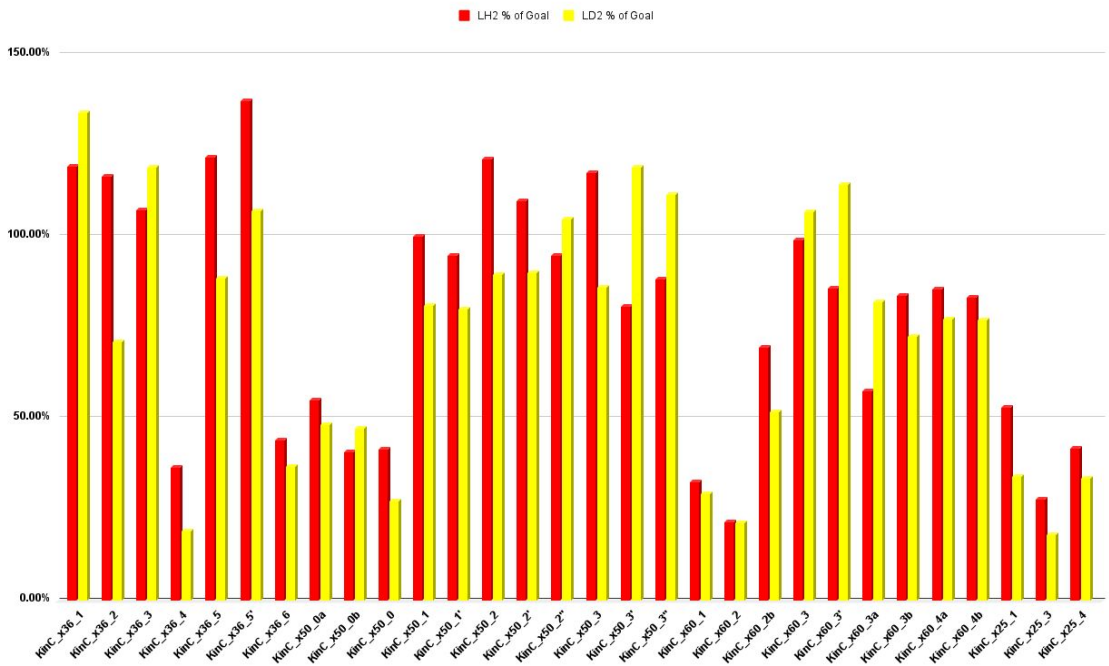
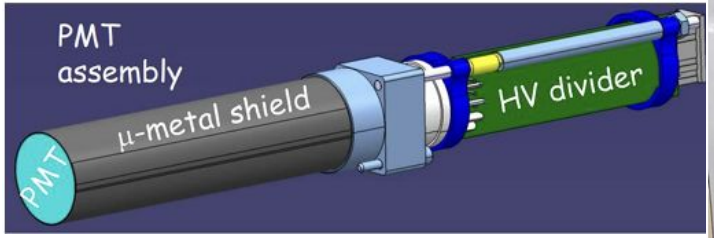
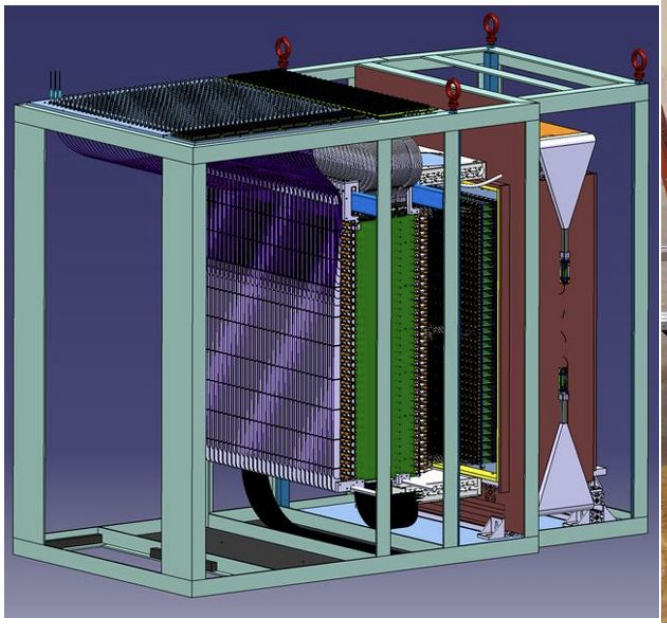


