RG-D and RG-E Status and Plans

CLAS Collaboration Meeting
Nov 14th, 2018

Lamiaa El Fassi
(for the EG2p Collaborations)

Run-groups Experiments

- RG-D, E12-06-106, “Study of Color Transparency in Exclusive Vector Meson Electroproduction off Nuclei”, was approved with B^+ rating and 60 PAC days.
- RG-E, E12-06-117, “Quark Propagation and Hadron Formation”, was approved with A^- rating and 60 PAC days.

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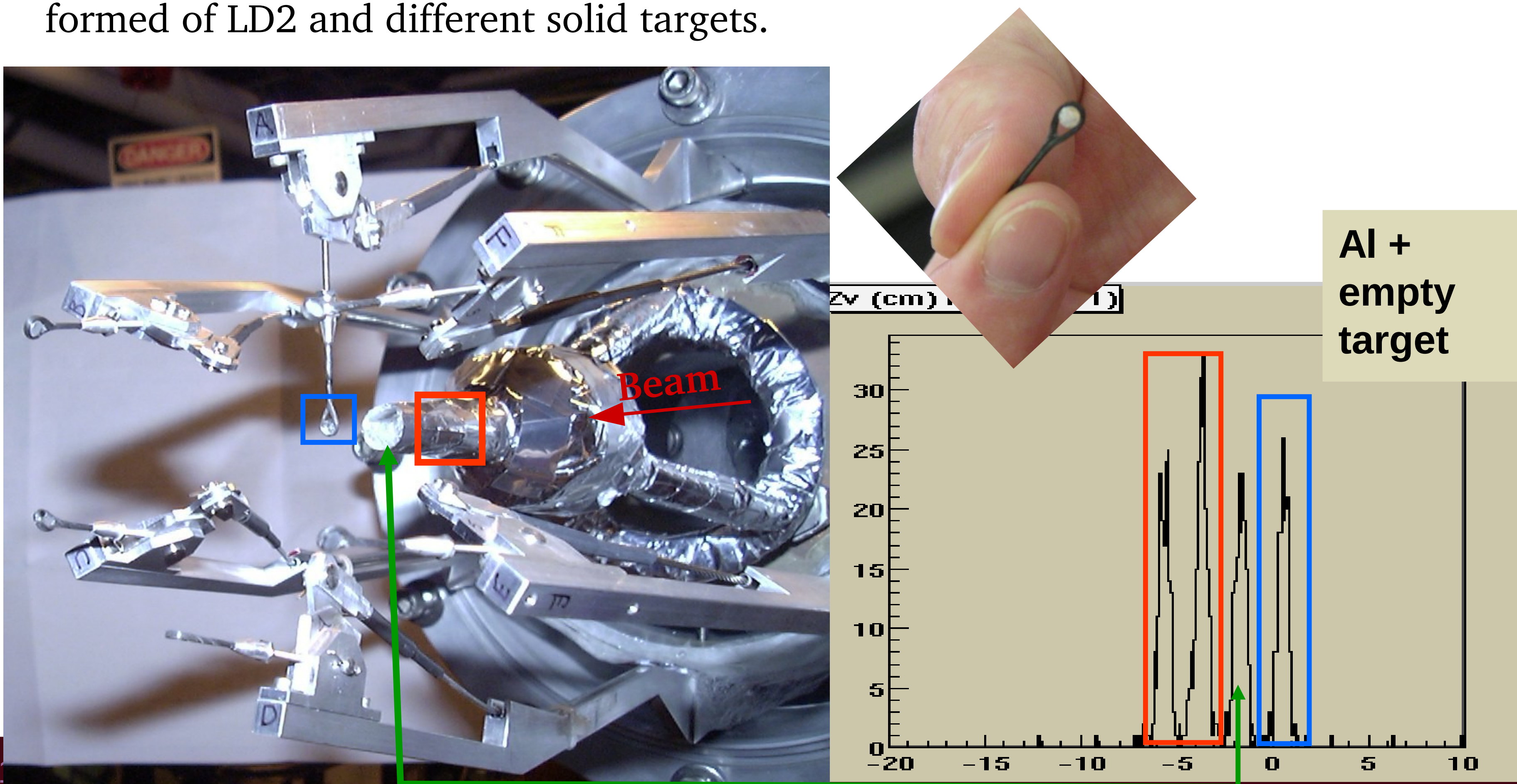
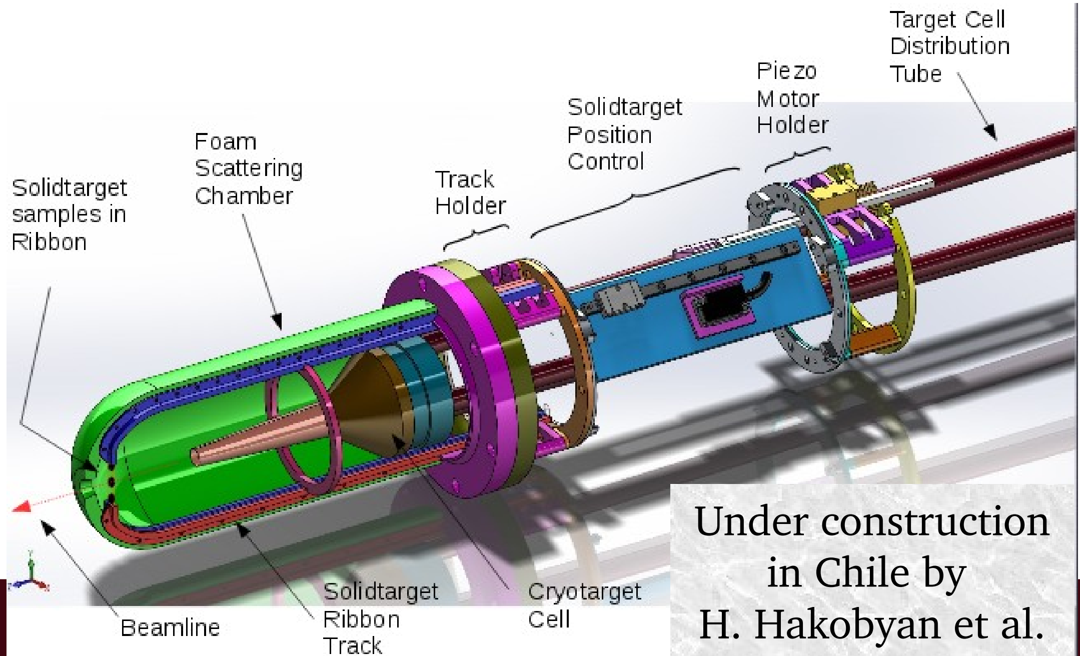


