Overview of Ongoing RG-D Data-taking Activities

Fall CLAS Collaboration Meeting

November 8th, 2023

Lamiaa El Fassi & Mikhail Yurov

(for Run Group D)

MISSISSIPPI STATE UNIVERSITY

CEBAF Large Acceptance Spectrometer

Run Group D

RG-D Experiments

E12-06-106: Study of Color Transparency (CT) in Exclusive Vector Meson Electroproduction off Nuclei

Spokespeople: W. Armstrong[1], L. El Fassi[3], K. Hafidi[1], M. Holtrop[4], and B. Mustapha[1]

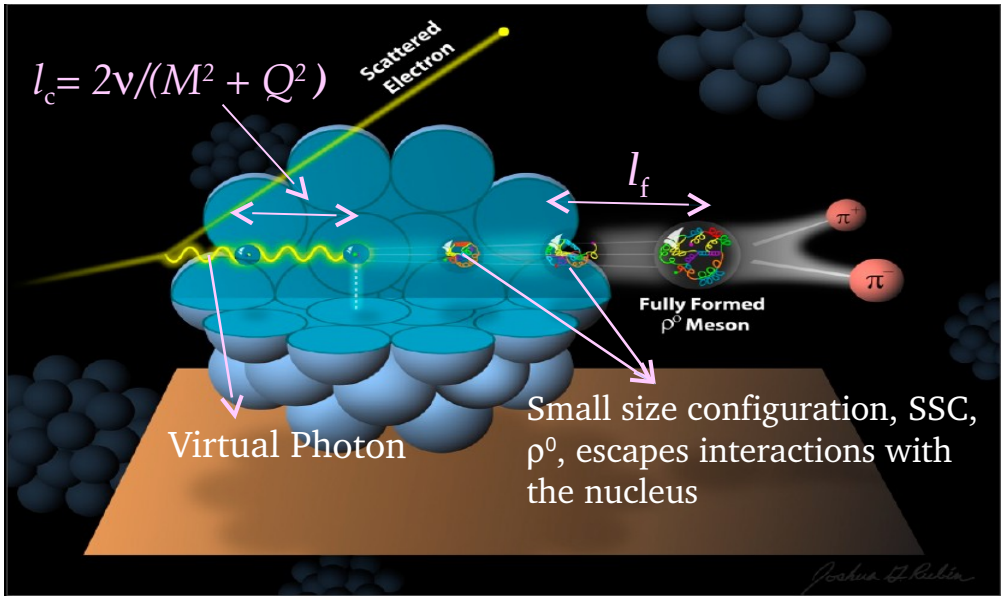
E12-06-106A (endorsed by *PAC-48*): Nuclear TMDs in CLAS12

Spokespeople: R. Dupré[2], L. El Fassi[3], Zein-Eddine Meziani[1], and Holly Szumila-Vance[5]

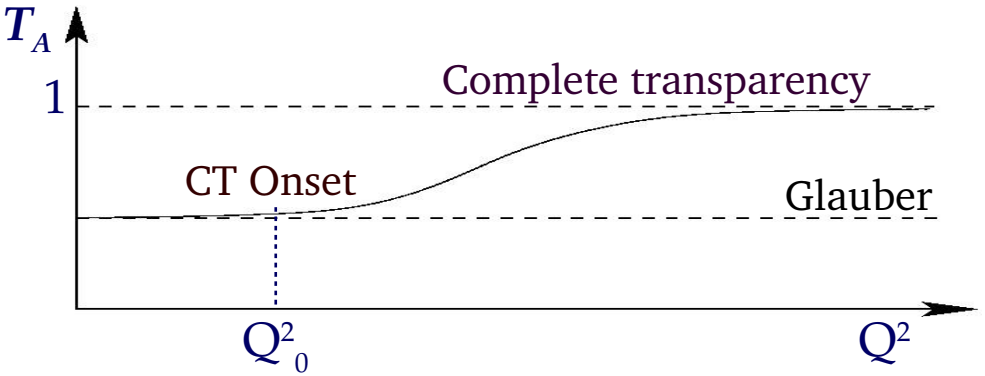
[1]: Argonne National Lab (ANL)
[2]: IJCLAB, Orsay, France
[3]: Mississippi State U. (MSSate)
[4]: University of New-Hampshire (UNH)
[5]: Jefferson Lab

RG-D: CT Experiment

- E12-06-106, CT, experiment was approved in PAC-48 Jeopardy review for 30 PAC days with B^+ rating.



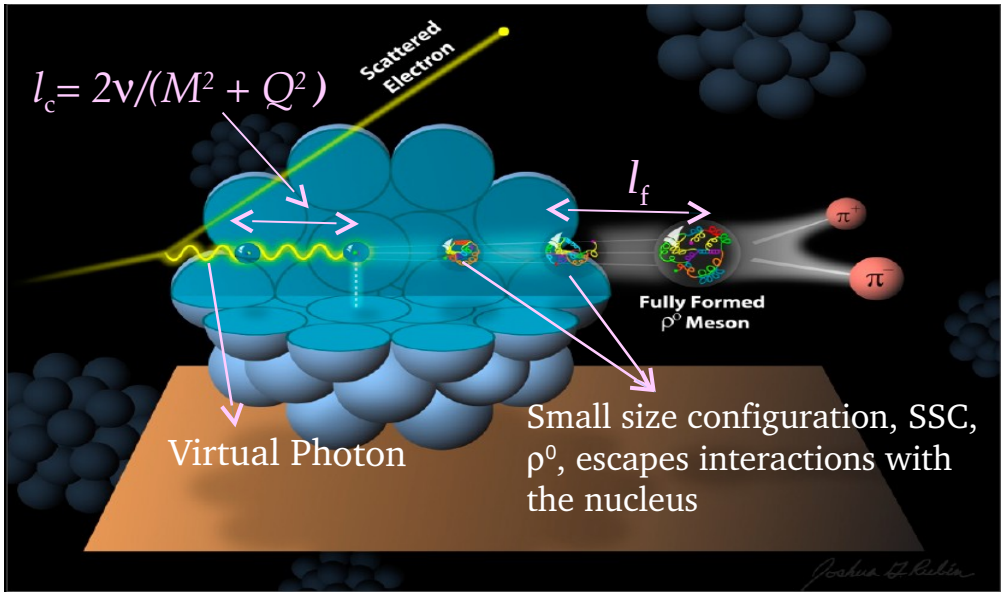
The CT signature is the increase of the medium "nuclear" transparency, $T_A = \frac{\sigma_A}{A\,\sigma_N}$, as a function of the four-momentum transfer squared, Q^2.



- Coherence length, l_c: the lifetime of the **qq-bar** pair.
- Formation time, l_f: the time evolution of SSC to an on-shell ρ^0 meson.

RG-D: CT Experiment & Nuclear TMDs

- E12-06-106, CT, experiment was approved in PAC-48 Jeopardy review for 30 PAC days with B+ rating.



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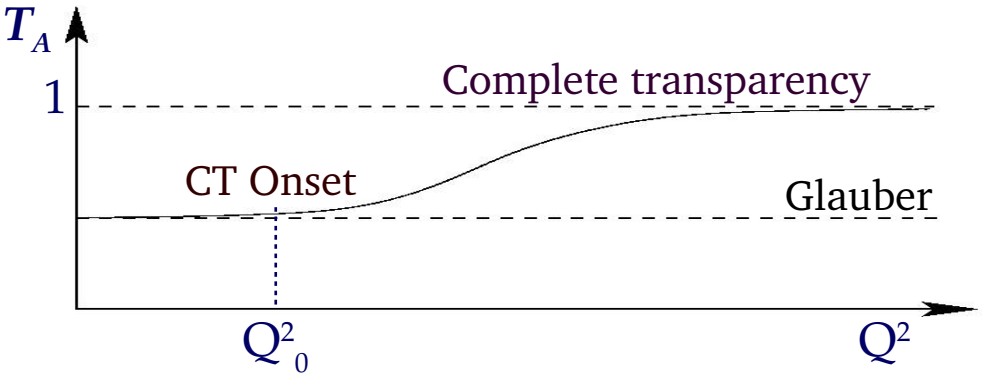
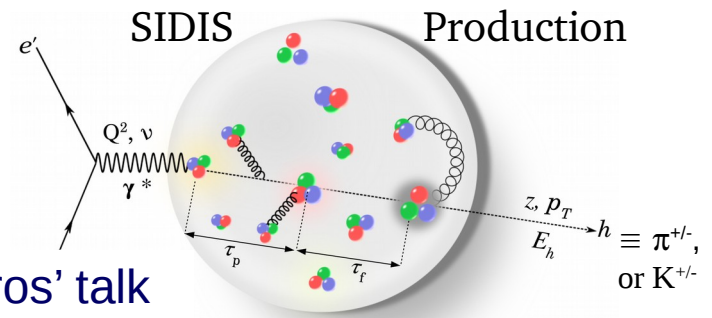


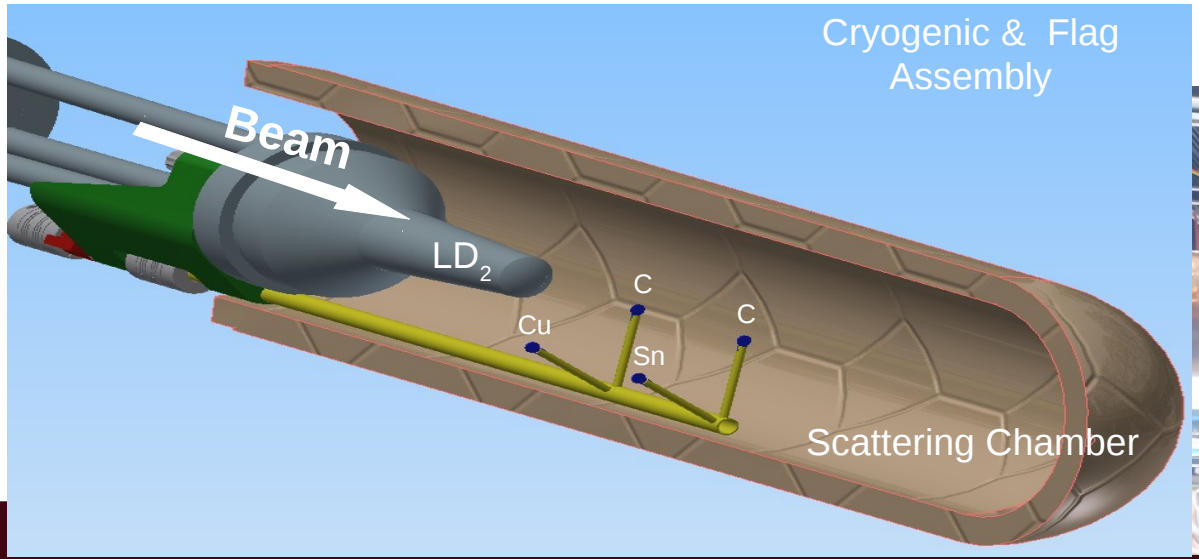
- E12-06-106A, Nuclear TMDs study uses the same CT running conditions except the beam polarization, and aims to explore
  - New approach for nuclear SIDIS
  - Fragmentation functions in nuclei
  - Medium modification of partons distributions and dynamics
  - Nuclear asymmetries at the partonic level



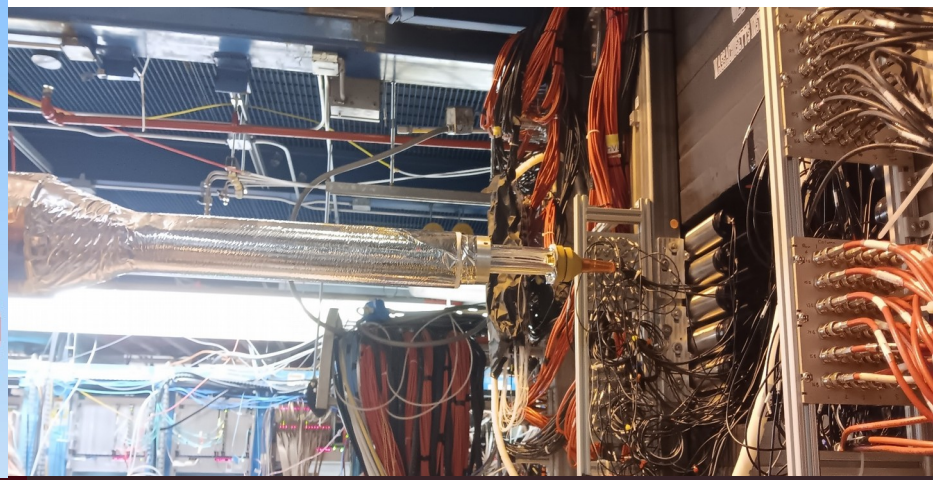
See D. Matamoros' talk

RG-D Run Configuration

- RG-D experiments run with
  - 10.54 GeV polarized beam;
  - Standard CLAS12 configuration with FT-OFF;
  - 5-cm-long LD_2 cell in the newly built cryogenic system positioned at -5 cm;
  - Remotely controlled 5-cm-apart solid foils centered @ -5 cm;
  - Different beam currents as approved in the Radiaiton Safety Analysis Document for various target's production runs, except for CuSn configuration!



Newly built Hall B cryogenic target;
See P. Achenbach's talk!