NPS Calorimeter

- 1080 PbWO4 blocks
- High energy resolution
- High light yield
- RadHard
- Temperature controlled frame
  - Hamamatsu 4125 PMTs
- HV divider and amplifier to reduced HV requirements
- LED system for gain monitoring
- HV, LV, and LED signals distributed to an entire column through distribution board





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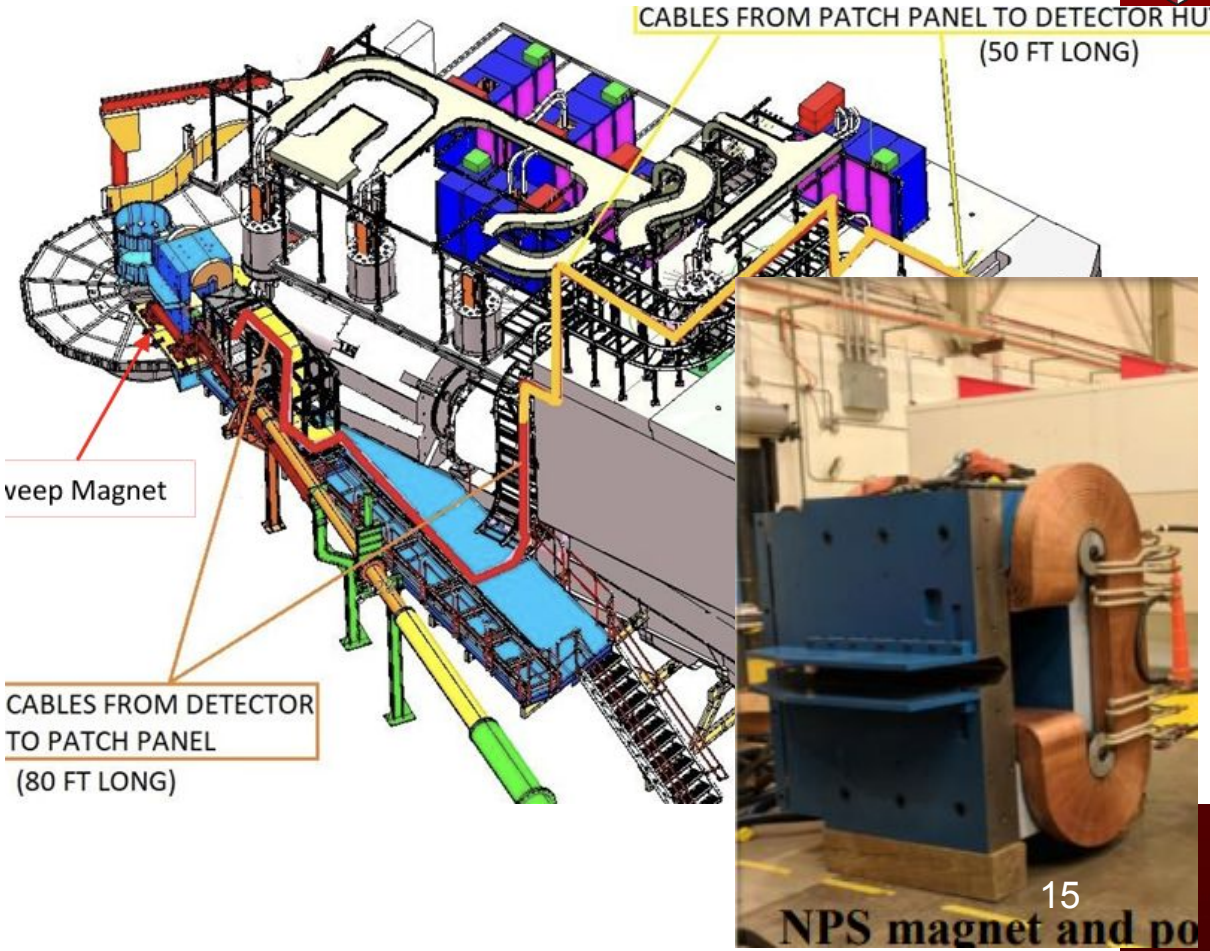
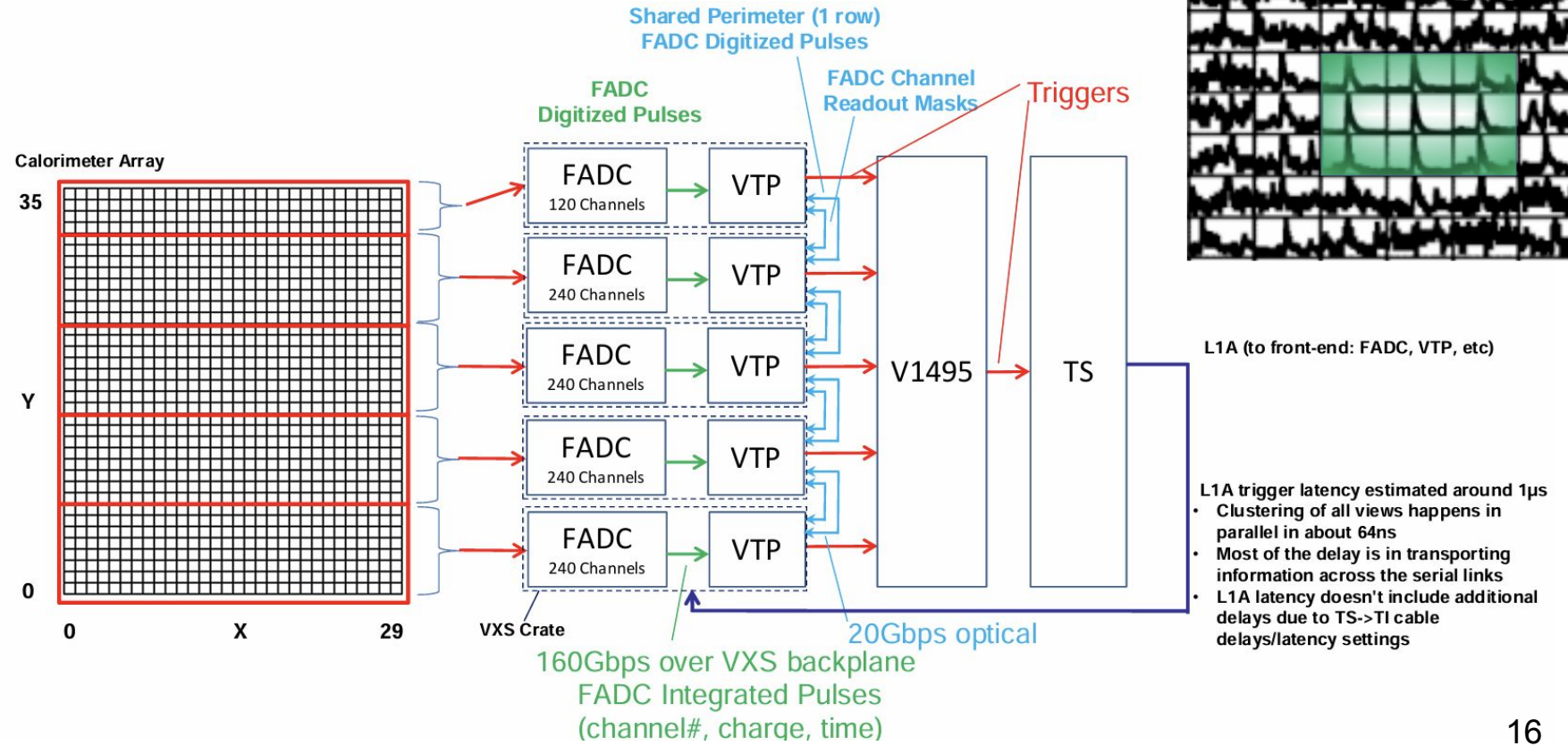