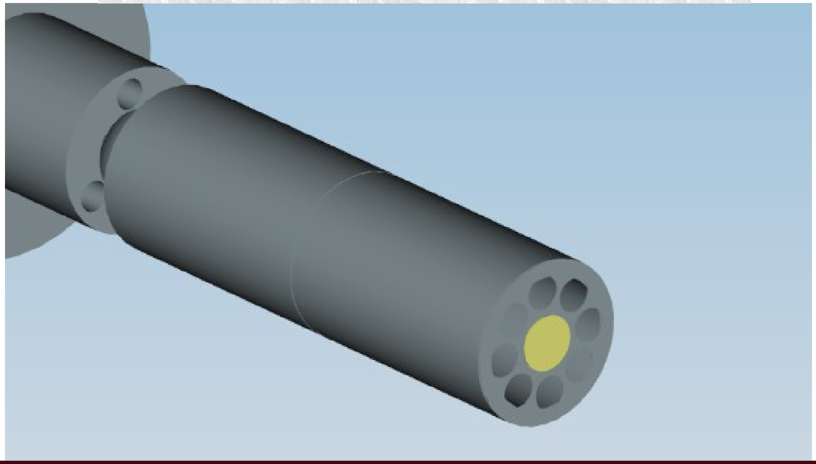
Run-groups Experiments

- RG-D, E12-06-106, “Study of Color Transparency in Exclusive Vector Meson Electroproduction off Nuclei”, was approved with B^{+} rating and 60 PAC days.
- RG-E, E12-06-117, “Quark Propagation and Hadron Formation”, was approved with A^{-} rating and 60 PAC days.
- In 6 GeV era, both experiments ran together as the EG2 run-group with a dual target formed of LD2 and different solid targets.
- For 12 GeV, both experiments will do their best to achieve running conditions that satisfy the scientific requirements of both, whenever possible. The plan is to use the new UTFSM dual target (EG2p) or the other target configuration (Hall-B solid target assembly) for any potential early run!

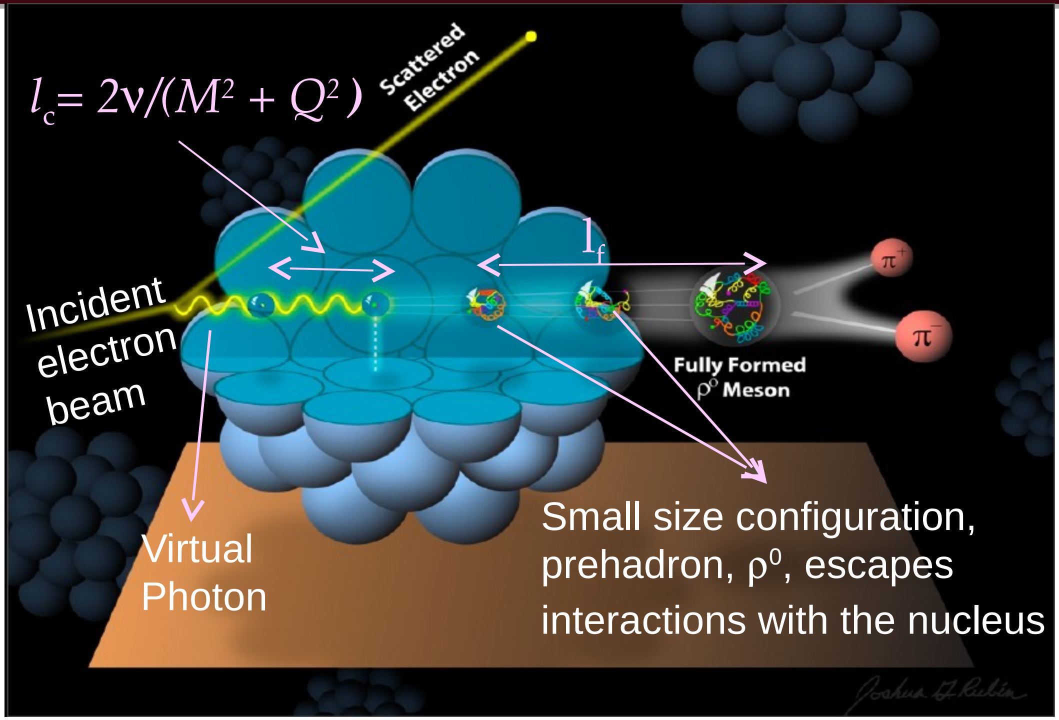


Under construction in Chile by H. Hakobyan et al.

Hall-B Solid Target Assembly

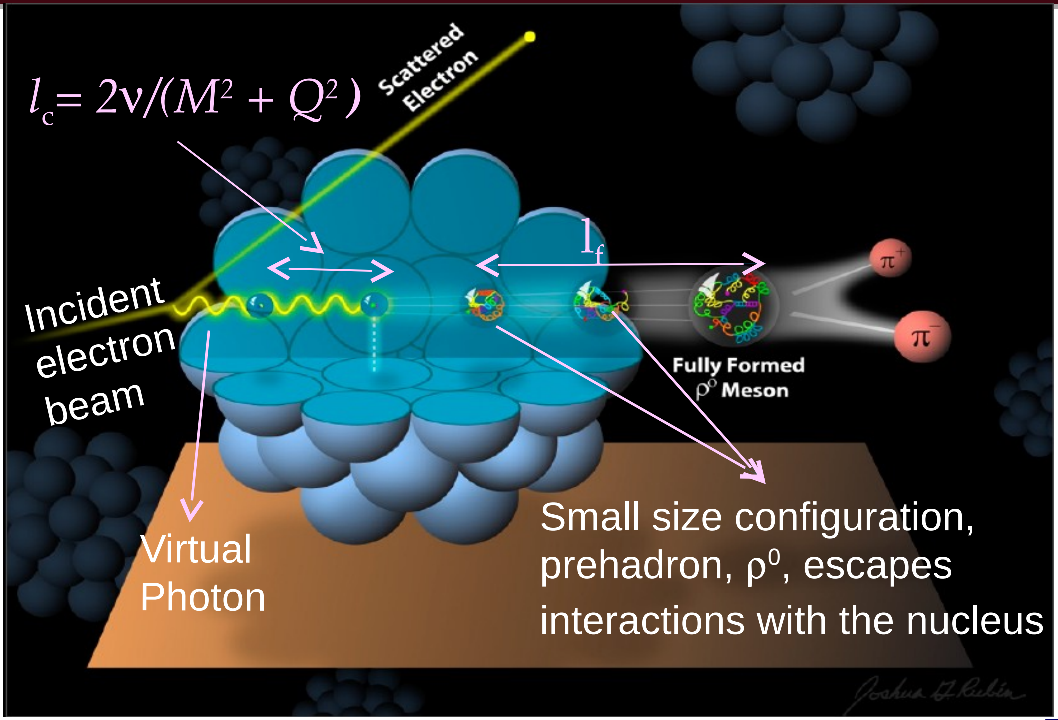


12 GeV CT Measurement with Exclusive ρ^0 Electroproduction



- Coherence length, l_c, is the lifetime of the **q**q-bar pair.
- Formation time, l_f, is the lifetime of the small size configuration before evolving to a full ρ^0 meson.