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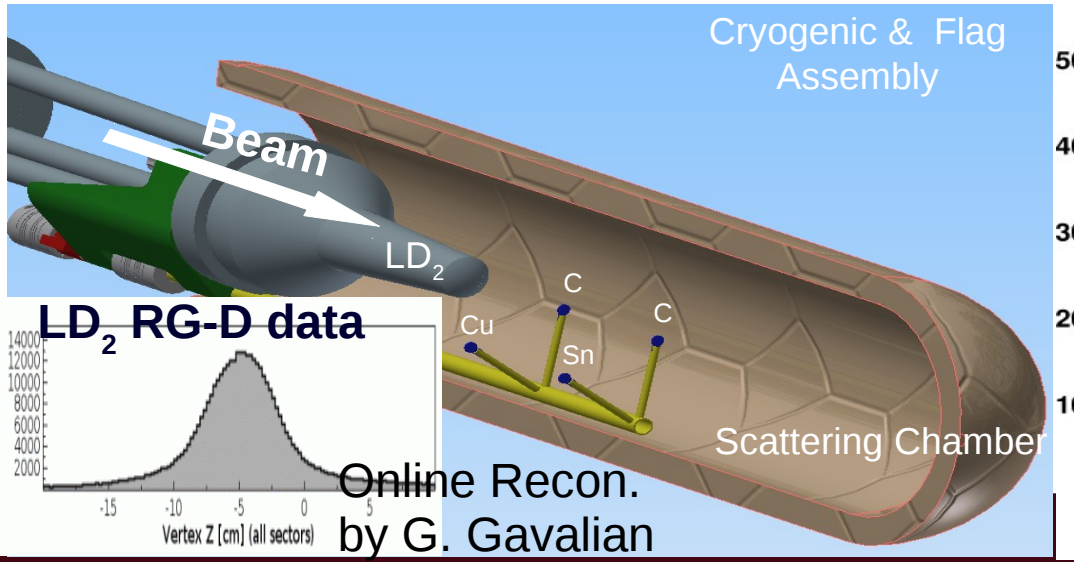
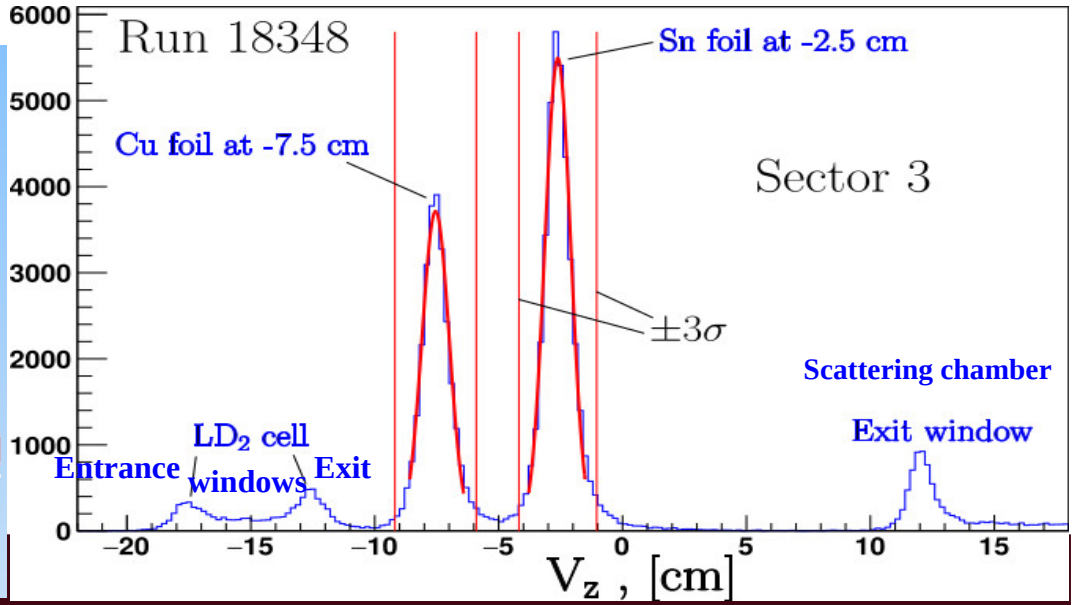




RG-D Run Info

- **Run-wiki**: https://wiki.jlab.org/clas12-run/index.php/Run_Group_D
- **Analysis wiki**: https://clasweb.jlab.org/wiki/index.php/Run_Group_D
- **Physics Division Liaison** (PDL)**:** Nathan Baltzell
- **RG/Analysis Coordinator**: Lamiaa El Fassi
- **Cooking Chef** (CC)**:** Mikhail Yurov
- **Run Coordinators**:

RG-D Run Coordinators Sign up Sheet for 72.5 Calendar Days Run Period

	September 2023							October 2023						November 2023					December 2023			
	Fri., 1st	Wed., 13th	~~Fri., 15th (Start of Run*)~~	Wed., 20th	~~Fri., 22nd (Start of Run*)~~	Wed., 27th	~~Fri., 29th (Start of Run*)~~	Sun., 1st	Tue., 3rd (Start of Run*)	Wed., 4th	Wed., 11th	Wed., 18th	Wed., 25th	Wed., 1st	Wed., 8th	Wed., 15th	Wed., 22nd	Wed., 29th	Fri., 1st	Wed., 6th	Wed., 13th	Fri., 15th (End of Run)
Target Fabri. & Comm.	Lamiaa El Fassi																					
~~Week 1~~		~~Hamza Attac~~																				
~~Week 2~~				~~Sangbaek Lee~~																		
Week 1			Canceled due to the target work delay						~~Utsav Shrestha~~													
Week 2										Susan Schadmand												
Week 3											Susan Schadmand											
Week 4												Utsav Shrestha										
Week 5													Susan Schadmand									
Week 6														Susan Schadmand								
Week 7															Raphael Dupre							
Week 8																Susan Schadmand						
Week 9																	Mikhail Yurov					
Week 10																		Susan Schadmand				
Week 11																				Whitney Armstrong		
Week 12																					Lamiaa El Fassi	

We are here

RG-D Commissioning Plan

- Developped based on Nathan's RG-D Special Runs compiled after the meeting with Hall B detector experts back in July:

Task	Special Run	Target
Beam Tuning	Tagger: New Møller Quad. PS	
	Faraday Cup	
Trigger Validation	30 kHz Random Trigger (@ 35 nA) to validate Electron trigger	
	Trigger w/. no-DC-roads (@ 35 nA) to validate trigger roads	LD_2
DC HV Scan, TOF Gain & ECAL Calib.	4 runs @ 35 nA to scan 4 DC (R_1, R_2, R_3) HVs: (9,9,9), (10,10,10); (10,11,11) & (11,12,12)	
Alignment	10 M @ 1 nA in FD	Empty
Luminosity Scan High B-Cur. Scan	5, 20, 35, and 50 nA 75 and 100 nA	
Luminosity Scan	10 / [20--45] / 45 / [50–90] / 75 nA	CxC
	100 / [110--130] nA / 130/ [150–200]/ 150/175 nA	CuSn
ECAL Calib.	Outbending Config.: 50 M @ 35 nA	LD_2

Interrupted due Solenoid fast dump due to LCW fluctuation

Performed for Inbending and Outbending Config. & Low-Q^2 suppression

RG-D Data Processing Summary

- RG-D Cooking Configuration

  - cooking chef account set up (Nathan)
  - new coatjava release 10.0.4 (several fixes)
  - updated yaml files and approriate schemas (Raffaella)
  - got trained on workflow preparation and submission

- Cooking Requests Summary

  - Trigger studies: In/Out, DC roads
  - Calibration: Gain, ECal, HTTCC, In/Out, 1st full
  - DC: HV scan
  - Luminosity scan: In/Out, Convn./AI/Denoised
  - CVT: alignment, efficiency, calibration
  - AI trigger studies: Level-3 AI/Denoised
  - Physics: first DST after full calibration
  - Alignmetn (Raffaella)

- RG-D Pass0 Cooking

  Timelines;
  See D. Carman talk

  - automated cooking of available runs
  - daily corresponding timline generation
  - started with pass0.1 until first full calibration
  - relaunched on Nov 2 with pass0.2

- RG-D Outputs Location

  /volatile/clas12/rg-d/production/trig
  /volatile/clas12/rg-d/production/calib
  /volatile/clas12/rg-d/production/dchv
  /volatile/clas12/rg-d/production/lumi
  /volatile/clas12/rg-d/production/cvt
  /volatile/clas12/rg-d/production/trig/v3_ai
  /volatile/clas12/rg-d/production/prod

  /volatile/clas12/rg-d/production/pass0.1
  /volatile/clas12/rg-d/production/pass0.2
  /volatile/clas12/rg-d/production/tline

Info summarized @ https://clasweb.jlab.org/wiki/index.php/Run_Group_D#tab=Data_Processing_2

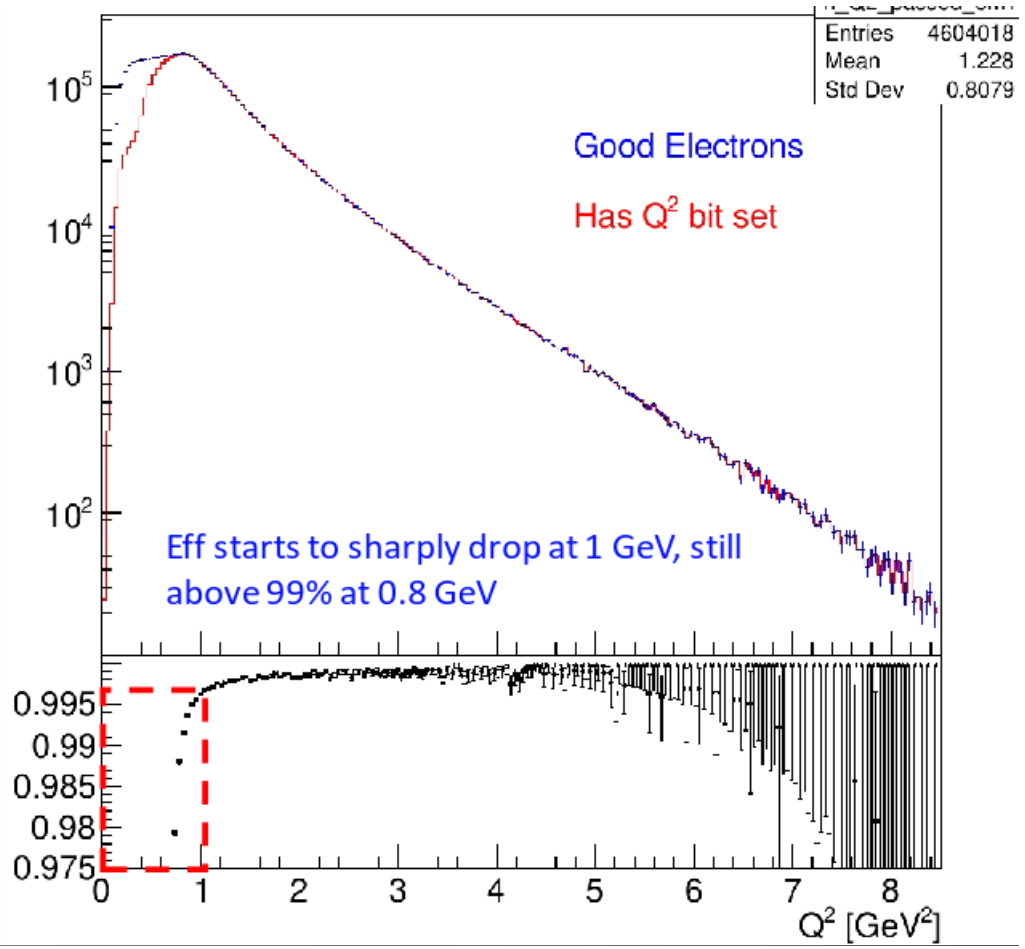
Slide Courtesy of CC: M. Yurov

Trigger Validation

- Processed dedicated runs with the appropriate schema requested by the trigger group:
  - ✔ Many thanks to Valery Kubarovsky, Ben Raydo and Rafayel Paremuzyan for preparing and validating our trigger files.

- Electron is selected as pid = 11, E_{PCal} > 60 MeV, and E_{tot} > 250 MeV;
- It is also required the Electron_WithoutDC bit to be set, then check whether the DC trigger bit (which includes low Q^2 suppression cut) is set.

Courtesy of R. Paramuzyan



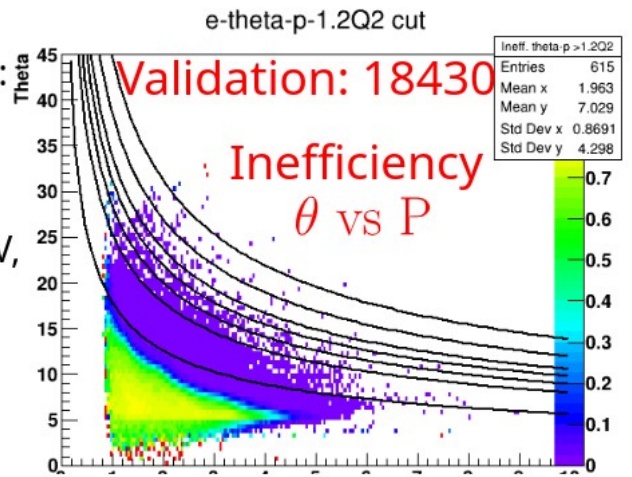
Trigger Validation

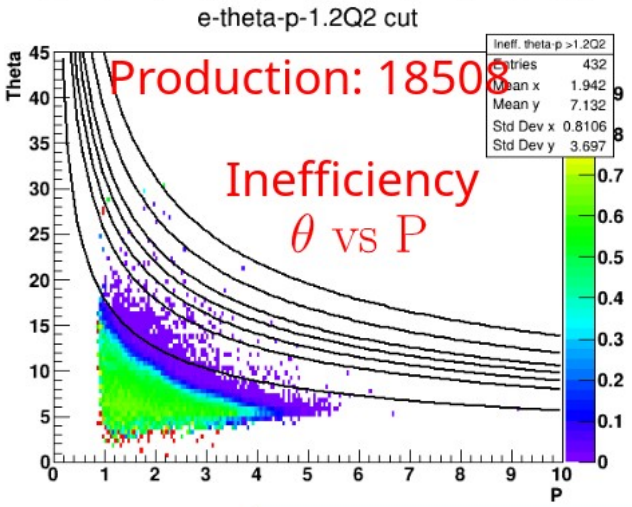
- Processed dedicated runs with the appropriate schema requested by the trigger group:
  - ✔ Many thanks to Valery Kubarovsky, Ben Raydo and Rafayel Paremuzyan for preparing and validating our trigger files.