NPS DAQ/Trigger Setup

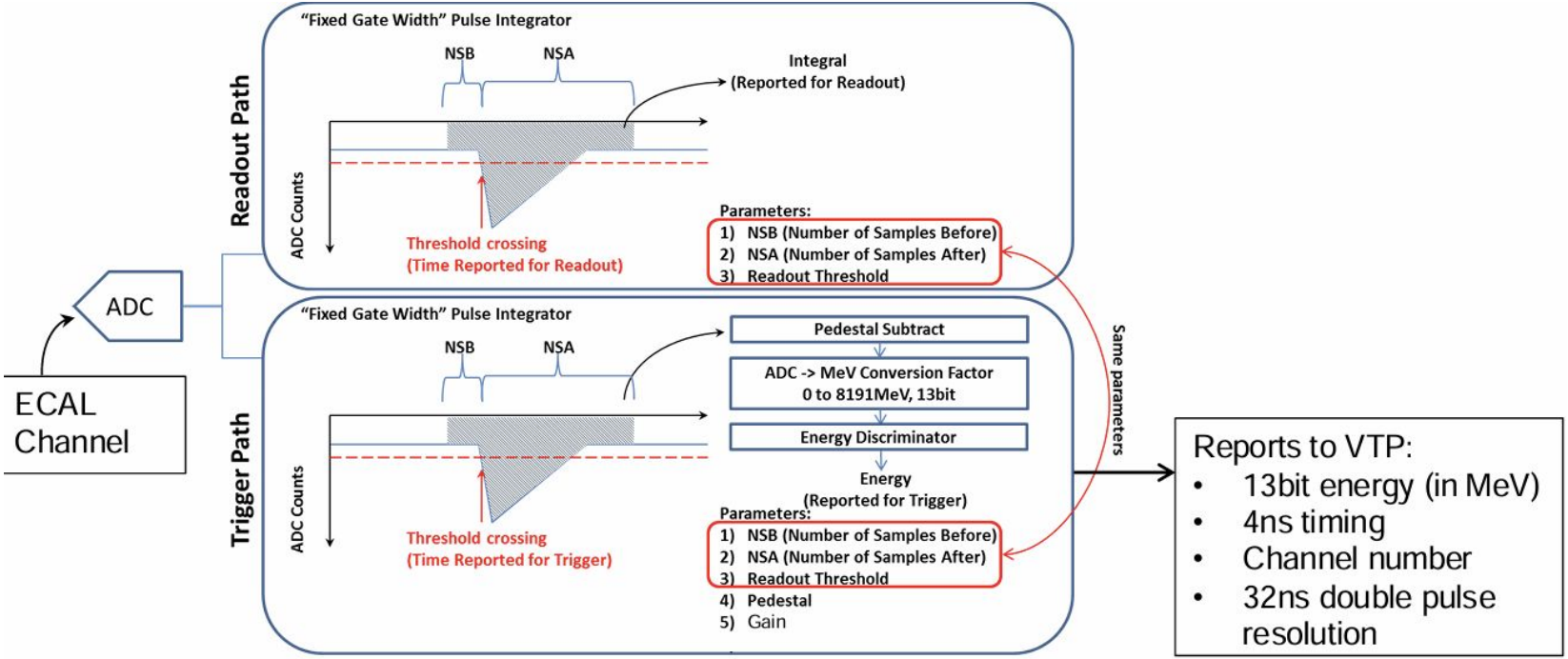


L1A trigger latency estimated around 1μs

- Clustering of all views happens in parallel in about 64ns
- Most of the delay is in transporting information across the serial links
- L1A latency doesn't include additional delays due to TS->TI cable delays/latency settings

