Run Group E
Readiness Report

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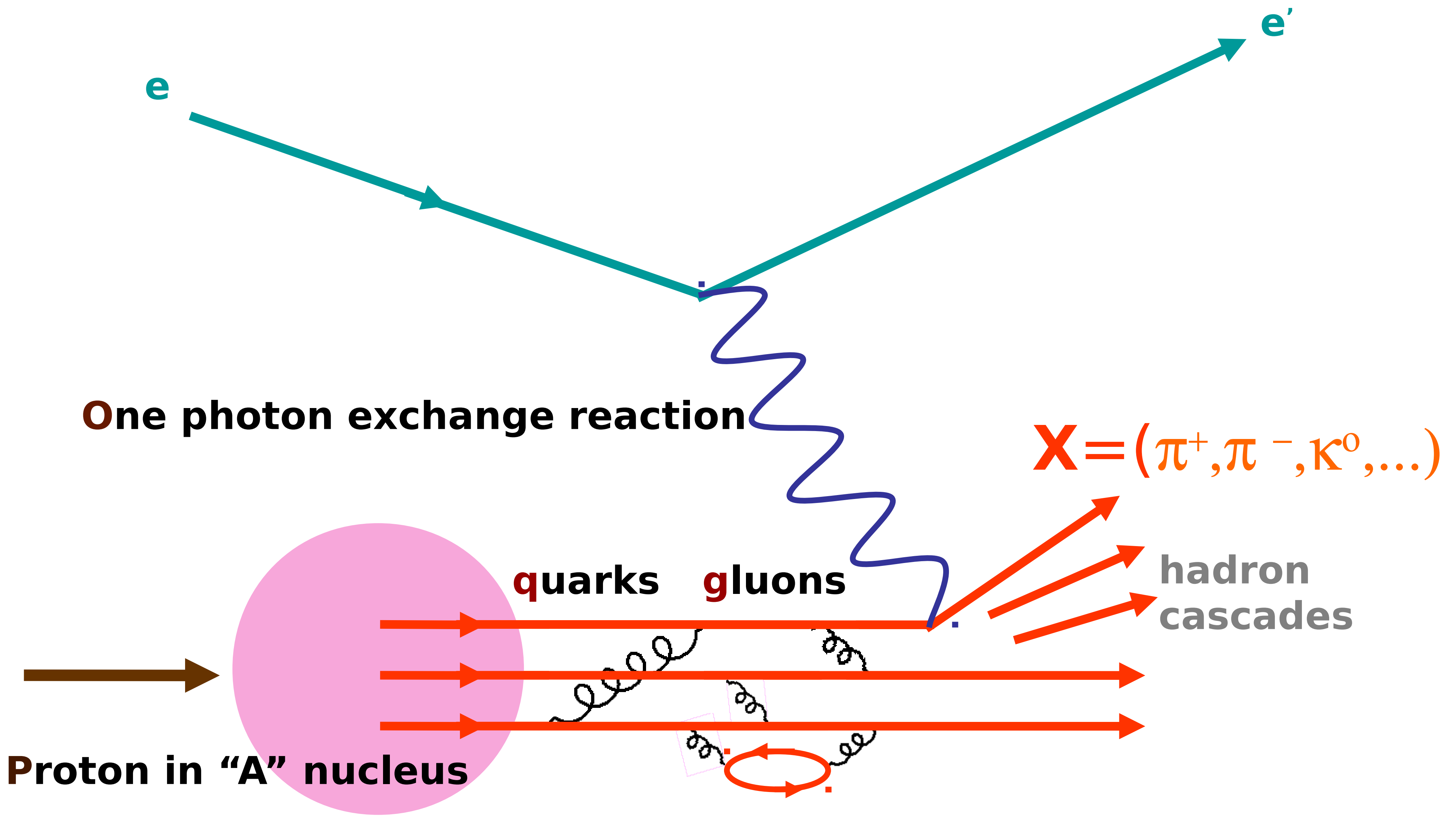
on behalf of the rest of the spokespersons:

W. Armstrong, W. K. Brooks, R. Dupre, A. El Alaoui, L. El Fassi, G. Gilfoyle, H. Hakobyan, K. Hicks, M. Holtrop, K. Joo, T. Mineeva, G. Niculescu, M. Niculescu, M. Wood