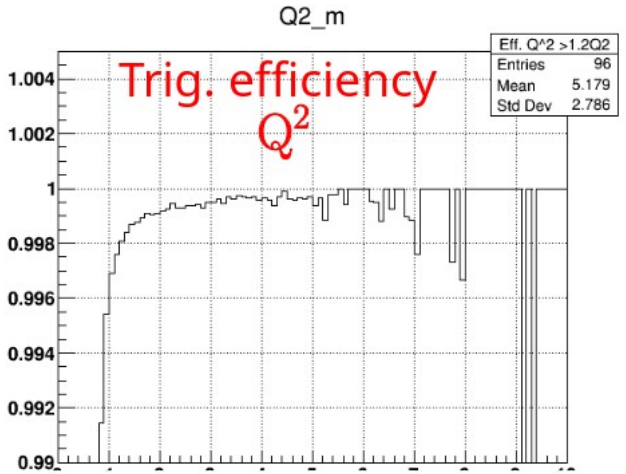
Good electrons:
pid=11,
FD,
PCAL>60MeV,
ETOT>250MeV,

Q^2 lines

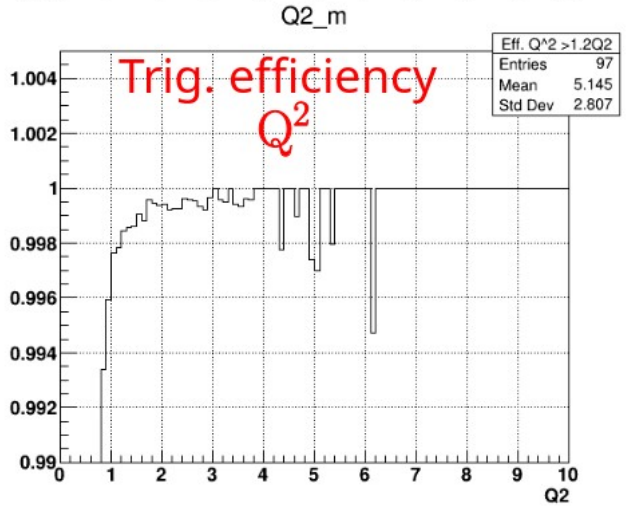
Top: 6.0 GeV^2
4.5 GeV^2
3.5 GeV^2
3.0 GeV^2
2.5 GeV^2
2.0 GeV^2
Bot: 1.0 GeV^2







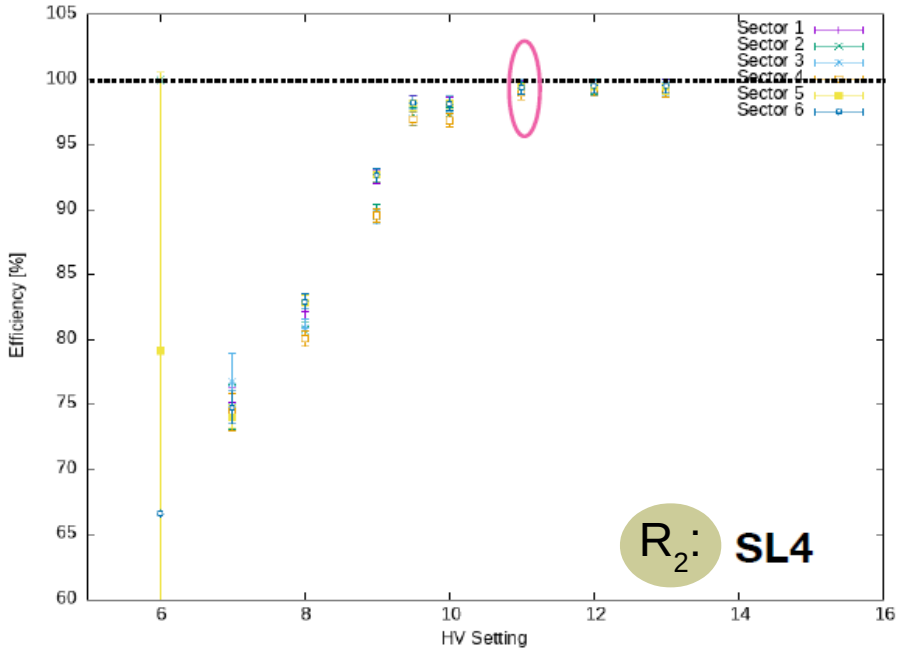
Validation run:
noDC(sec) bit vs
DC_lowQ2(set) bit

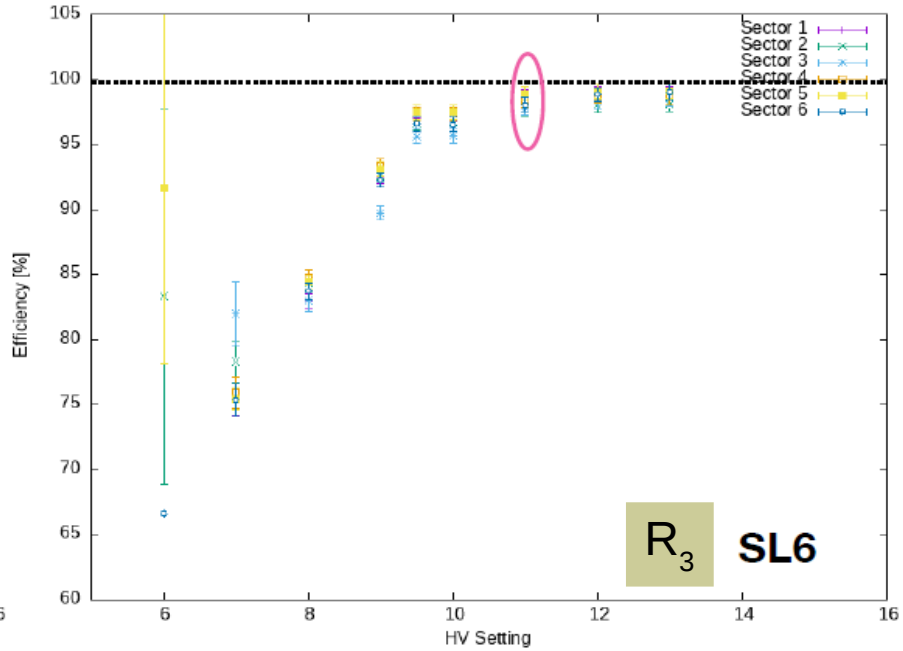


Production run: uses x50 scaled
noDC(sec) bits vs
DC_lowQ2(set) bit

Courtesy of M. Yurov

DC Efficiency Scan

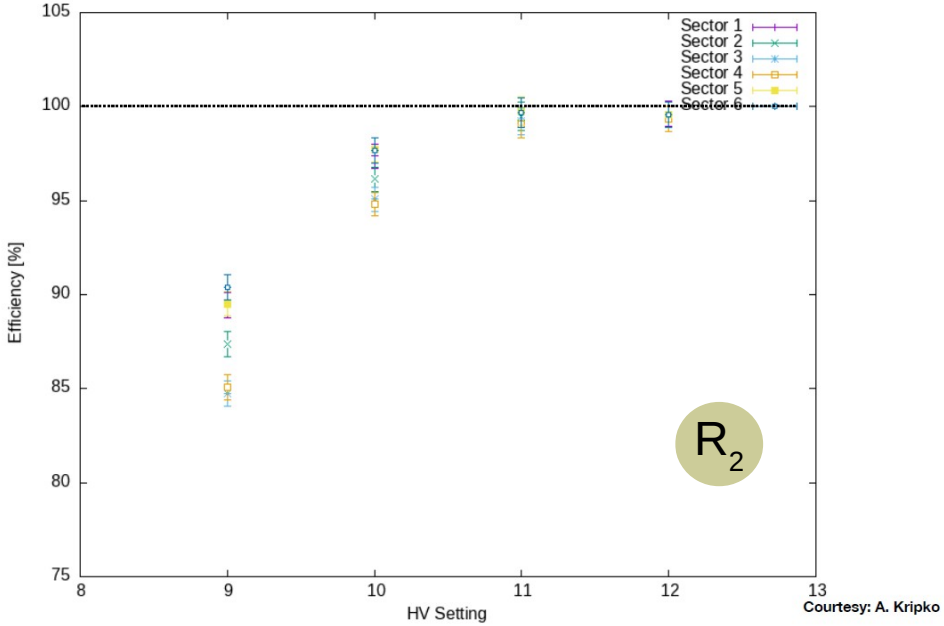




- **Previous conclusion from RGC scan: (10,11,11) might be optimal**
- **4 Settings for RGD study (R1,R2,R3)**
  - **(9,9,9)**
  - **(10,10,10) —> used in RGM and RGC**
  - **(10,11,11)**
  - **(11,12,12)**
- **Analysis with 'dclayeffi' program from Veronique, done by Aron Kripko**
- **Gains between R1 and R2/R3 are similar for setting 10,11,11**

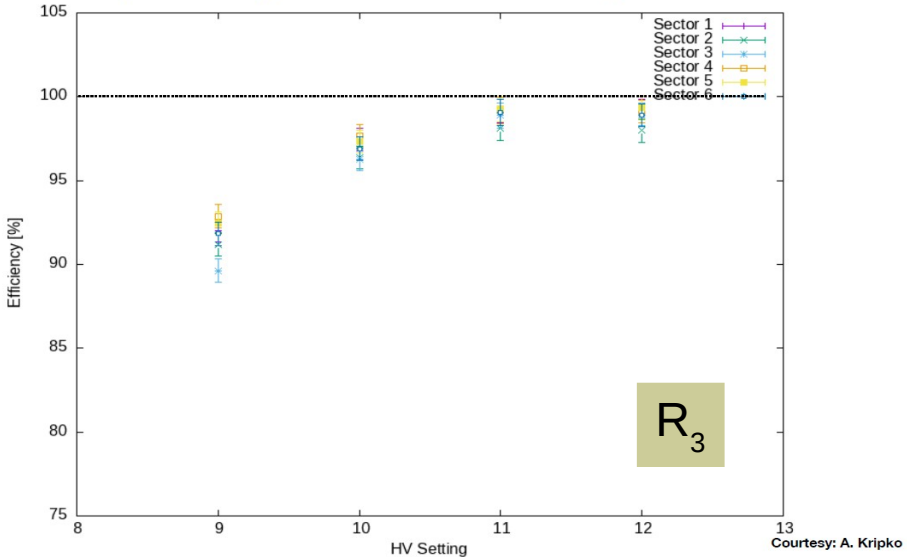
Courtesy of Florian Hauenstein

Super layer 4 Efficiency RGD



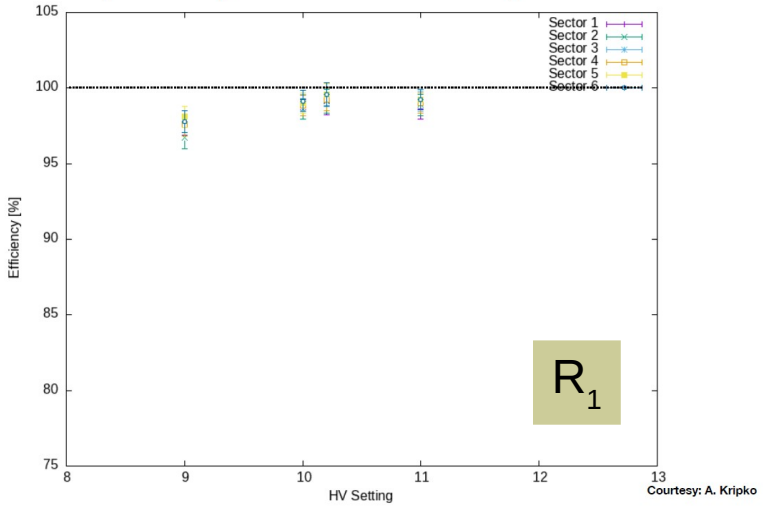
- Plateau from Setting 11 on (as previously observed)
- 2% gain in efficiency from 10 -> 11

Super layer 6 Efficiency RGD



- Similar than SL4
- 2% gain in efficiency from 10 -> 11

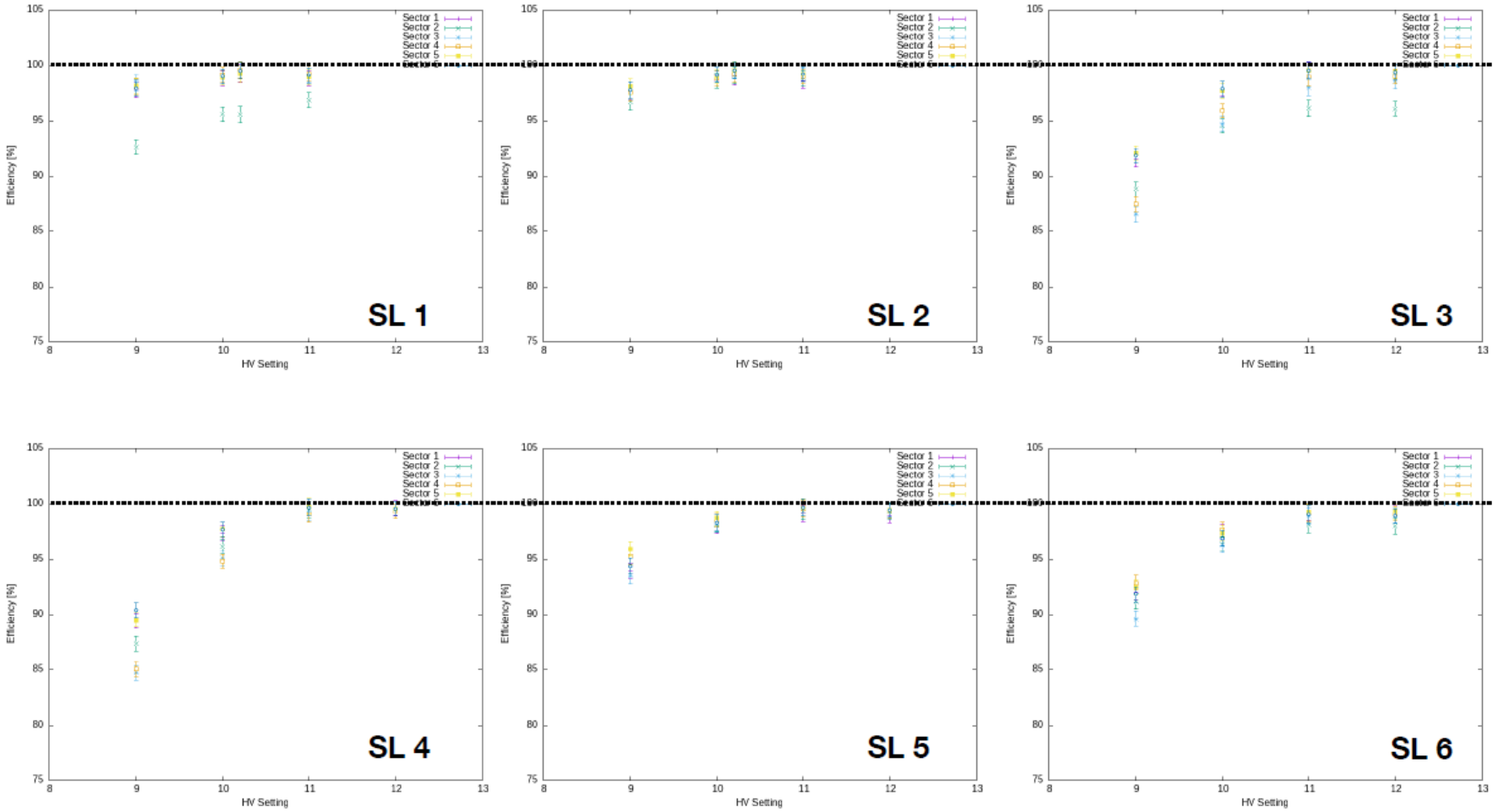
Super layer 2 Efficiency RGD



- Already plateau in setting 10

Courtesy of Florian Hauenstein

Detector Efficiency (all superlayers) from RGD



Courtesy: A. Kripko

- **Conclusion: Efficiency plateau for (10,11,11) —> Keep there for RGD**
- **Consistent with the conclusions from RGC scan!**

Courtesy of Florian Hauenstein

Online Calibration & Alignment Status

- Summarized @ https://clasweb.jlab.org/wiki/index.php/Run_Group_D#tab=Calibration_and_Alignment:
  - ✔ Many thanks to detector and calibration experts (*CALCOM group in general*) for their efforts to calibrate and align the RG-D data online.