12 GeV CT Measurement with Exclusive ρ^0 Electroproduction



- The CT signature is the increase of the medium "nuclear" transparency, T_A, as a function of the four-momentum transfer squared, Q^2.

$$T_A = \frac{\sigma_A}{A\,\sigma_N}$$

σ_A is the nuclear cross section

σ_N is the free (nucleon) cross section

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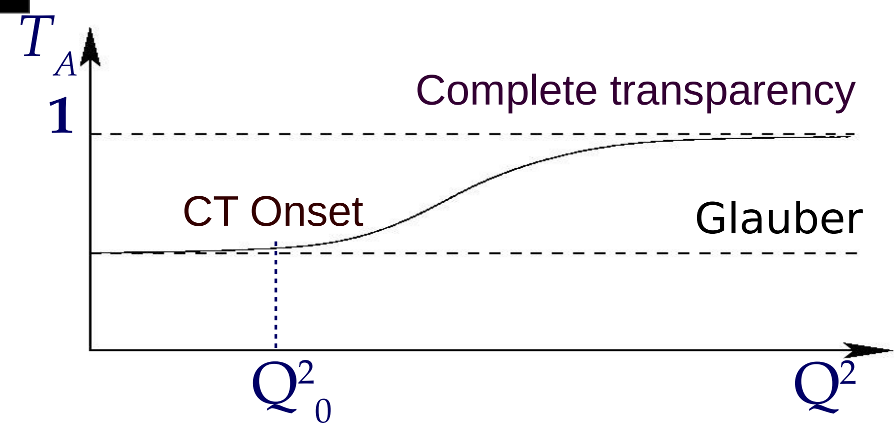
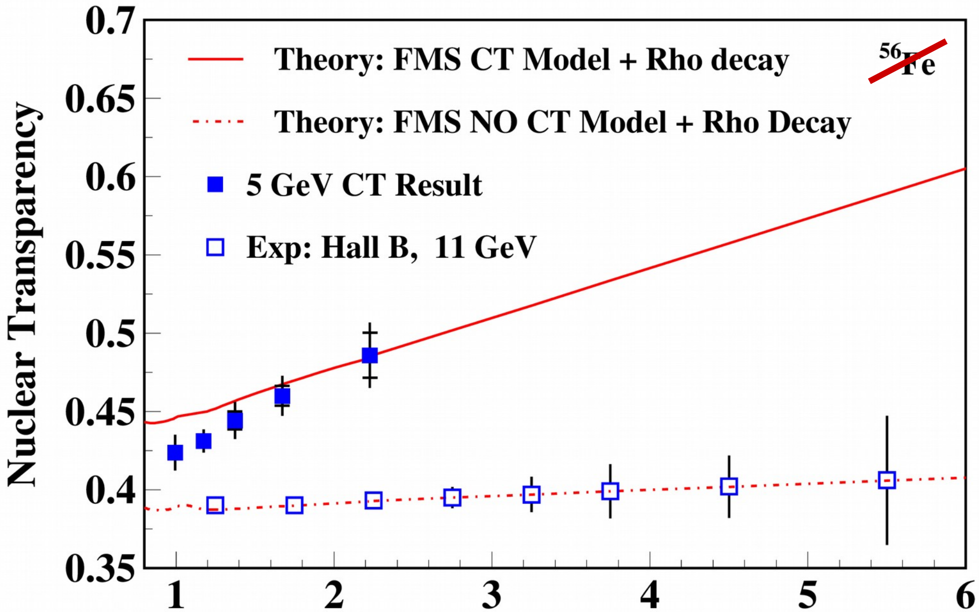
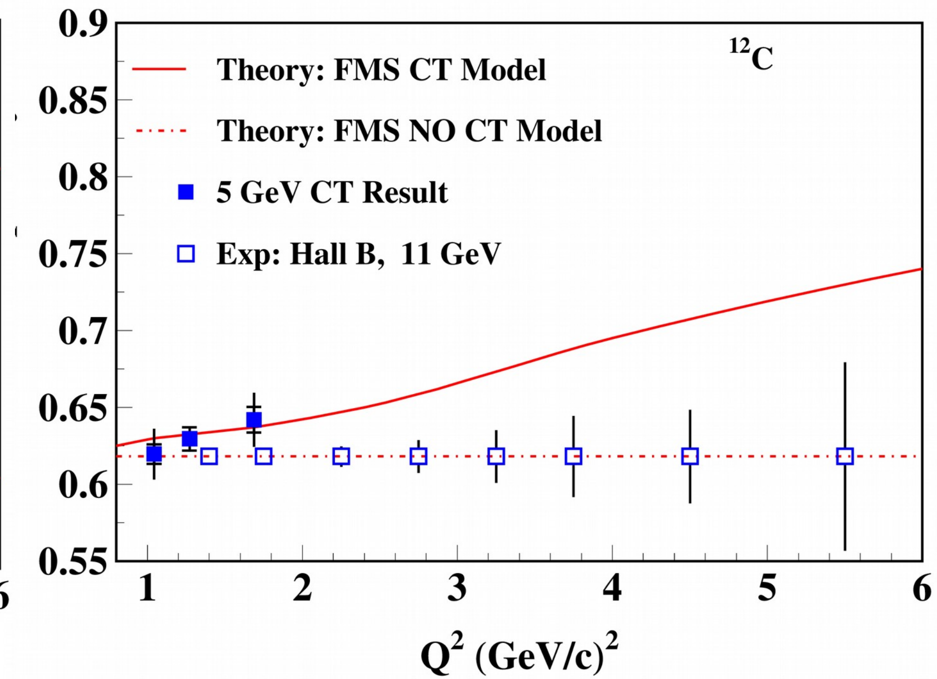
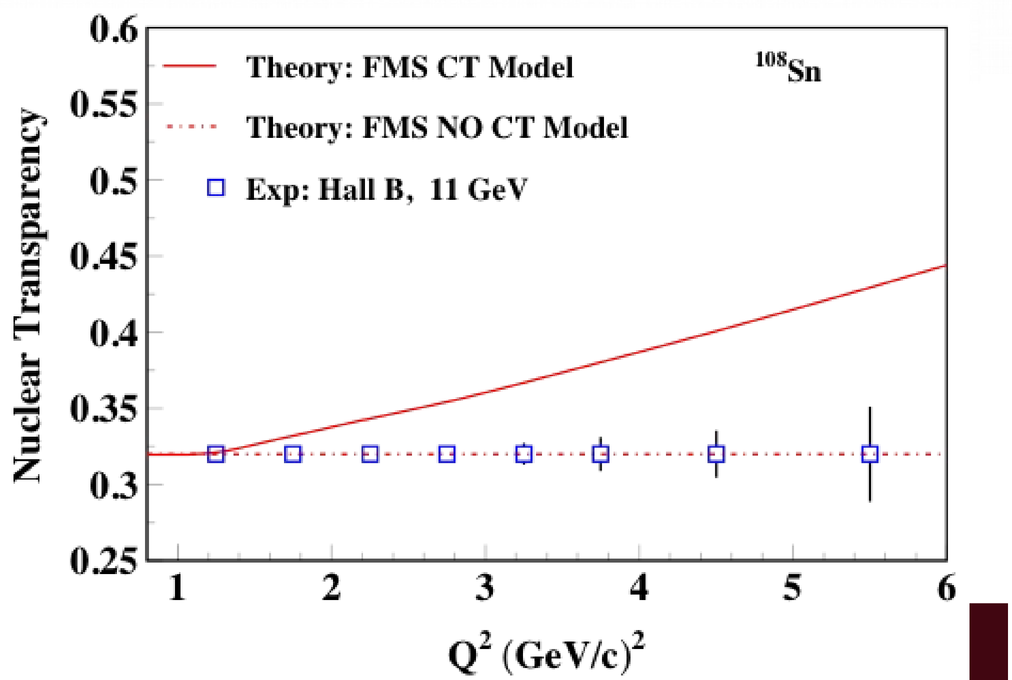
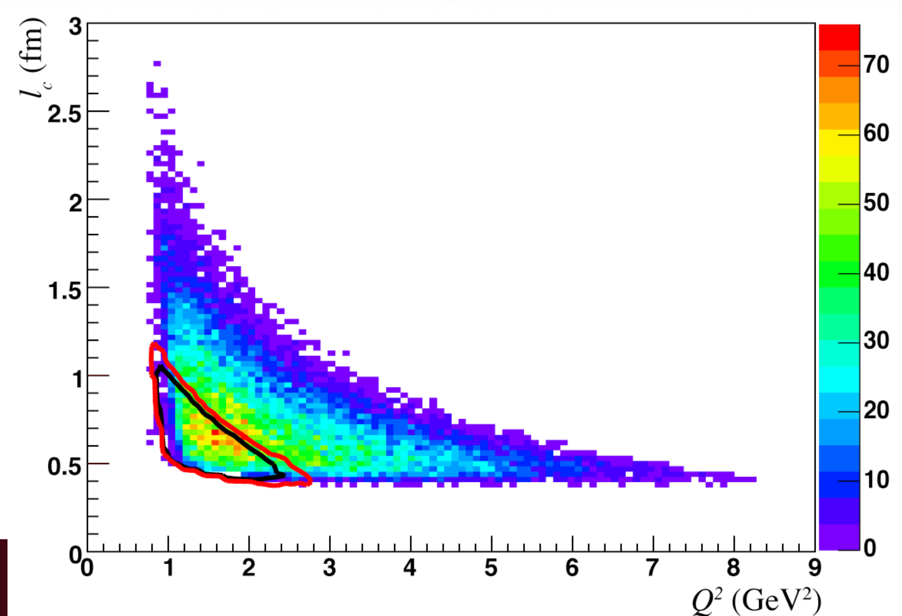