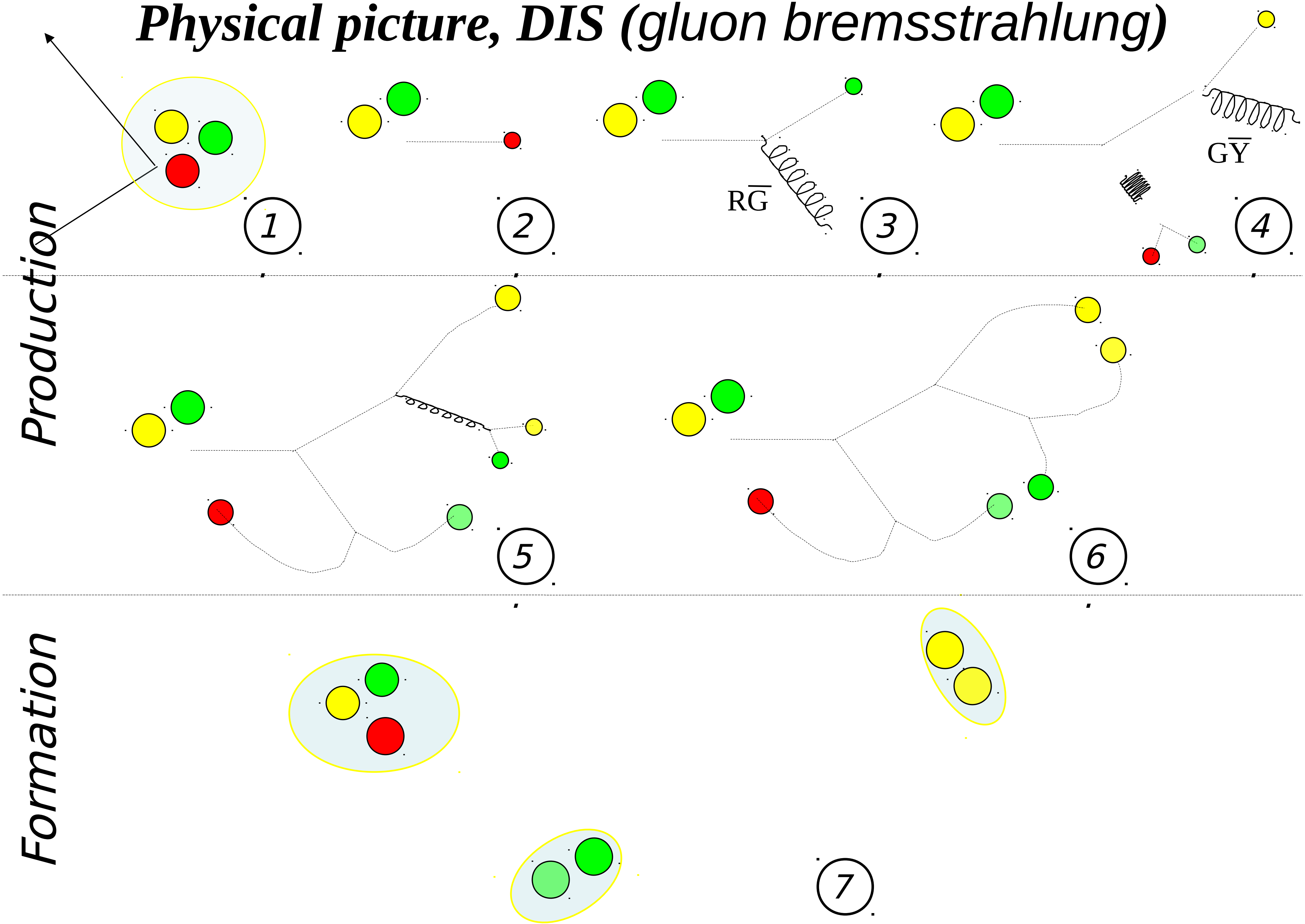
10 institutions

November 13, 2019
CLAS Collaboration meeting

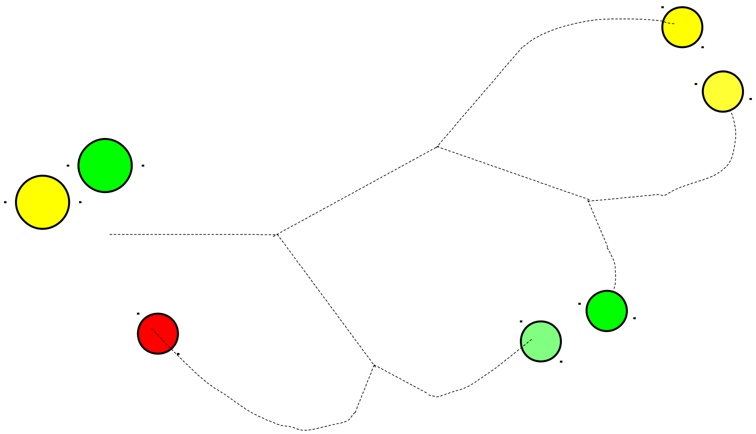
Semi-inclusive DIS of an electron off a single nucleon vs. a nucleon inside a nucleus