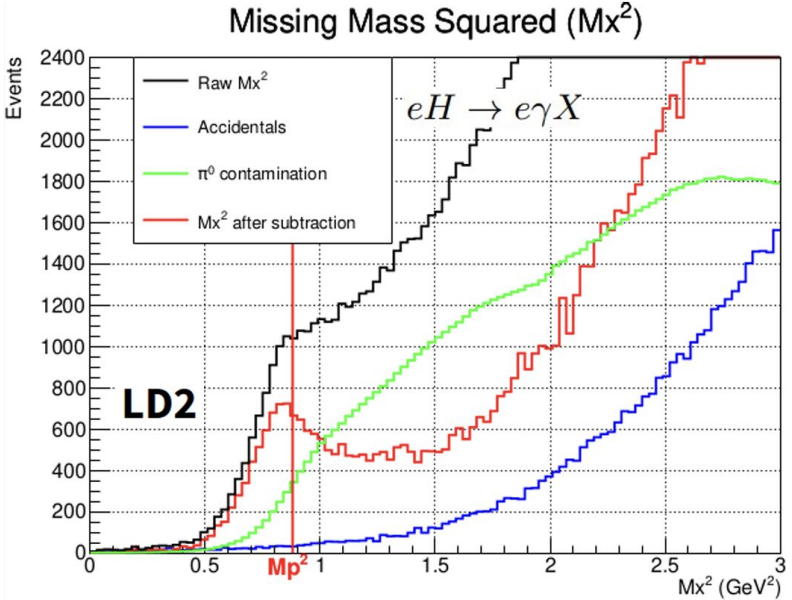
NPS DAQ/Trigger Setup

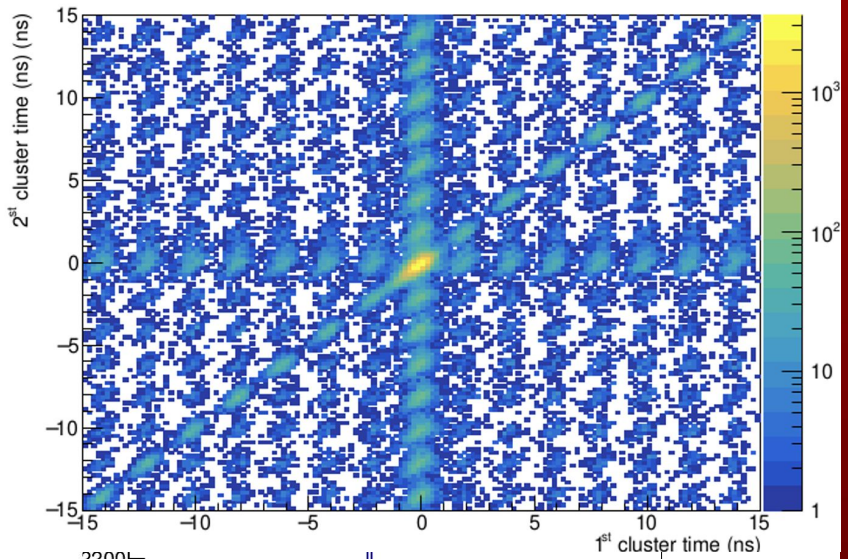
- Trigger pedestal is the same parameter that would be calculated for the readout data.
- Trigger gain parameter normally used to scale ADC -> MeV
- **Both pedestal and gain require calibration to determine parameters.**

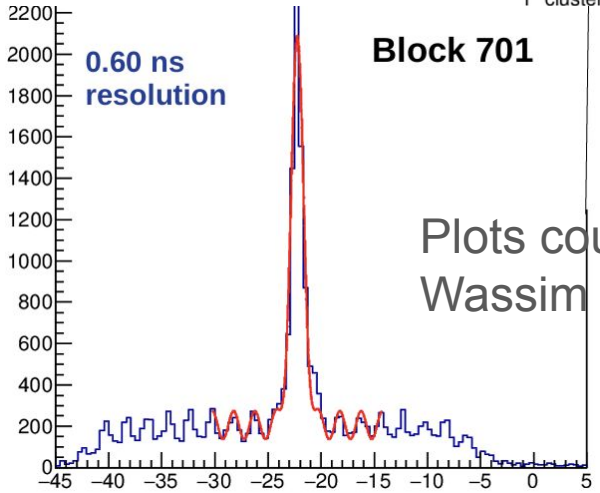


Energy and Timing resolution

- Beam bunch time, HMS coincidence time
- Cluster coincidence time
- Energy resolution of NPS