Projections for 12 CT GeV Measurement with C, Cu and Sn, unfortunately no Fe

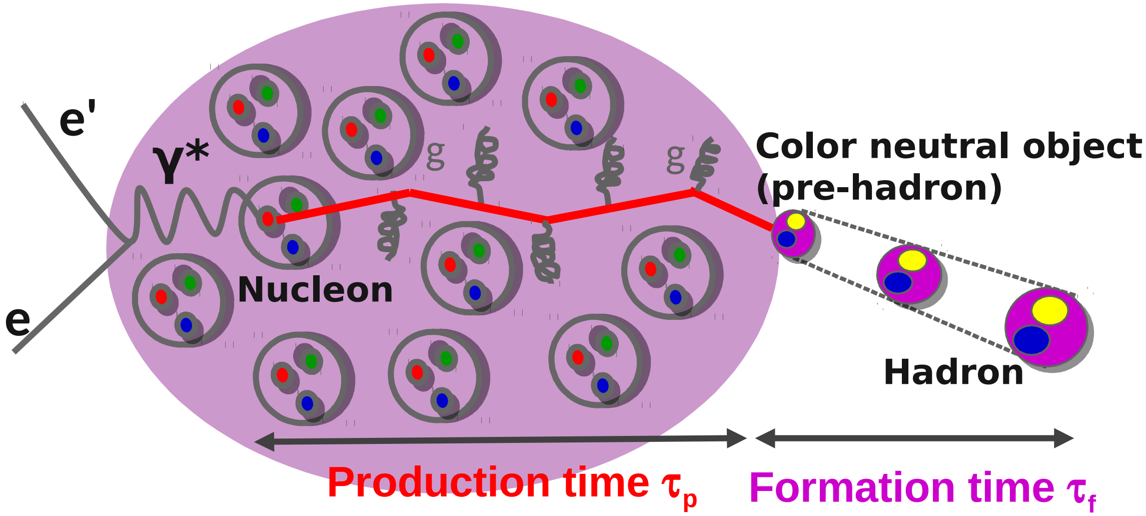








- Study the quark (or color) propagation (CP) and fragmentation in nuclei to probe the QCD confinement dynamics - **Hadronization process**



- Use semi-inclusive deep inelastic scattering (SIDIS) to access hadronization time-scales:
  - **Production time τ_p**: Time spent by a deconfined quark to neutralize its color charge.
  - **Formation time τ_f**: Time required to form a regular hadron (h).

E12-06-117: CP Experiment

- Study the quark (or color) propagation (CP) and fragmentation in nuclei to probe the QCD confinement dynamics - **Hadronization process**
- Use semi-inclusive deep inelastic scattering SIDIS to access hadronization time-scales:
  - **Production time τ_p**: Time spent by a deconfined quark to neutralize its color charge.
  - **Formation time τ_f**: Time required to form a regular hadron (h).
- Comparison of the production of different hadrons and quark's flavor in the QCD medium and vacuum(LD2) allows the extraction of τ_p and τ_f via
  - **Transverse momentum broadening**: $\Delta P_T^2 = \langle P_T^2 \rangle_A - \langle P_T^2 \rangle_D$

    triggered by the quark energy loss due to the in-medium stimulated gluon bremsstrahlung.
  - **Hadron Multiplicity Ratio:**

$$R_M^h(z,\nu,p_T^2,Q^2) = \frac{\left\{\dfrac{N_h^{DIS}(z,\nu,p_T^2,Q^2)}{N_e^{DIS}(\nu,Q^2)}\right\}_A}{\left\{\dfrac{N_h^{DIS}(z,\nu,p_T^2,Q^2)}{N_e^{DIS}(\nu,Q^2)}\right\}_D}$$

    to study the hadron attenuation as a result of the hadron and/or pre-haron interactions with the medium.

DIS channels: *stable* hadrons, accessible with 11 GeV JLab experiment PR12-06-117

Actively underway with existing 5 GeV data

meson	cτ	mass	flavor content
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$
π^+, π^-	7.8 m	0.14	$u\bar{d}$, $d\bar{u}$
η	170 pm	0.55	$u\bar{u}d\bar{d}s\bar{s}$
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$
ϕ	44 fm	1.0	$u\bar{u}d\bar{d}s\bar{s}$
$f1$	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$
K^0	27 mm	0.50	$d\bar{s}$
K^+, K^-	3.7 m	0.49	$u\bar{s}$, $\bar{u}s$

baryon	cτ	mass	flavor content
p	stable	0.94	ud
$\bar{p}$	stable	0.94	$\overline{ud}$
Λ	79 mm	1.1	uds
$\Lambda(1520)$	13 fm	1.5	uds
Σ^+	24 mm	1.2	us
Σ^-	44 mm	1.2	ds
Σ^0	22 pm	1.2	uds
Ξ^0	87 mm	1.3	us
Ξ^-	49 mm	1.3	ds

EG2p Collaboration

K. Joo (U. Connecticut)

K. Hicks and T. Chetry (Ohio U.)

K. Hafidi, Sereres Johnston and B. Mustapha (ANL)

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M. Holtrop (U. of New Hampshire)

R. Dupre (IPN-Orsay)

W. K. Brooks, A. El Alaoui, H. Hakobyan and T. Mineeva (UTFSM)

L. Weinstein and M. Hattawy (Old Dominion Univ.)

J. Gilfoyle (U. of Richmond)

I. Niculescu and G. Niculescu (James Madison Univ.)

M. Wood (Canesius College)

CLAS-6 CT or CP Experiment Spokespersons

CLAS-12 CT and/or CP Experiment Spokespersons

CT & CP Run Conditions

- Will use the CLAS12 in its standard configuration with most likely
  - FT-OFF configuration because
    - Both experiments are interested to a high-Q^2 region,
    - At least for now, no interest to detect photons at small angles (2.5°- 4.5°),
    - To reach the highest luminosity possible, which is critical especially for CP to make a first measurement of rare states like the Φ meson.
  - FMT-Out configuration as a good vertex resolution can be achieved within our kinematics.
  - Simulation studies are needed to validate this run scenario.