Online Calibration w/. Outbending Data

Oct. 31st, 2023

- FTOF: Daniel calibrated the attenuation length, effective velocity, gain balance, status, time walk, time walk position, time offsets, and timing resolution using a run 18437. Constants applied to a run range 18419-infinity; see his HBLOG entry #: 4212976.

Oct. 28th, 2023

- FTOF: Gain & HV tables were updated by Daniel using the outbending run 18437; see HBLOG entry #: 4210799.

Oct. 26th, 2023

- Beam Offset: Mariana Tenorio, in coordination with Raffaella, extracted beam offsets using the outbending run 18437 that was processed after the DC alignment; see HBLOG entry #: 4209436.

Oct. 24th, 2023

- CTOF: Daniel calibrated the attenuation length, effective velocity, gain balance, status, time offsets, hposbin, and tres using run 18437. Constants applied to a run range 18419-infinity; see his HBLOG entry #: 4207408.

Oct. 20th, 2023

- DC: Florian updated the T2D pressure dependence using the RG-K fall 2018 pass2 calibration constants for the outbending runs starting from run 18419; see HBLOG entry #: 4203834

Oct. 14th, 2023

- Ecal: FTIME and DTIME tables were adjusted to zero residual offsets based on the outbending run 18419 for the whole datasets (18300 - Inf.); see HBLOG entry #: 4199712;
  Gain and attenuation tables were updated by Cole using the outbending run 18419 for the range (18418 - Inf); see HBLOG entry #: 4199724;

Online Calibration/Alignment w/. Empty Target

Oct. 31st, 2023

- Yuri Gotra uploaded the CVT alignment constants extracted using the run 18316 to the RG-D variation "rgd_fall2023"; see HBLOG entry #: 4213129.

Oct. 20th, 2023 See M. Maynes' talk

- Raffaella and Matthew completed the third DC alignment iteration using the run 18316, which included a y-shift of 0.715 cm to account for the beam offset; see the info recorded on the rgd_fall2023 variation.

Oct. 17th, 2023

- Yuri Gotra uploaded RG-C CVT alignment constants to the RG-D variation "rgd_fall2023" as the initial constants for FD alignment, calibration, and cooking; see HBLOG entry #: 4201866.

Oct. 11th, 2023

- DC: Florian loaded the T2D calibration constants to CCDB, which were extracted using the alignment run 18316; see HBLOG entry #: 4197254.

Online Calibration & Alignment Status

- Summarized @ https://clasweb.jlab.org/wiki/index.php/Run_Group_D#tab=Calibration_and_Alignment:
  - ✔ Many thanks to detector and calibration experts (*CALCOM group in general*) for their efforts to calibrate and align the RG-D data online.

Online Calibration w/. Inbending Data

Oct. 31st, 2023

- DC: Florian performed T0 time offsets calibration with individual sector/superlayer offsets (T00) based on Run 18335 (inbending) with results from 18437 (outbending) for Sec1SL6 due to bad fits for run 18335. Also, a correction was done for the cable swaps in sectors 1 and 4, which were present in previous run groups but do not apply to RG-D. Constants applied to a run range of 18000-infinity; see his HBLOG entry #: 4213246.
- FTOF: Daniel calibrated the attenuation length, effective velocity, gain balance, status, time walk, time walk position, time offsets, and timing resolution using a run 18335. Constants applied to a run range 18305-18401; see his HBLOG entry #: 4212976.

Oct. 26th, 2023

- Beam Offset: Mariana Tenorio, in coordination with Raffaella, extracted beam offsets using the inbending run 18335 that was processed after the DC alignment; see HBLOG entry #: 4209436.

Oct. 25th, 2023

- Ecal: FTIME and DTIME tables were adjusted to zero residual offsets based on the inbending calibration of a run 18335. It's applied to the run range 18300 - 18417; see HBLOG entry #: 4208437;

Oct. 24th, 2023

- CTOF: Daniel calibrated the attenuation length, effective velocity, gain balance, status, time offsets, hposbin, and tres using run 18335. Constants applied to a run range 18305-18401; see his HBLOG entry #: 4207408.

Oct. 20th, 2023

- CTOF: Daniel calibrated the TDC-FADC time offset using run 18355. He also adjusted the 4 ns shift of some run ranges 18343-18344, 18360-18366, 18376-18377, 18420-18422, and 18475-18478 using the TDC-FADC time offset calibration of run 18362; see his HBLOG entry #: 4203856.
- DC: Florian updated the T0 DC time offsets with individual sector/superlayer offsets (T00) based on inbending run 18333 for Sec4SL6 and Sec6SL6 due to bad fits of this run in the Pass0.1 timeines; see HBLOG entry #: 4203834

Oct. 10th, 2023

- ECAL & PCAL: Cole updated the HV tables using the inbending run 18312 while being down due to the solenoid trip in the Swing shift; see HBLOG entry #: 4196847.

Oct. 9th, 2023

- DC: Florian Hauenstein performed T2D calibration using the alignment run 18316; see HBLOG entry #: 4196249.

Oct. 8th, 2023

- RF: Raffaella updated the "RF offsets" using the inbending run 18309; see HBLOG entry #: 4195642.

Oct. 6th, 2023

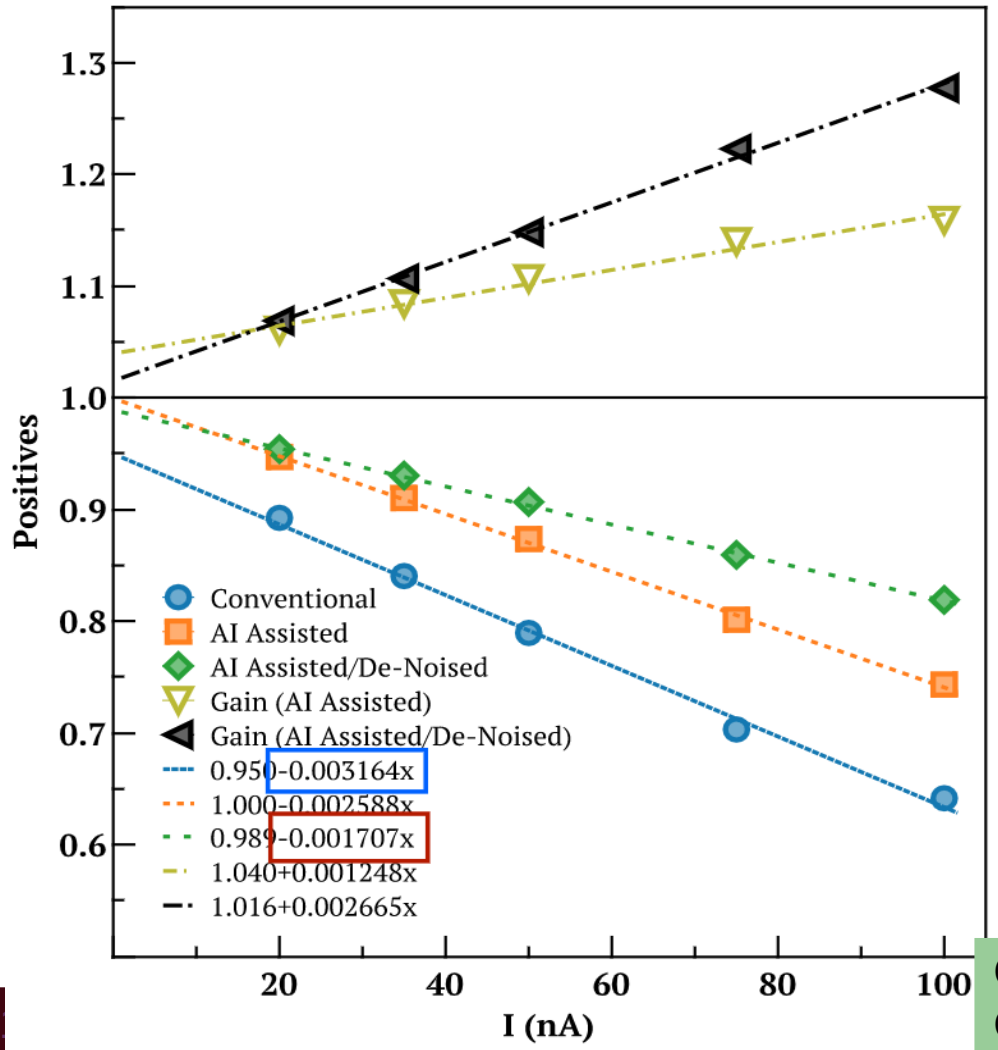
- HTCC: Gain and Time calibration was done by Izzy Illari using the inbending run 18309; see HBLOG entry #: 4194103;
  Gain tables, "CTOF_HTCC/adcctof1_gain.cnf", used in the trigger were updated by Izzy using the inbending run 18309; see HBLOG entry #: 4194054.
- Ecal: Gain and Attenuation were updated by Cole Smith using the inbending run 18312; see HBLOG entry #: 4194393;
  : Time calibration was done by Cole using the inbending run 18312; see HBLOG entry #: 4194914;
- FTOF: Gain & HV tables were updated by Daniel using the inbending run 18312; see HBLOG entry #: 4193839.
- CTOF: Gain & HV tables were updated by Daniel Carman using the inbending runs 18309 & 18312; see HBLOG entry #: 4193758.

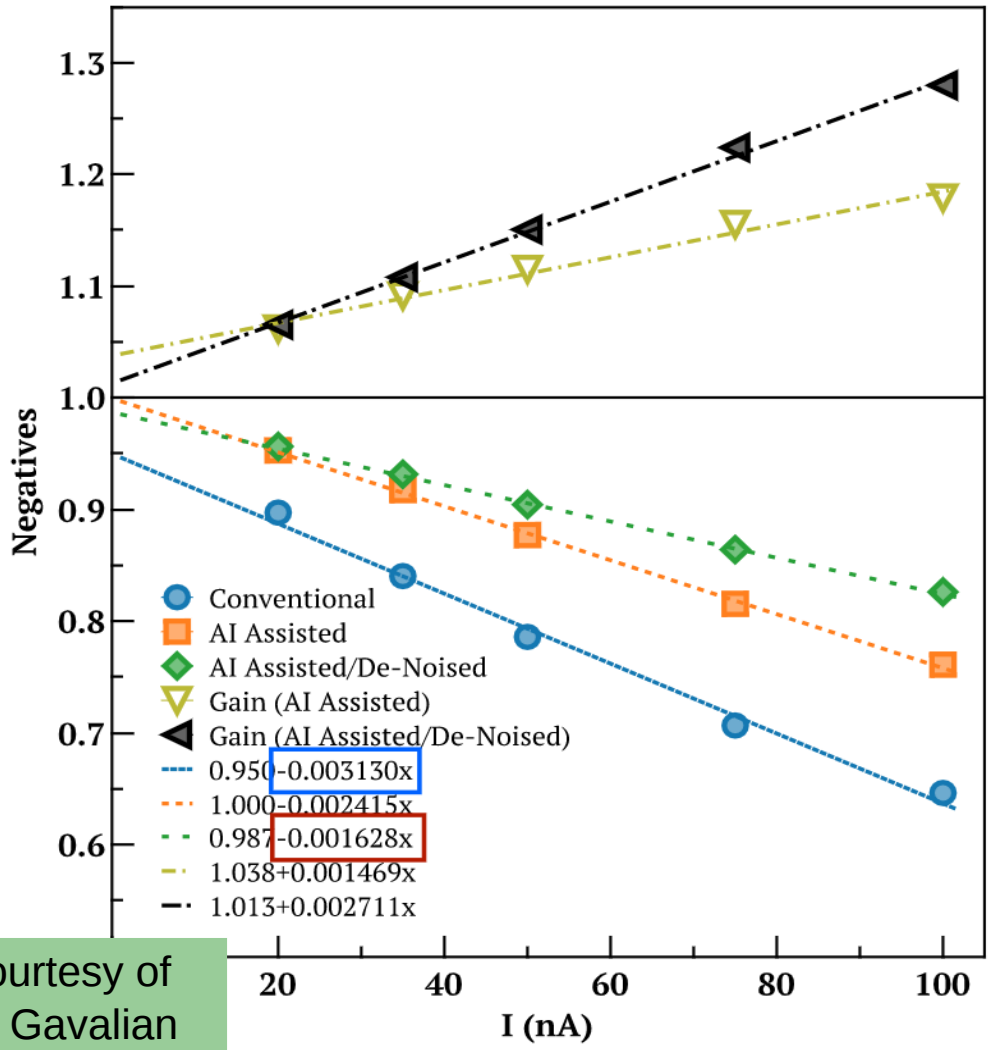
Sept. 29th, 2023

- Raffaella De Vita set the RF clock to 2.004 ns (*64 cycles @ 500 MHz electron bunch frequency*) for the RG-D run period since only three halls are running; see HBLOG entry #: 4189477.