Plots courtesy Wassim Hamdi

Brief Analysis Update

Pass1 complete

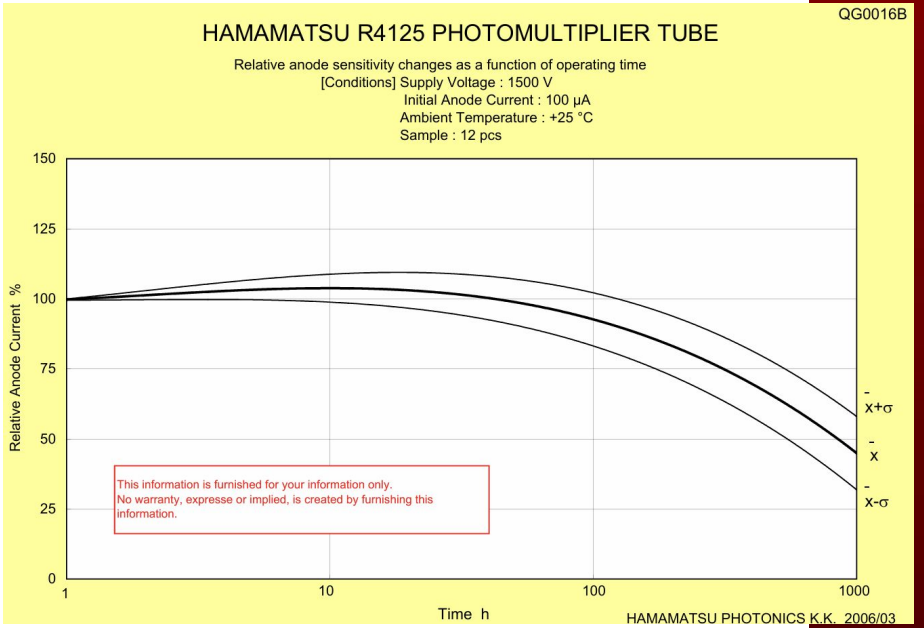
- HMS detector calibrations
- NPS pi0 calibration on ~half the kinematics — Talk By Mr. Hao Huang
- Elastic waveform analysis completed — Talk By Wassim Hamdi
- Optics matrix element update — Next talk By Christine Ploen
- Target luminosity discrepancy — Next talk By Mark Mathison
- Initial data-to-MC comparisons of SIDIS yield — Next talk By Josh Crafts

NPS Refurbishment

- Active components in the Keysight card for temperature sensing - replaced / moved
- Check resistance chain on dividers (Fernando's group)
  - Limited to 850V due to resistor chain, can it be reworked for 1500V?
- PMTs - first few columns
  - Remove some from first few columns, test to failure, and get spares
  - check connection to crystal for dried optical connection
- Cable management (On Steven L. list)
- Resolve issue with connectors on calorimeter side (electronics group)
  - possibly have an intermediate patch panel
  - replace connectors?
- Optional: Shielding to shield strips on boards to reduce noise between boards
- Optional refurbishment: Crystals
  - may try to bleach is all is disassembled anyway

NPS Refurbishment for Future Experiments

- Active components in the Keysight card for temperature sensing - replaced / moved
- Check resistance chain on dividers (Fernando's group)
  - Limited to 850V due to resistor chain, can it be reworked for 1500V?
- PMTs - first few columns
  - Remove some from first few columns, test to failure, and get spares
  - check connection to crystal for dried optical connection
- Cable management (On Steven L. list)
- Resolve issue with connectors on calorimeter side (electronics group)
  - possibly have an intermediate patch panel
  - replace connectors?
- Optional: Shielding to shield strips on boards to reduce noise between boards
- Optional refurbishment: Crystals
  - may try to bleach is all is disassembled anyway



Thank you
Questions?