CT & CP Run Conditions (Cont'd)

- Initial run-plan for both experiments is:

CT (as approved)

Targets	Beam Time (days)
^{1}H	8
C	12
~~Fe~~ Cu	16
Sn	24

CP (tentative)

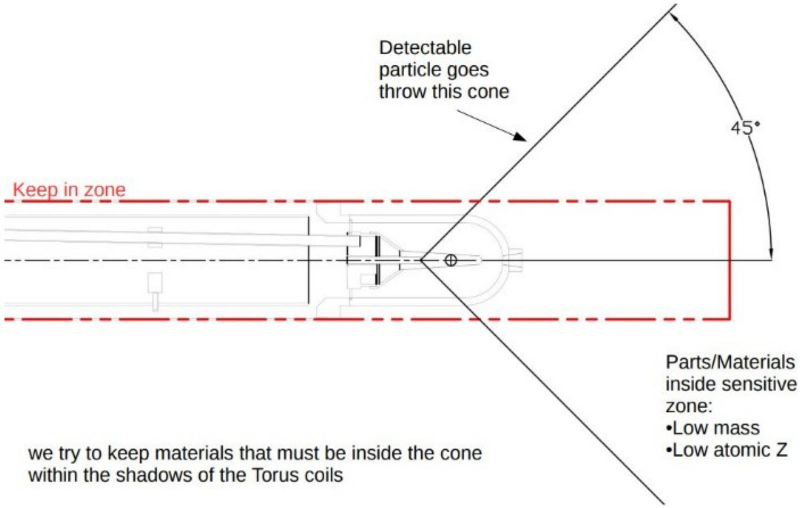
Targets	Beam Time (days)
C	9
Al	9
~~Fe~~ Cu	9
Sn	14
Pb	19

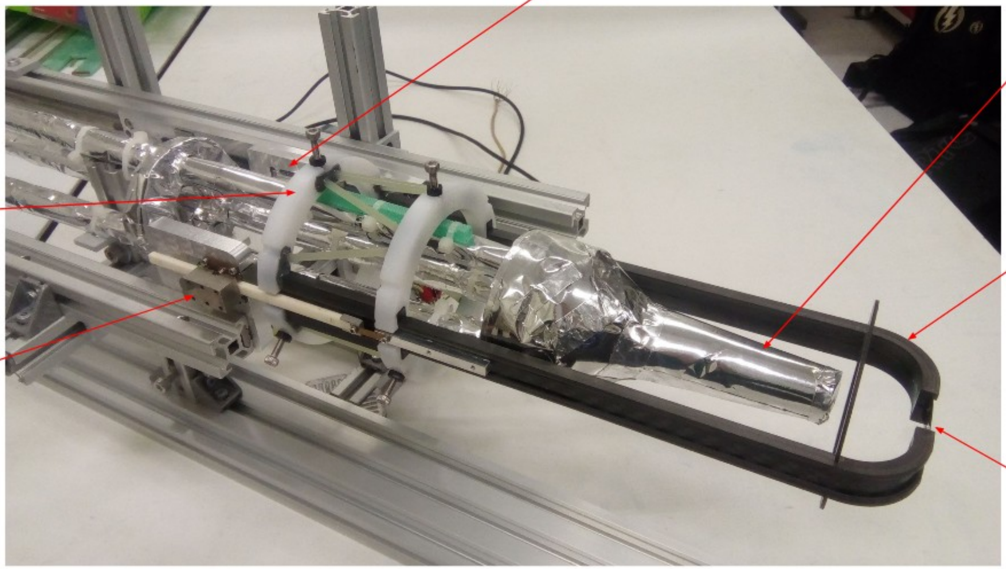
- CP needs equal integrated luminosity on all targets with the emphasis on Pb, which is used with a half-thickness (½ areal density) to reduce the secondary EM processes.
- CP should have equal run-time with "normal" and "reversed" toroidal field to guarantee a high quality measurement for the lightest hadrons, π^+ and π^-, unless demonstrated otherwise with simulation.

CT & CP Run Conditions: Target Configuration (Plan 1)

- EG2p dual target will operate under extreme conditions:
  - High vacuum (6x10^{-6} mbar),
  - Magnetic field (5 Tesla),
  - Cryotarget at 30 K,
  - Radiation hardness,
  - Reduced space.
- Challenge: control target positioning to the required level, under these conditions.

Detector Acceptance Region





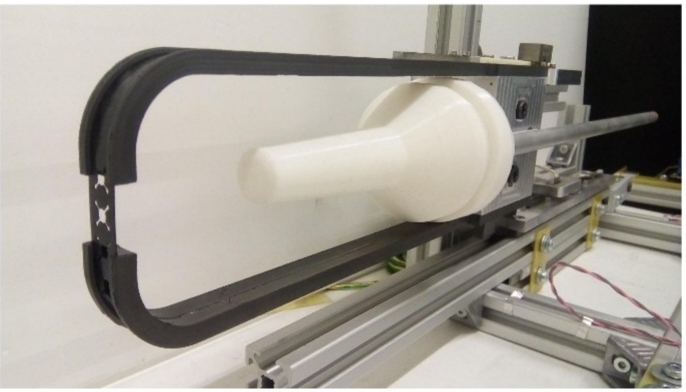
Solid target attached to the existing cryo target.

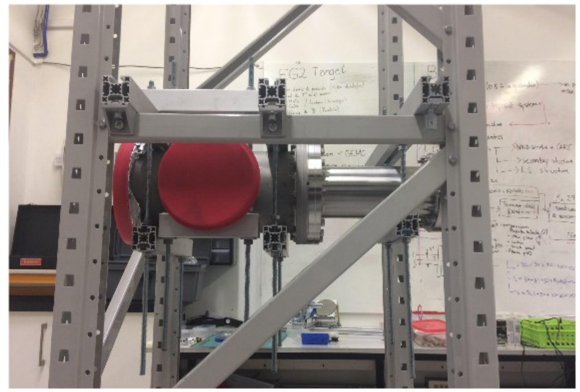
Courtesy of Iñaki Vega (UTFSM)

CP & CT Run Conditions: Target Configuration (Plan 1)

Tests

- Develop a control system for the movement precision and the mechanical robustness (in UTFSM)
- Test the target in vacuum (in UTFSM)
- Low Magnetic field (in MIT)
- Test in vacuum, high magnetic field and low temperatures (in JLab)