Luminosity Scan AI-assisted Study

- Many thanks to Raffaella De Vita and Gagik Gavalian for their coordination to obtain these results.





Courtesy of G. Gavalian

Target & Current Setting

- Approved beam currents and target thicknesses (*within 2% X_0*) for production runs;
  - ✔ Currents can be increased up to ~ 100 nA for LD_2 and CxC (150 for CuSn) and ~ 200 nA for LH_2 in luminosity scans and detector efficiency studies.

Targets	Thickness (2 foils) (cm)	Density ($g.cm^{-3}$)	Areal Density (T) ($mg.cm^{-2}$)	Radiation Length (X_0) ($g.cm^{-2}$)	Radiation Lengths (T/X_0) (%)	Beam Current (nA)	Per-nucleon Luminosity ($10^{35}\,cm^{-2}\,s^{-1}$)
LH_2	5	0.071	355	63.04	0.56	100	1.3
LD_2	5	0.164	820	125.98	0.65	50 (/ 60)	1.5 (/ 1.8)
^{12}C	0.2 (0.4)	2.2	440	42.7	1.03 (2.06)	50	1.7
^{63}Cu / ^{120}Sn	0.0093 / 0.0171	8.96 / 7.31	83.33 / 125	12.86 / 8.82	0.65 / 1.417	150	1.2

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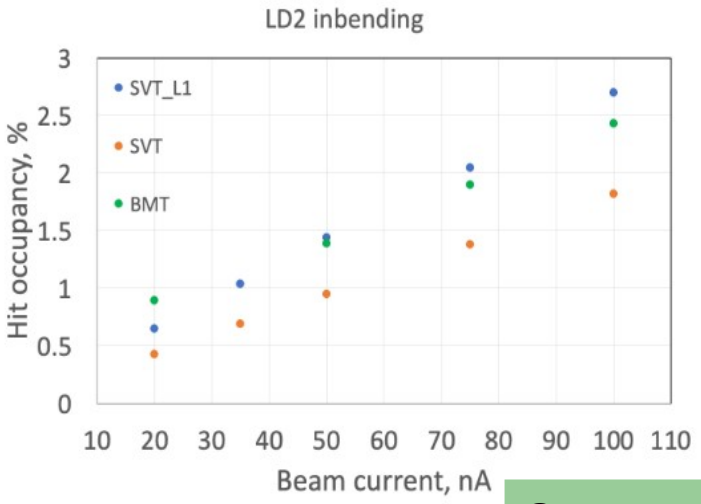
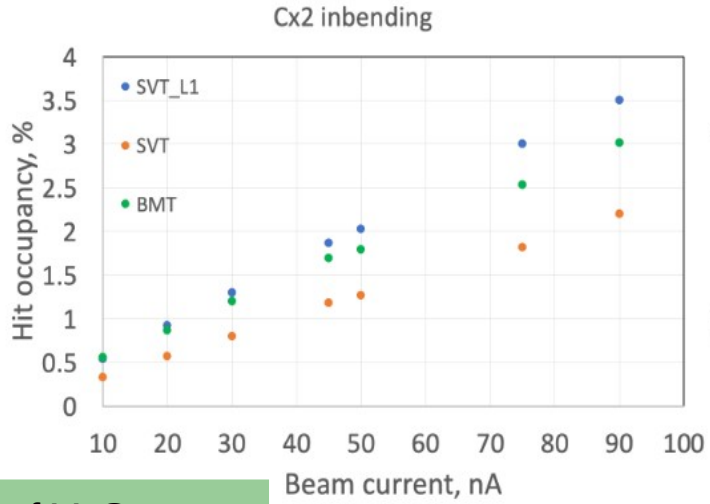
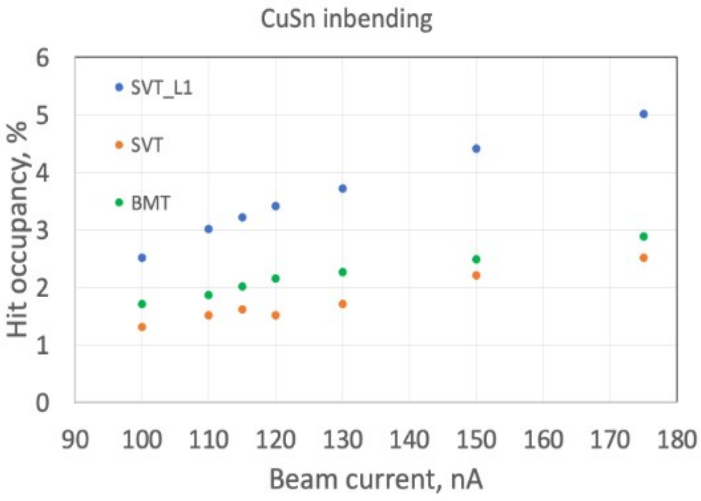
- Approved beam currents and target thicknesses (*within 2%* X_0) for production runs;
  - ✔ Currents can be increased up to ~ 100 nA for LD_2 and CxC (150 for CuSn) and ~ 200 nA for LH_2 in luminosity scans and detector efficiency studies.
  - ✔ Lesson learned from Lumi. scans:







Courtesy of Y. Gotra

RG-D Target & Current Setting

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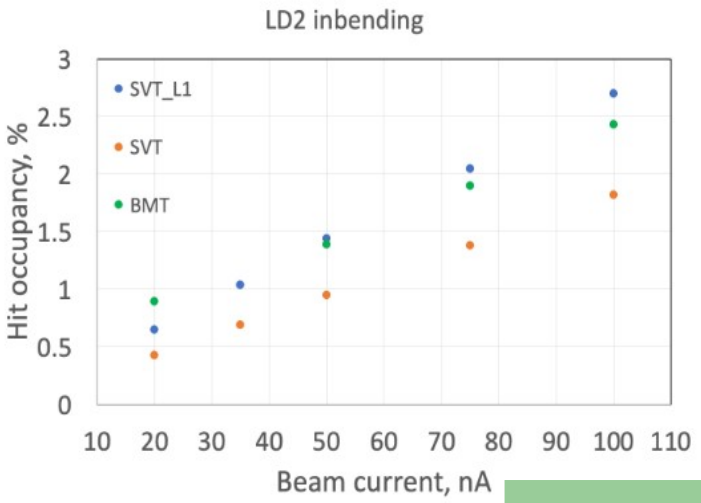

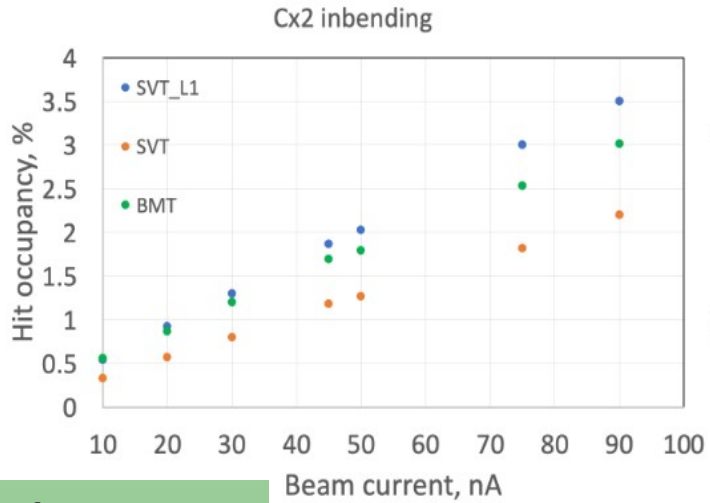

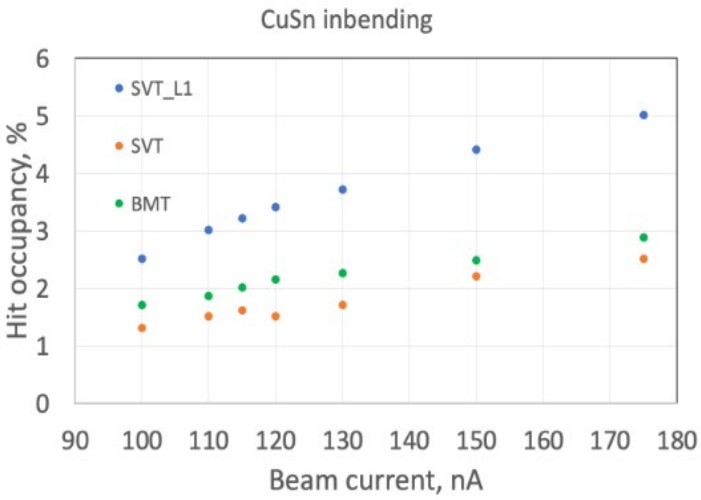

Courtesy of Y. Gotra

  - ✔ To protect CD, MVT & SVT, from X-ray radiation damage caused by Sn and maintain their long-term efficiency, the consensus was reached to reduce the production beam current of this target configuration and extend the RG-D run-period to achieve the desired statistics for Cu and Sn targets.

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Targets	Thickness (2 foils) (cm)	Density ($g.cm^{-3}$)	Areal Density (T) ($mg.cm^{-2}$)	Radiation Length (X_0) ($g.cm^{-2}$)	Radiation Lengths (T/X_0) (%)	Beam Current (nA)	Per-nucleon Luminosity ($10^{35}\,cm^{-2}\,s^{-1}$)
LH_2	5	0.071	355	63.04	0.56	100	1.3
LD_2	5	0.164	820	125.98	0.65	50 (/ 60)	1.5 (/ 1.8)
^{12}C	0.2 (0.4)	2.2	440	42.7	1.03 (2.06)	50	1.7
^{63}Cu / ^{120}Sn	0.0093 / 0.0171	8.96 / 7.31	83.33 / 125	12.86 / 8.82	0.65 / 1.417	95	0.76

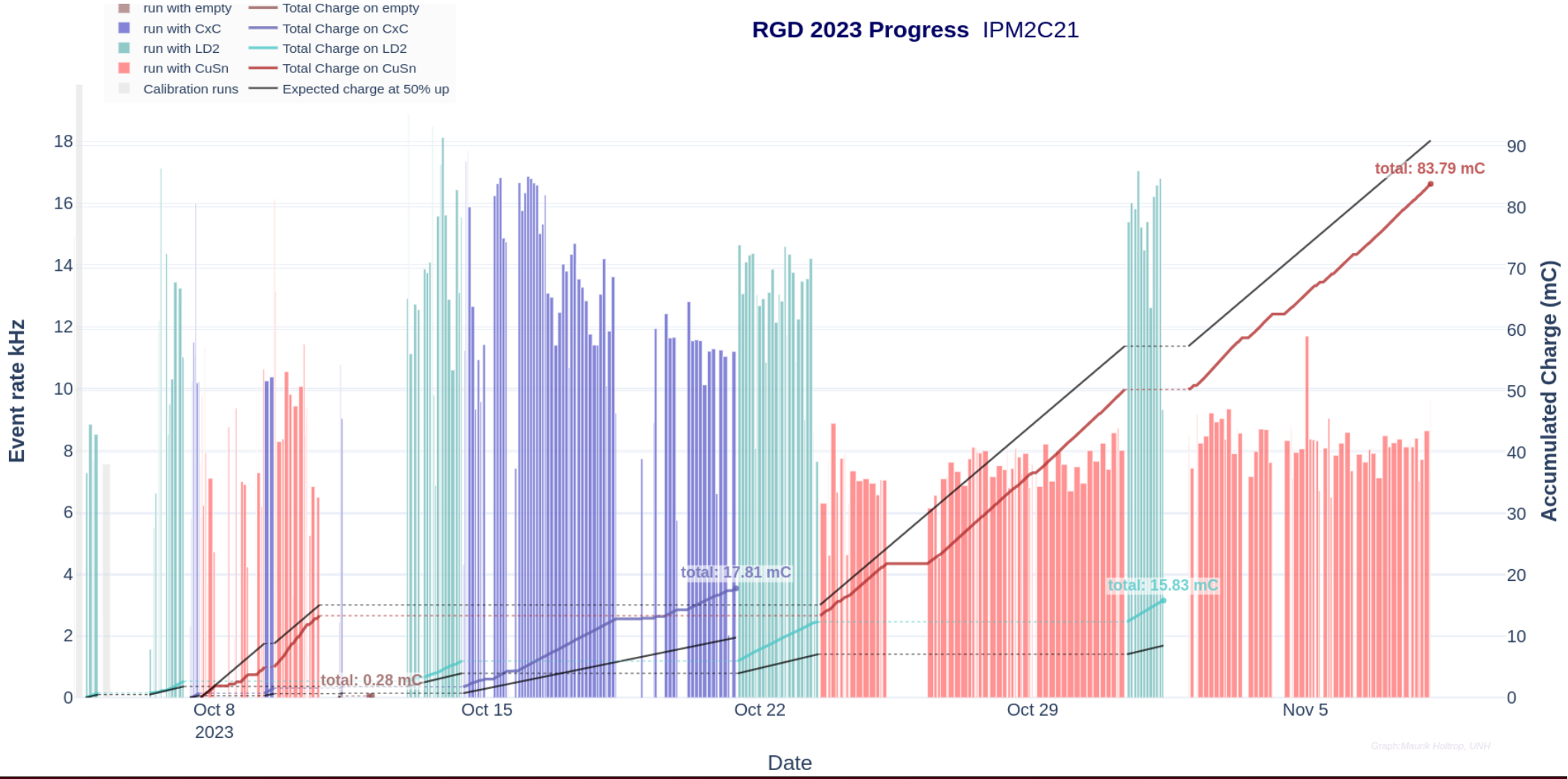
Revised Run Plan

- More beam-time is allocated to CuSn, but less to LD_2 & CxC due to their current reach!