*Vacuum chamber in construction

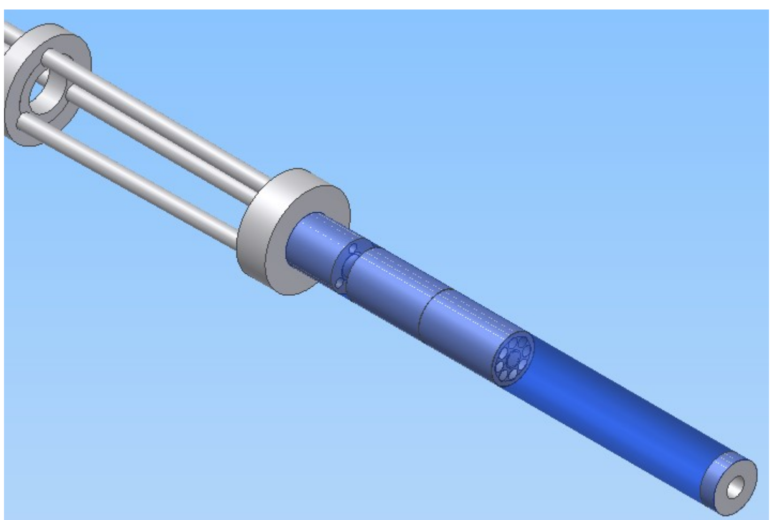
Part of RG-M ERR →

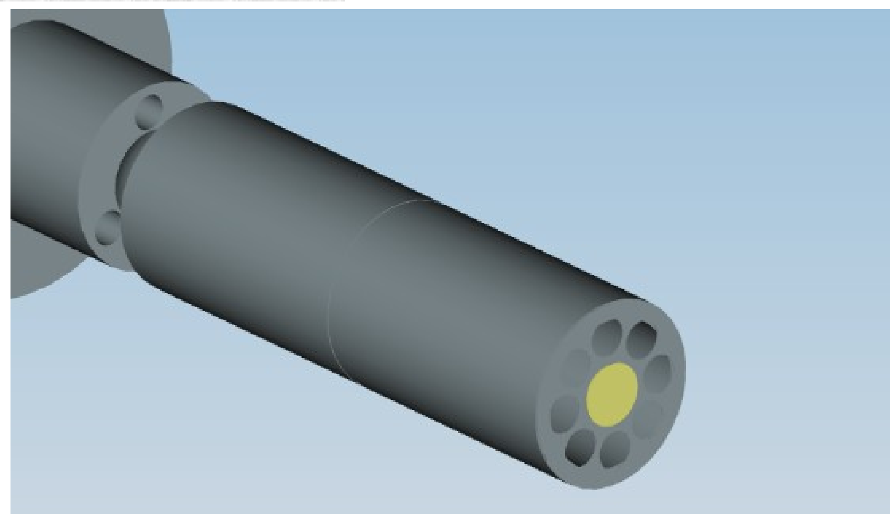
	October 2018	November 2018	December 2018	January 2019	February 2019	March 2019	April 2019	May 2019	June 2019	July 2019
ERR										
Vacuum test										
Update design and construction										
Low magnetic field test										
Update design and construction										
Real conditions at JLab										
Update design and construction										
Background simulations										

CP & CT Run Conditions: Target Configuration (Plan 2)

- Target's foils are 5 cm apart for vertex resolution.
  - Design already exists,
  - Can run with up to three targets simultaneously in the beam-line,
  - Solid targets are glued to a kapton disk, which is glued to a foam cylinder, and held inside a kapton cylinder filled with helium.

Hall-B Solid Target Assembly





CT & CP Run Conditions: Trigger

- We could use the same RG-A electron trigger, however, dedicated simulation studies are needed to:
  - determine the minimum energy deposition in the PCAL & ECAL and the associated trigger rates.
  - study the effect of the maximum luminosity on the trigger rates and DC occupancies,
  - optimize the trigger for the CP rare states measurements.

CT & CP Work Plan & ERR

- We established recently a working group with these initial tasks:
  - Develop a run-plan for CP (W. Brooks, UTFSM),
  - Followup on the construction and test plans of the EG2p target (H. Hakobyan + engineers, UTFSM),
  - Carry several simulation studies for:
    - CP: Implement the EG2p dual target in GEMC to estimate the nuclear target's background (H. Hakobyan + students, UTFSM),
    - CT: Implement the Hall-B solid target's setup in GEMC and get the projections for different run configurations with and without LD2 simultaneously in the beam-line (M. Hattawy & myself),
    - RG proposal's addition (R. Dupre + student, IPNO & M. Hattawy, ODU).
  - Contacted recently P. Rossi requesting an ERR in March, 2019. The ERR date will be fixed by the end of Dec./early Jan.
  - Our WG assignment tasks will get prioritized based on the ERR charges list.
  - ERR documentation include ESAD, RSAD, COO, ERG and OSPs.
  - A draft of our ERR wiki-page has been created (*include some previous ERR documents as examples; to be updated*).

Backup Slides

CP & CT Run Conditions: Target Configuration (Plan 1)

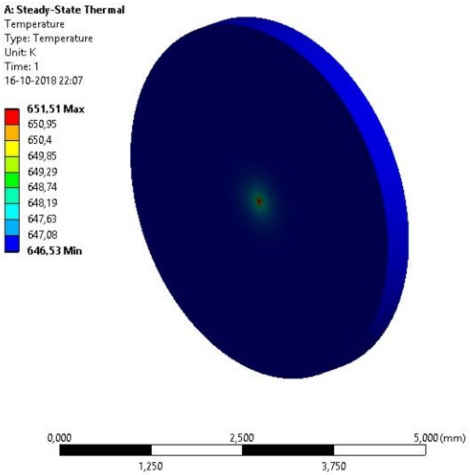
Specs

- Mass: ~0.5 kg
- Materials: non magnetics, low gas load
- Temperature resistance
- Wear resistance

Thermal analysis (WIP)

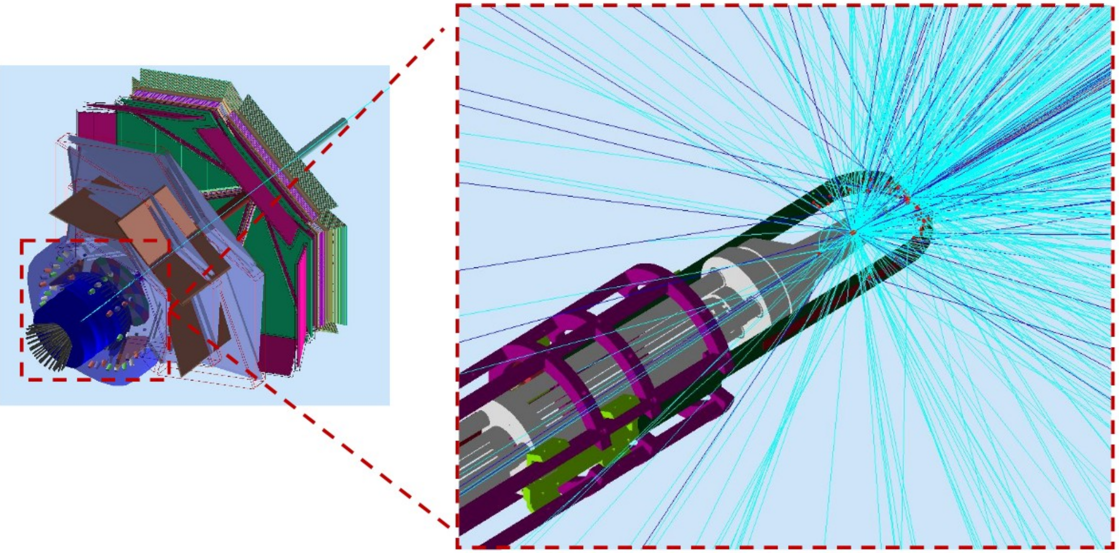
Preliminary thermal analysis (Iron):

- Heat flow: 60 [mW]
- Radiation boundary condition
- Maximum temperature: 378.4 [°C]
- beam diameter: 100 [µm]



By Milan Ungerer

Background study (WIP) GEMC



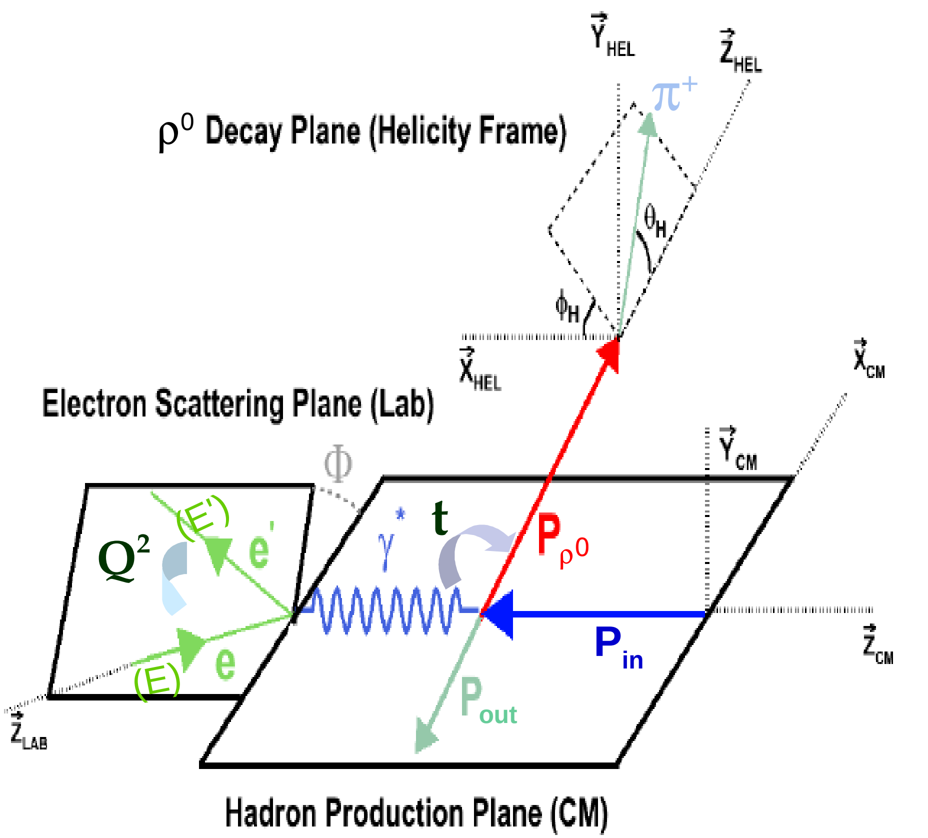
Preliminary simulation with GEMC for background study.

Next steps:

- Include Magnetic fields
- Include the target to CLAS12 equipment
- Generate a complete background study for the support structure

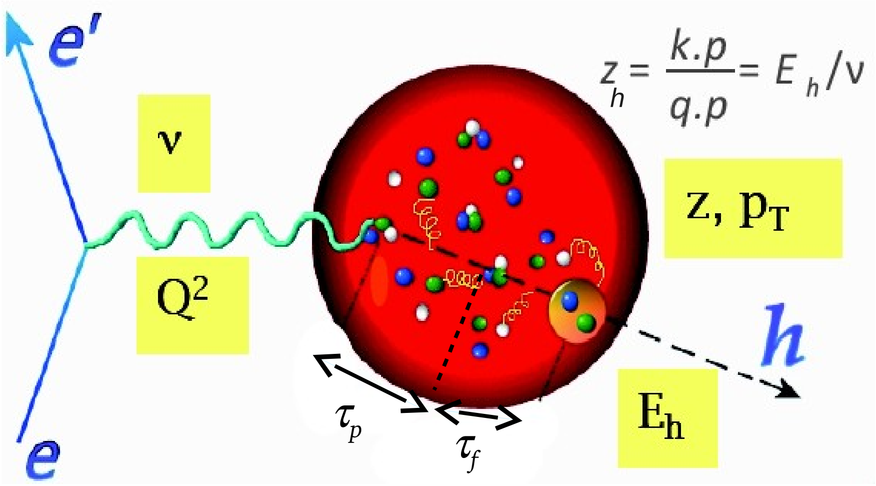
ρ^0 Electro-production Kinematics

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



- **$W \geq 2$ 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

Color Propagation SIDIS Kinematics



Variables:

ν : Electron energy loss,

≡ Initial energy of a struck quark

Q^2: Four-momentum transferred,

~ 1/(spatial resolution) of the probe

y : ν/E_{beam}, Electron energy fraction transferred to a struck quark,

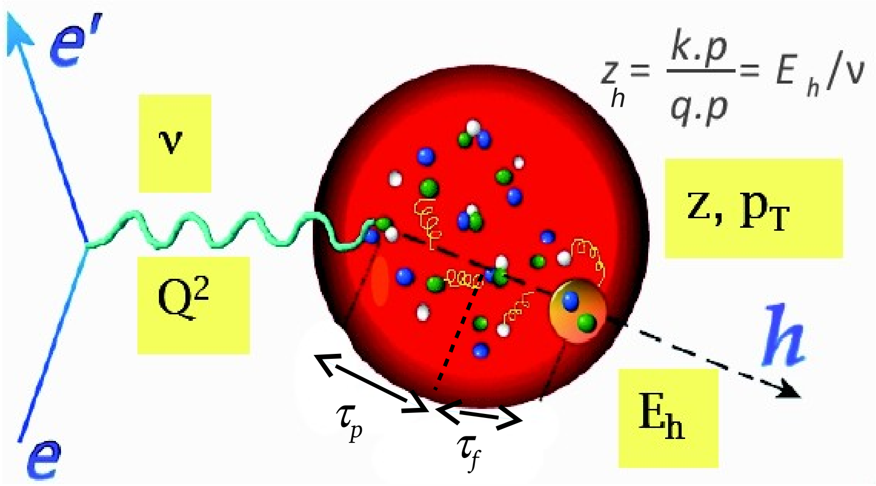
$W : \sqrt{M_n^2 + 2\nu M_n - Q^2}$ *w/. M_n is a nucleon mass*, is the mass of the total hadronic final state,

z_h: Fraction of the struck quark's initial energy carried by the formed hadron ($0 < z_h < 1$)

p_T: Hadron momentum transverse to a virtual photon direction.

x_F: $\frac{P_L}{P_L^{max}}$, *Feynman variable*, a fraction of the maximum longitudinal momentum carried by the observed hadron.

Color Propagation SIDIS Kinematics



Kinematical cuts:

Q^2: Four-momentum transfer,

> 1, to probe the intrinsic structure of nucleons,

y : ν/E_h, Electron energy fraction transferred to a struck quark,

< 0.85, to reduce the size of the radiative effects on multiplicity ratios

$W : \sqrt{M_n^2 + 2\nu M_n - Q^2}$ *w/. M_n is a nucleon mass*, is the mass of the total hadronic final state,

> 2, to avoid a contamination from the resonance region

x_F: Fraction of the maximum longitudinal momentum carried by the observed hadron.