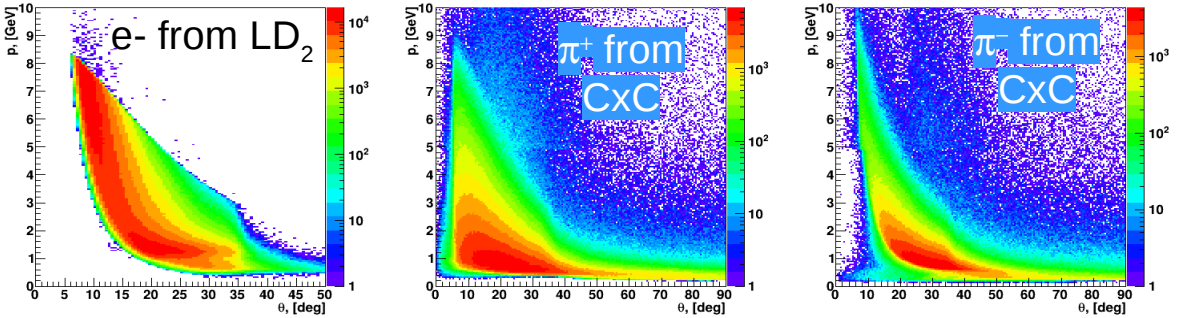
Targets Configuration (Current Setting)	Beam Time (PAC days)
LD_2 (@ 35 - 50 nA)	1.5
CuSn (@ 130 → 100 nA)	4
LD_2 (@ 50 nA)	1.5
CxC (@ 50 nA)	3.5
LD_2 (@ 60 nA)	0.5
CuSn (@ 90 - 95 nA)	3.5
LD_2 (@ 60 nA)	1
CxC (@ 50 nA)	2.2
LD_2 (@ 60 nA)	0.5
CuSn (@ 95 nA)	8
LD_2 (@ 60 nA)	0.5
CuSn (@ 95 nA)	3
LD_2 (@ 60 nA)	0.5
LH_2 + *target change* + *Møller Meas.*	2

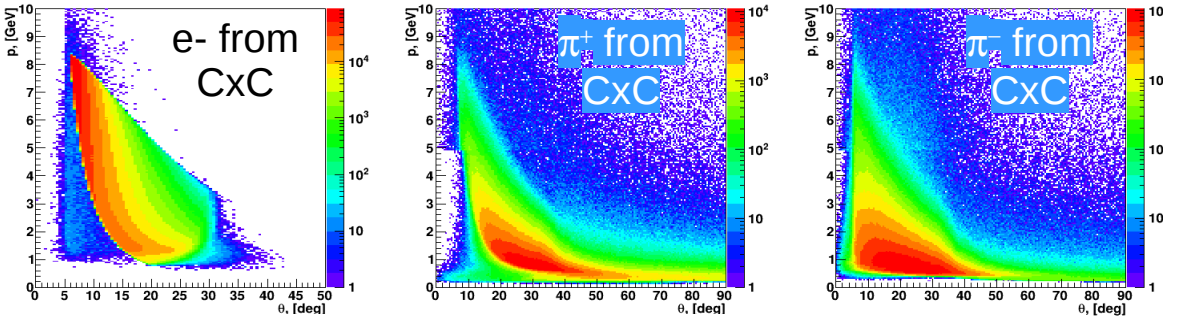
Current Status of Accumulated Data

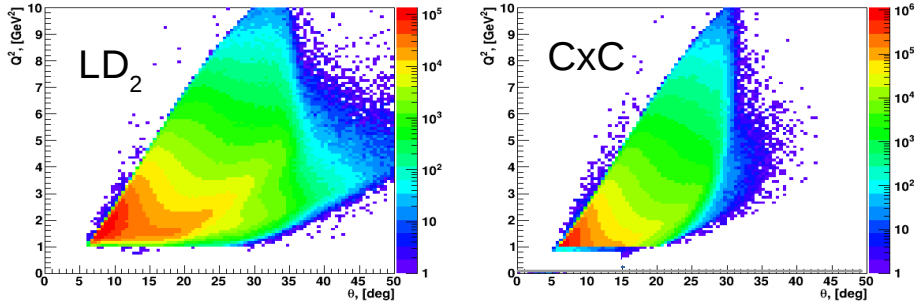
- No Faraday Cup info due to ion pump failure, thus rely on the current reading from the upstream beam position/current monitor, 2C21A.

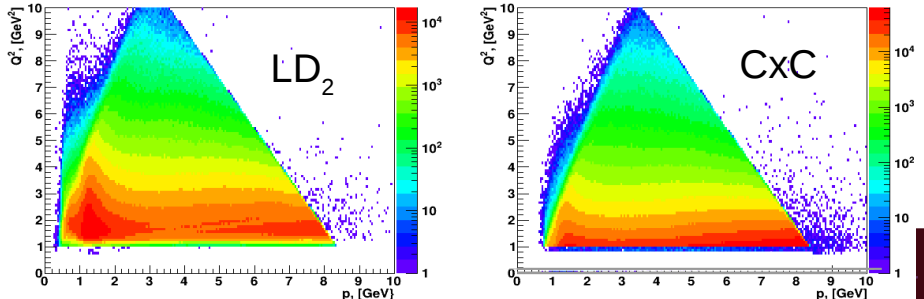


Online RG-D Analysis

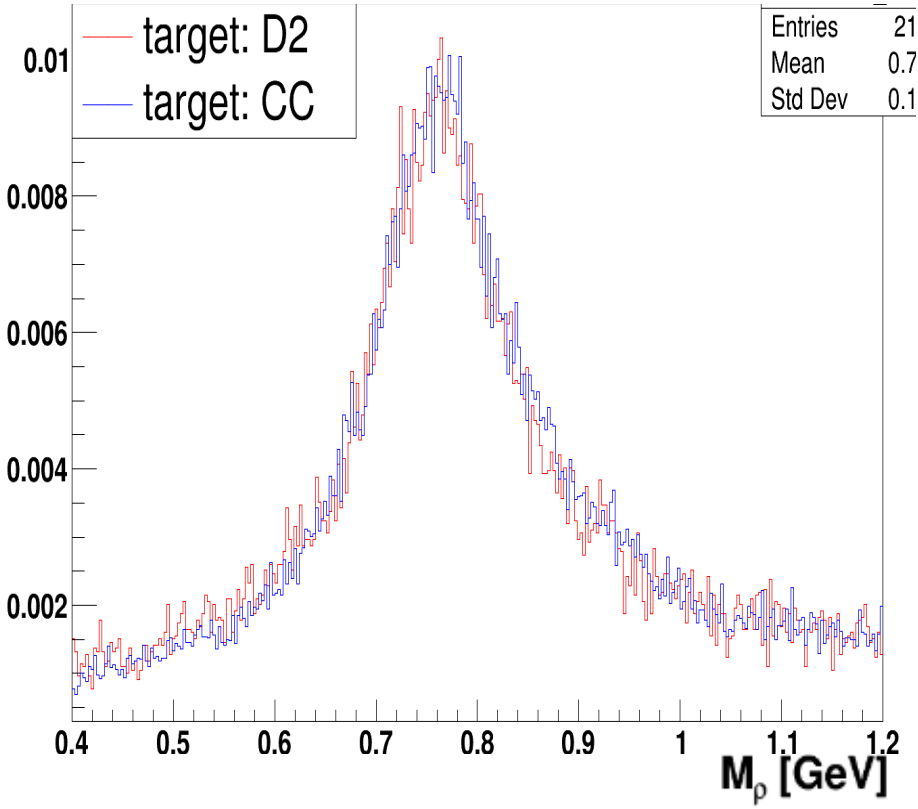




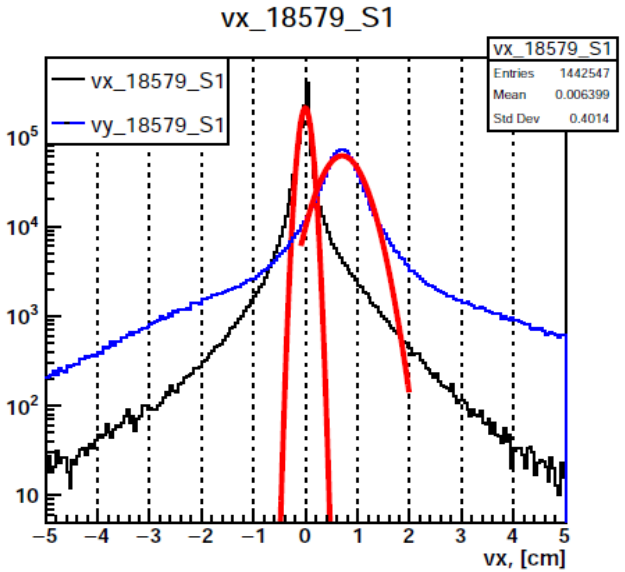


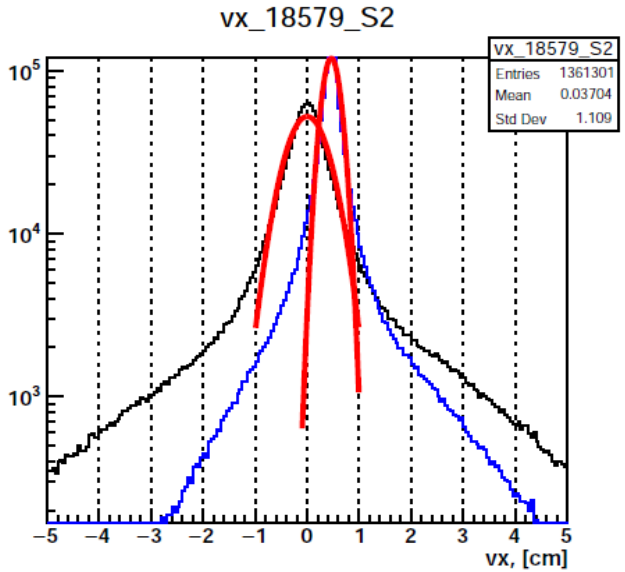


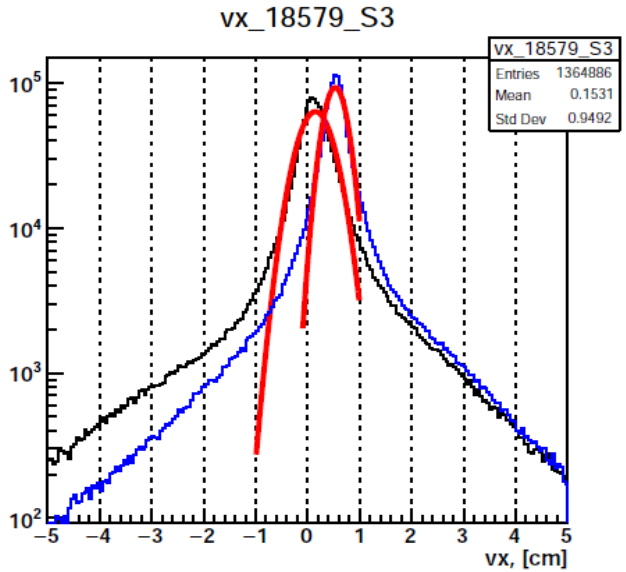
LD_2 and CxC ρ^0 Invariant Mass Comparison