> 0, selects the current fragmentation region.

< 0, selects the backward (target-remnant) fragmentation region.

DIS channels: *stable* hadrons, accessible with 11 GeV JLab experiment PR12-06-117

Actively underway with existing 5 GeV data

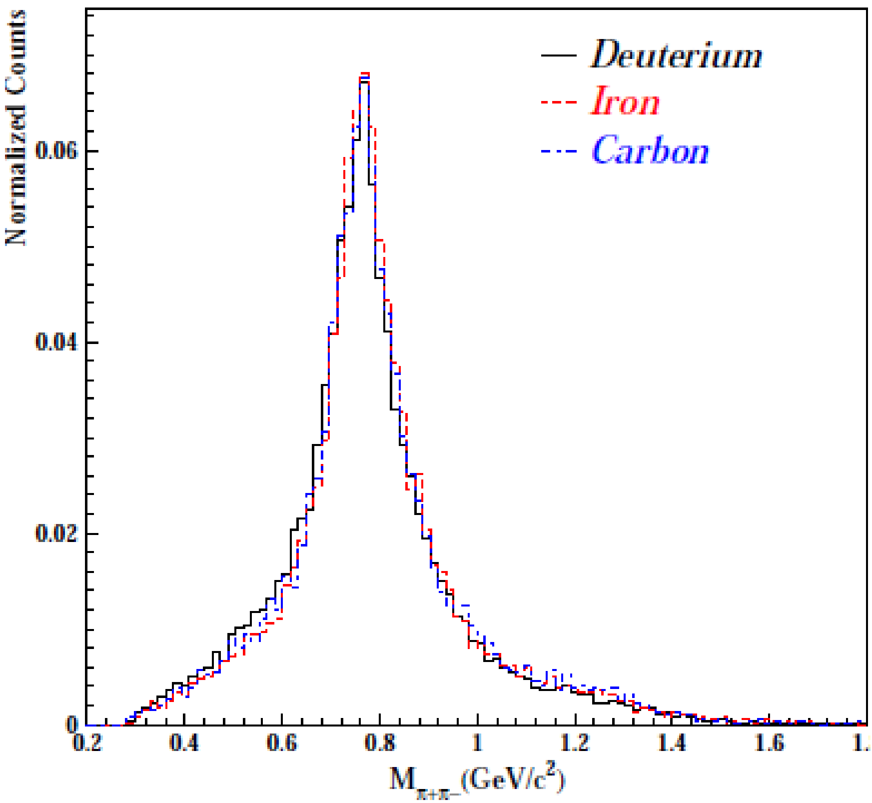
meson	cτ	mass	flavor content
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$
K^0	27 mm	0.50	$d\bar{s}$
K^+, K^-	3.7 m	0.49	$u\bar{s}$, $\bar{u}s$

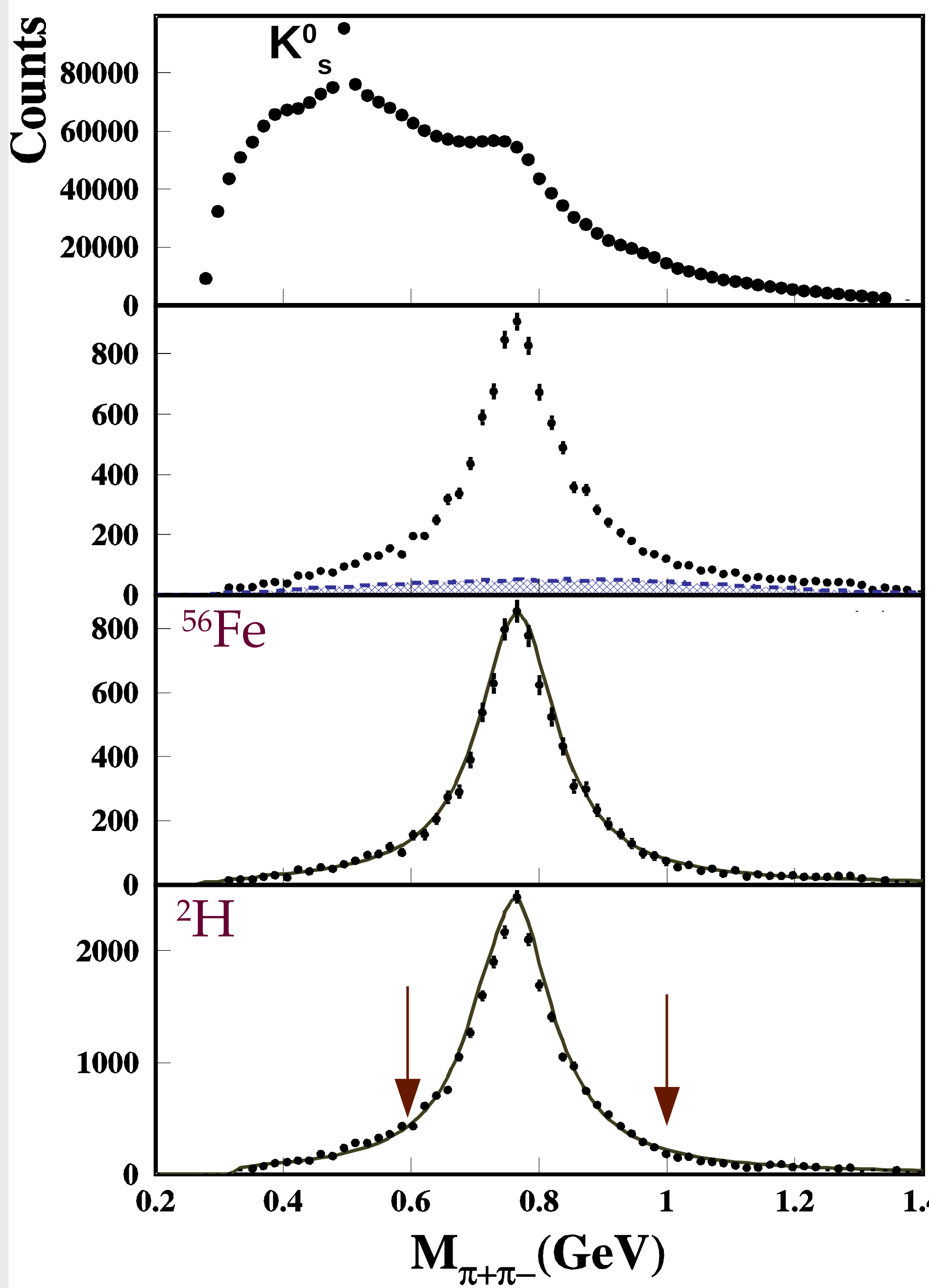
baryon	cτ	mass	flavor content
n	stable	0.94	ud
Ξ^0	87 mm	1.3	us
Ξ^-	49 mm	1.3	ds

- Span a wider range of nuclei masses ⟹ Better understanding of the A dependence,
- Study the production of a variety of hadrons ⟹ Improve our understanding of hadron's formation mechanism,
- Cover much larger kinematical coverage,
- 10 times higher luminosity compared to CLAS-6 (1000 higher than Hermes),

⟹ Determines the two hadronization time-scales and constrain the existing theoretical models with the correct production picture!

Two pions invariant mass





Multi-pions Processes

- $Z_h \geq 0.9$ is effective in removing muti-pions final state contribution.