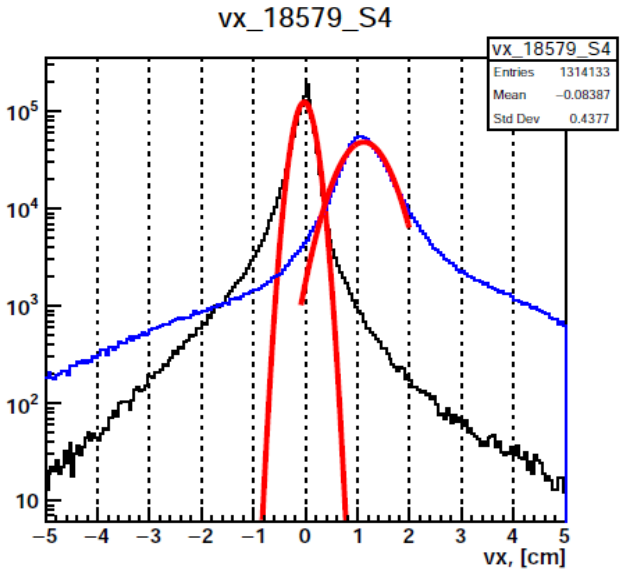


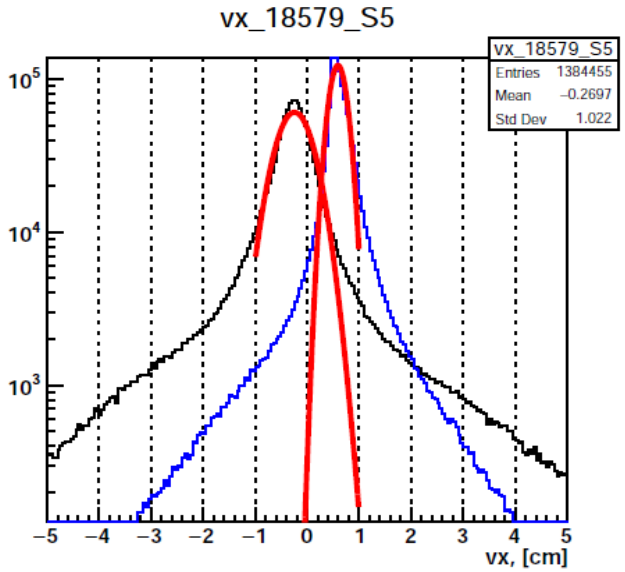
Vertex Cuts for Cu & Sn Separation

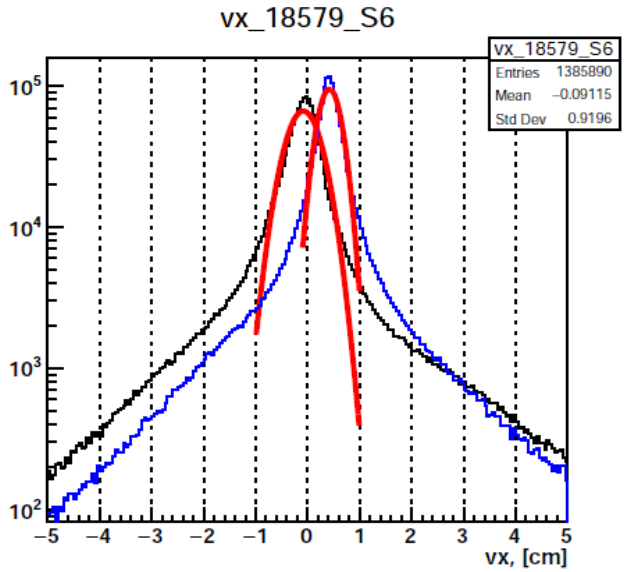












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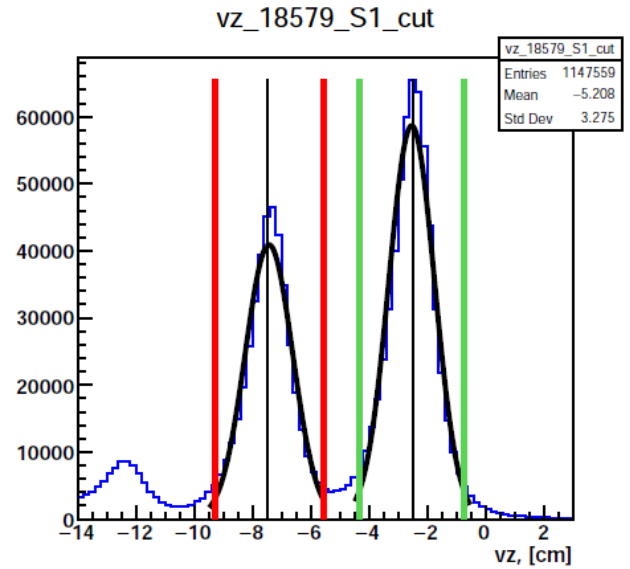
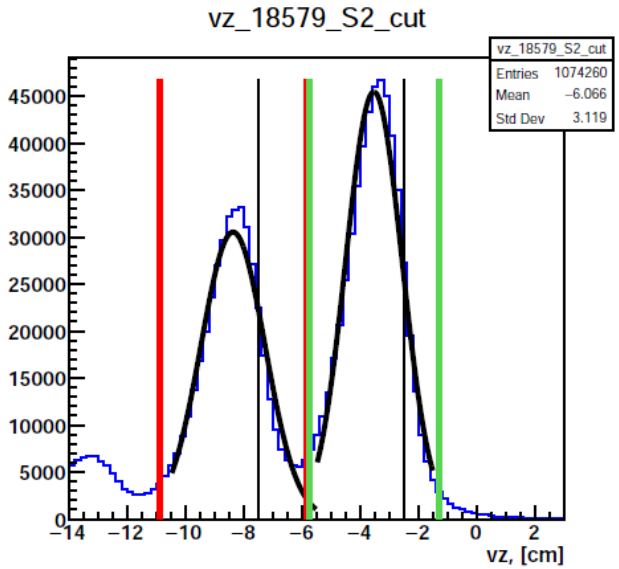
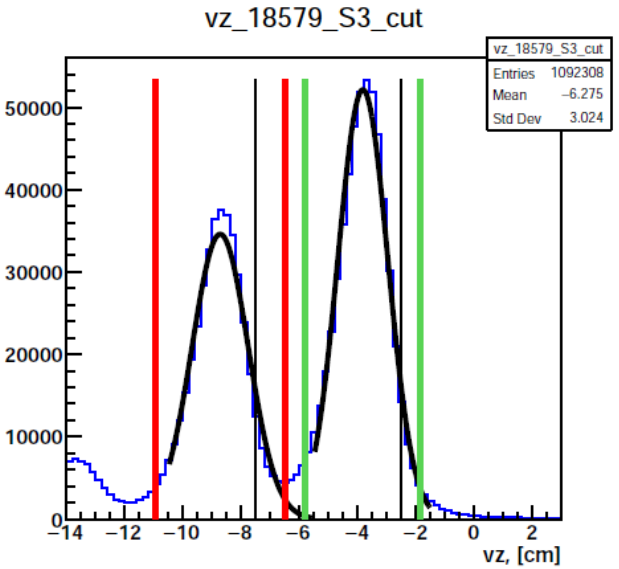
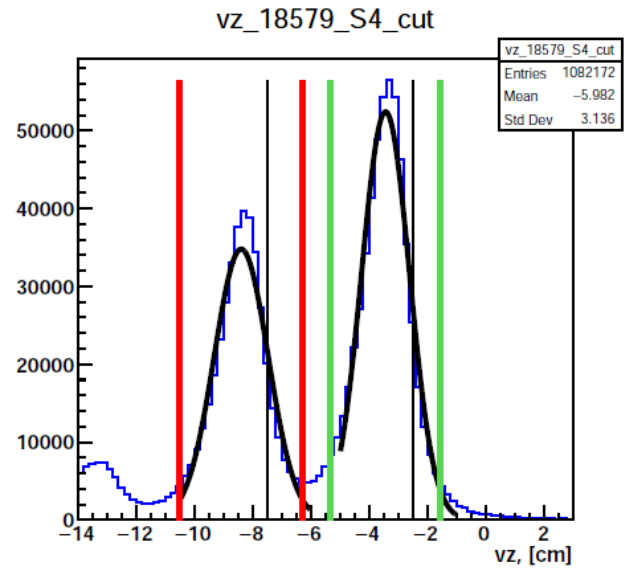
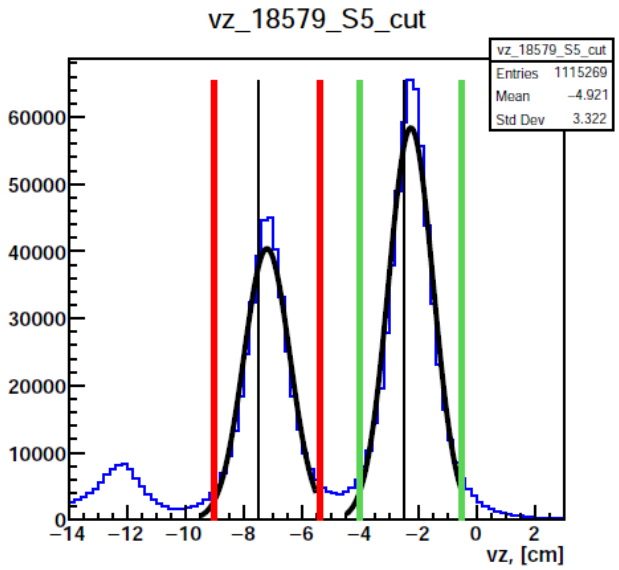
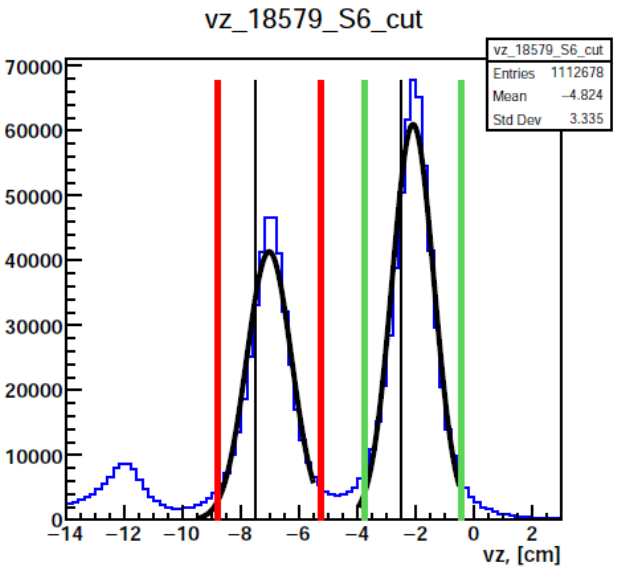




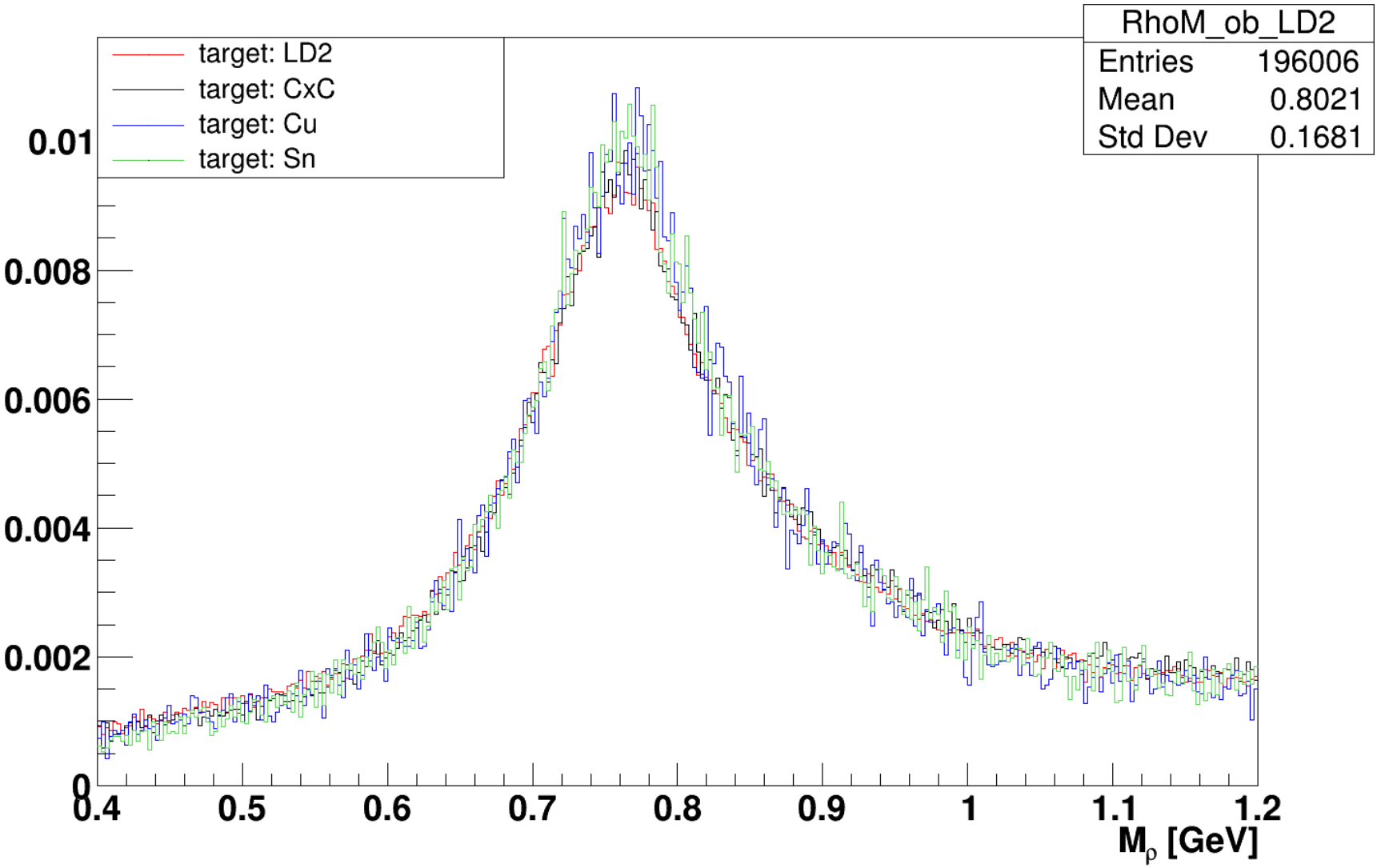








Online RG-D Analysis: Invariant Mass Comparison



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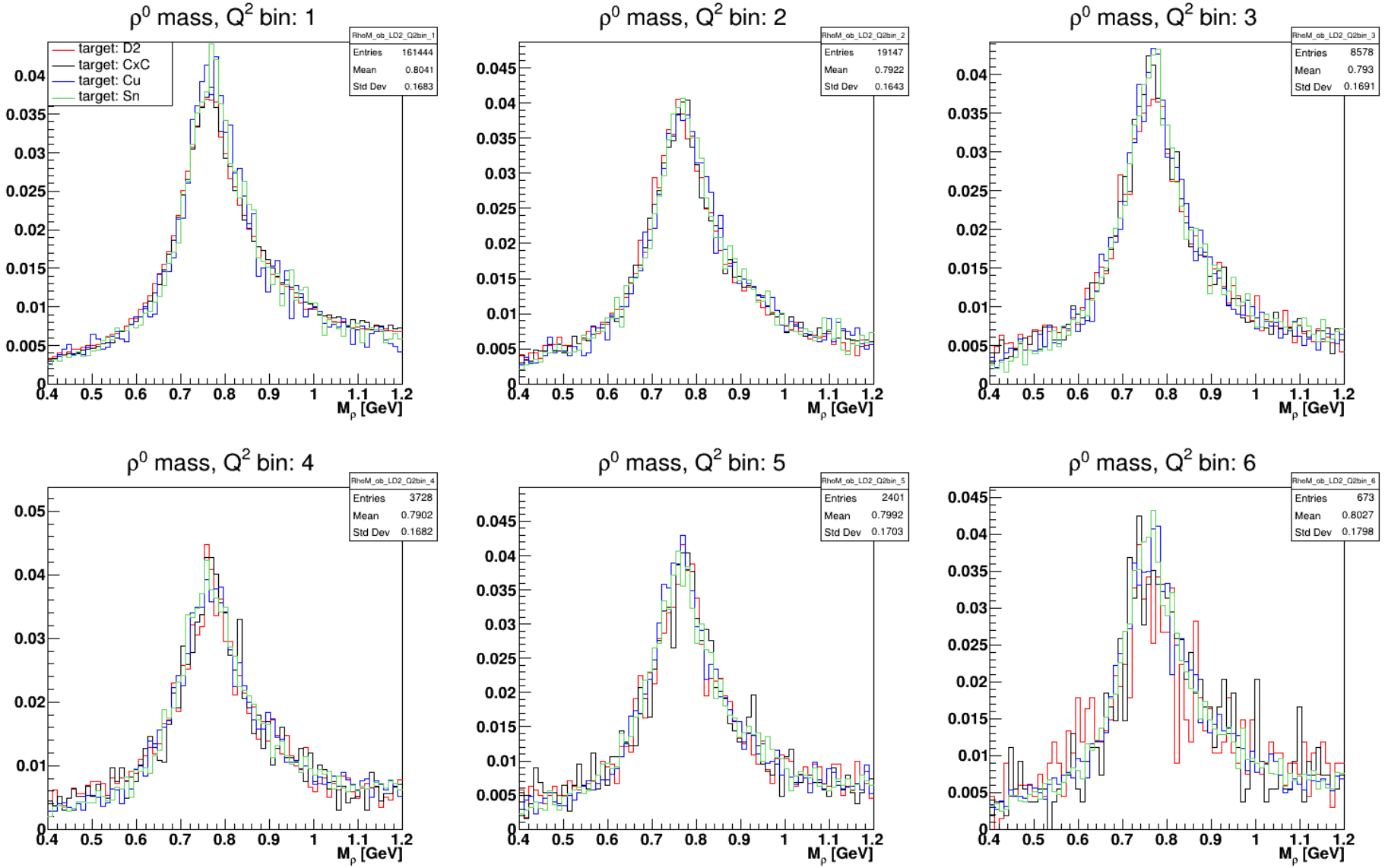

Summary Notes

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- Special thanks to everyone contributing to make RG-D run a success:
  - ✔ Hall B staff, engineers, technicians, and leadership;
  - ✔ Detector and calibration experts;
  - ✔ Target group;
  - ✔ Physics and Accelerator divisions;
  - ✔ PDL;
  - ✔ Run coordinators;
  - ✔ Shift takers;
  - ✔ Cooking chef;
  - ✔ RG and analyzers;
  - ✔ Collaboration as a whole, especially for accommodating RG-D to extend and complete its data-taking due to CuSn run restrictions.

Backup Slides

Previous Run Plan & Expected Projections

- Run plan for 60 calendar days:

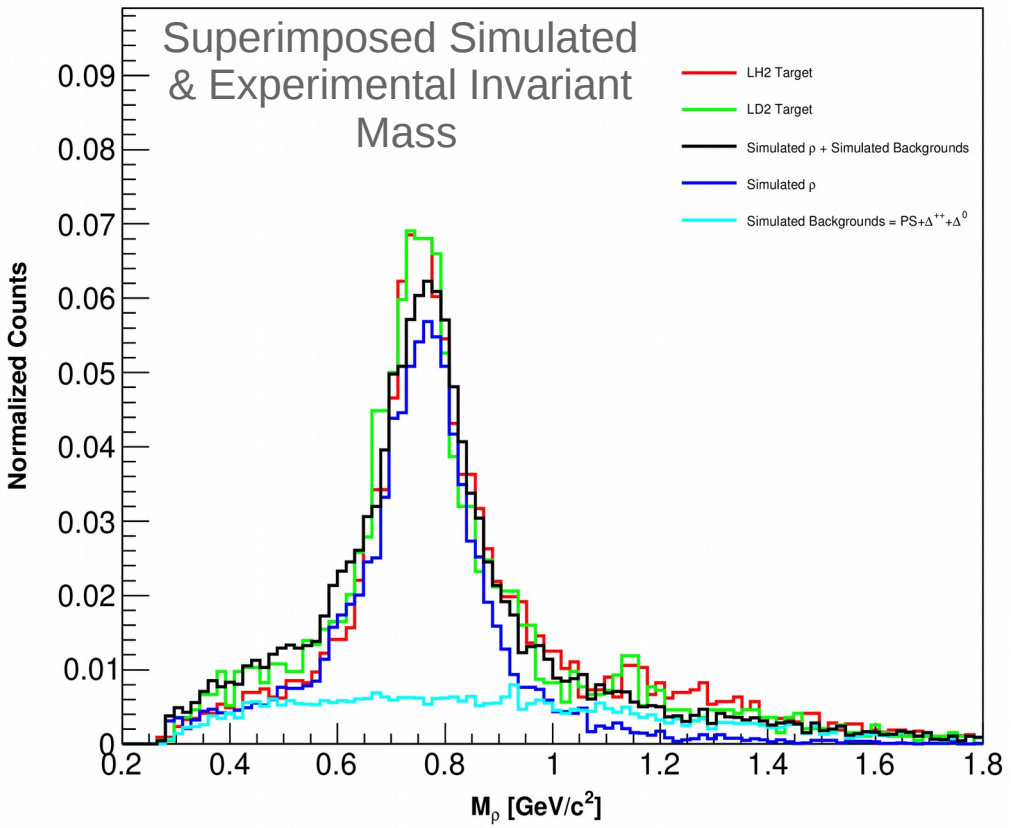
Targets Configurations	Beam Time (PAC days)
^{12}C / ^{12}C (each 0.2 cm thick)	7
LD_2	7
^{63}Cu / ^{120}Sn (0.0093/0.0171 cm thick)	14
Lumi. scan + target change + Moller Meas.	2

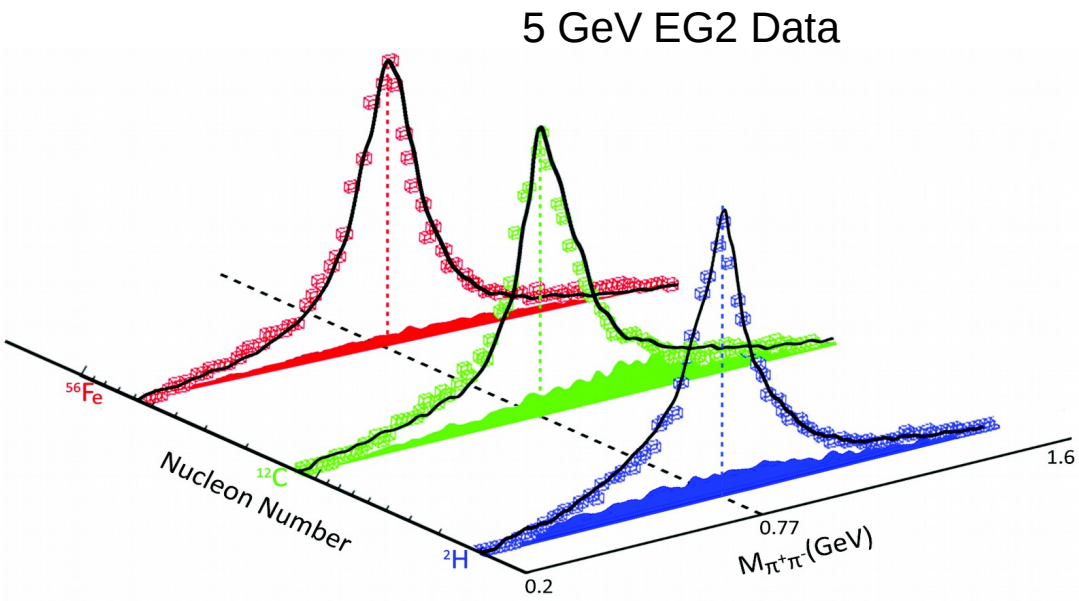
- Expected statistical precision for the lowest l_c bin:

Q^2(GeV^2) / Targets	1.5 ± 0.5	2.25 ± 0.25	2.75 ± 0.25	3.25 ± 0.25	4.0 ± 0.5	5.25 ± 0.75
^{12}C (%)	1.1	1.5	2.0	2.7	4.6	6.1
^{63}Cu (%)	1.3	1.7	2.1	3.1	4.8	6.3
^{120}Sn (%)	1.3	1.8	2.6	3.2	4.8	6.3

Negative Polarity Data

- The reconstructed ρ^0 invariant mass distribution in our kinematics range,





Simulated Background's Shapes

$e + p \rightarrow e + p + \pi^+ + \pi^-$

$e + p \rightarrow e + \Delta^{++} + \pi^-$

$e + p \rightarrow e + \Delta^0 + \pi^+$

ρ^0 production: $e + p \rightarrow e + p + \rho^0$

Two-pion Invariant Mass

- Our event generator incorporates the measured cross sections for the electroproduction of ρ^0 and main background processes by Cassel *et al.*

D. G. Cassel *et al.*, Phys. Rev. D 24, 2787 (1981)

Simple Breit-Wigner

$e + p \rightarrow e + p + \rho^0$

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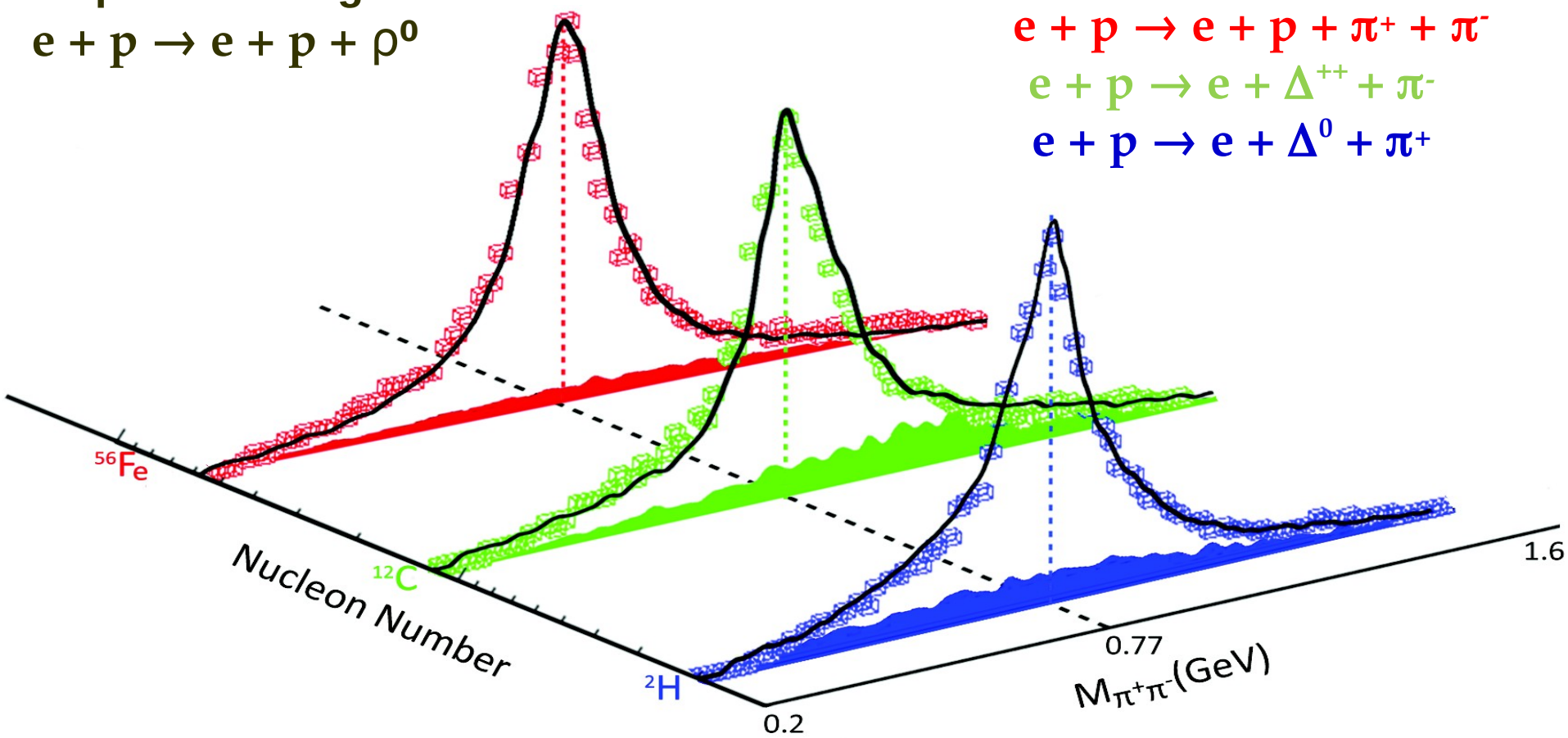
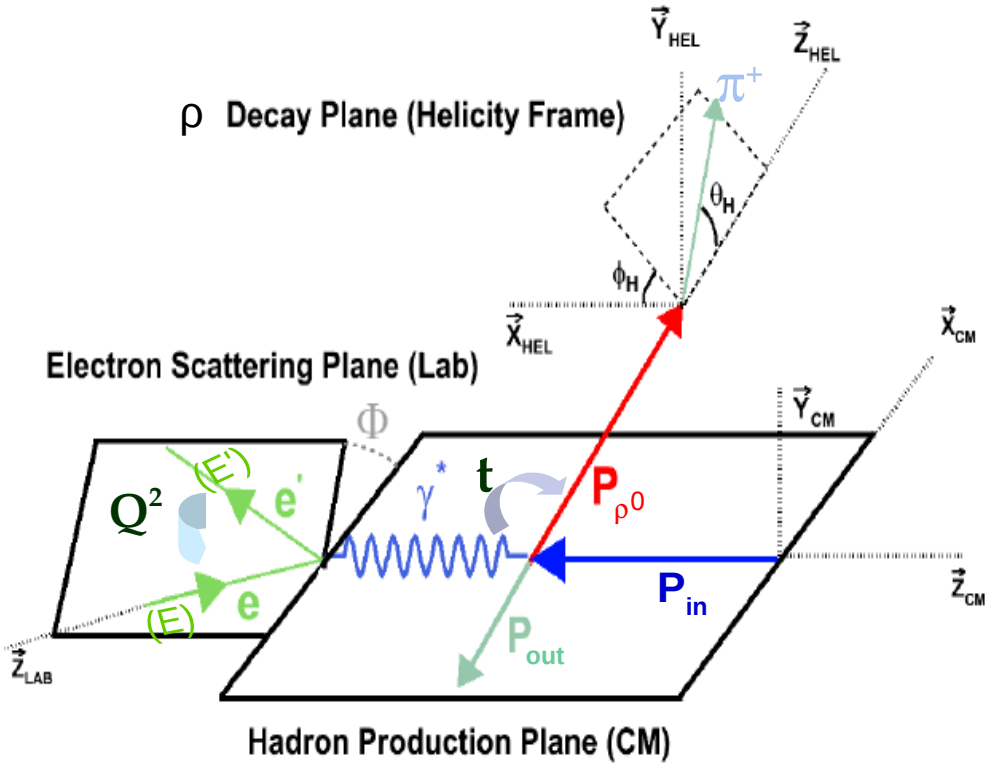


ρ^0 Electro-production Kinematics

- $\nu = E - E'$: virtual photon (γ^*) energy in the Lab frame,
- $Q^2 = -(P_e - P_{e'})^2 = 4 E E' \sin^2(\theta/2)$: photon virtuality,
- $t = (P_{\gamma^*} - P_\rho)^2$: momentum transfer square,
- $W^2 = (P_{in} + P_{\gamma^*})^2 = -Q^2 + M_p^2 + 2M_p\nu$: invariant mass squared in (γ^*, p) center of mass (CM).



- $W > 2$ GeV
  $\Rightarrow$ avoid resonance region
- $-t < 0.4$ GeV^2
  $\Rightarrow$ select diffractive process
- $-t > 0.1$ GeV^2
  $\Rightarrow$ exclude coherent production
- $Z_h = E_h/\nu \geq 0.9$
  $\Rightarrow$ select elastic channel