Physical picture, DIS (gluon bremsstrahlung)



Kopeliovich, Nemchik, Predazzi, Hayashigaki, Nuclear Physics A 740 (2004) 211–245



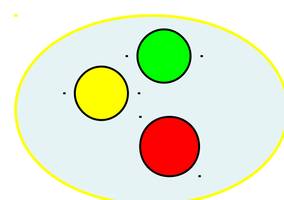
Two distinct dynamical stages, each with characteristic time scale

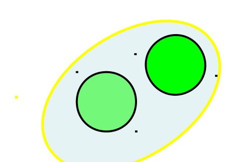
Production time t_p

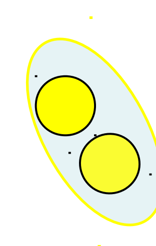
Formation time t_f

Time during which quark emits gluons is deconfined. Signaled by medium-stimulated energy loss via gluon emission: (p_T broadening)

Time required to form color field of hadron Signaled by interactions with known hadron cross sections No gluon emission (Hadron attenuation)



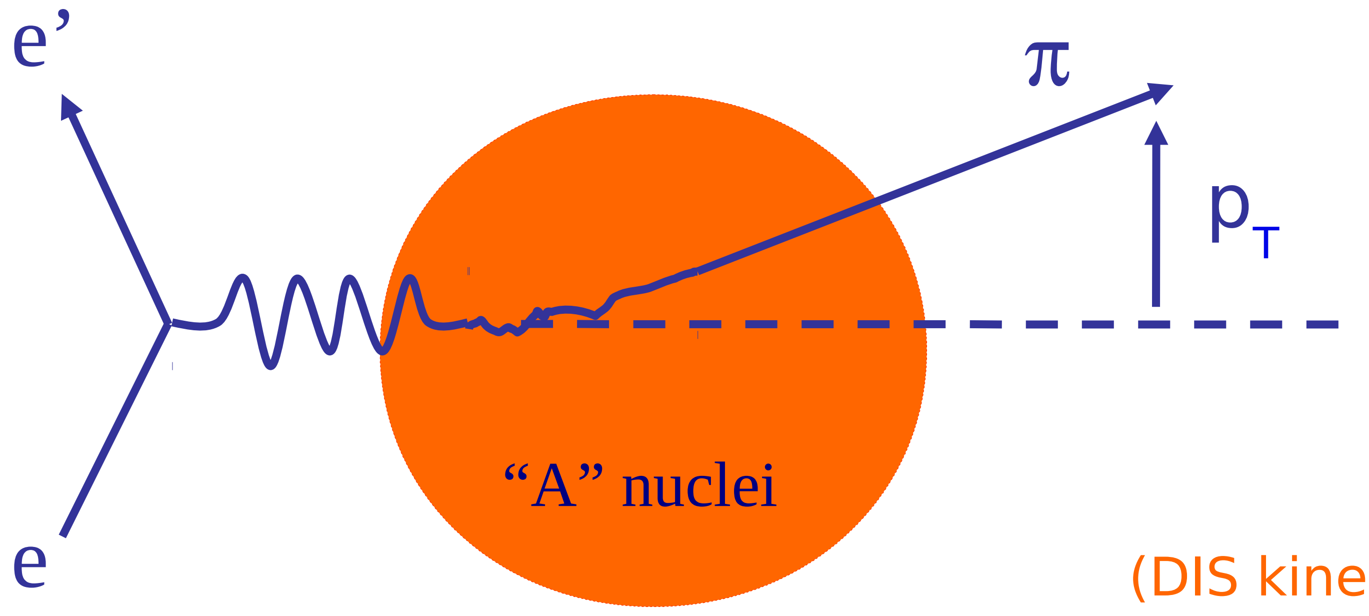




Experimental observables

Transverse momentum broadening:

$$\Delta p_T^2 = p_T^2(A) - p_T^2(^2H)$$

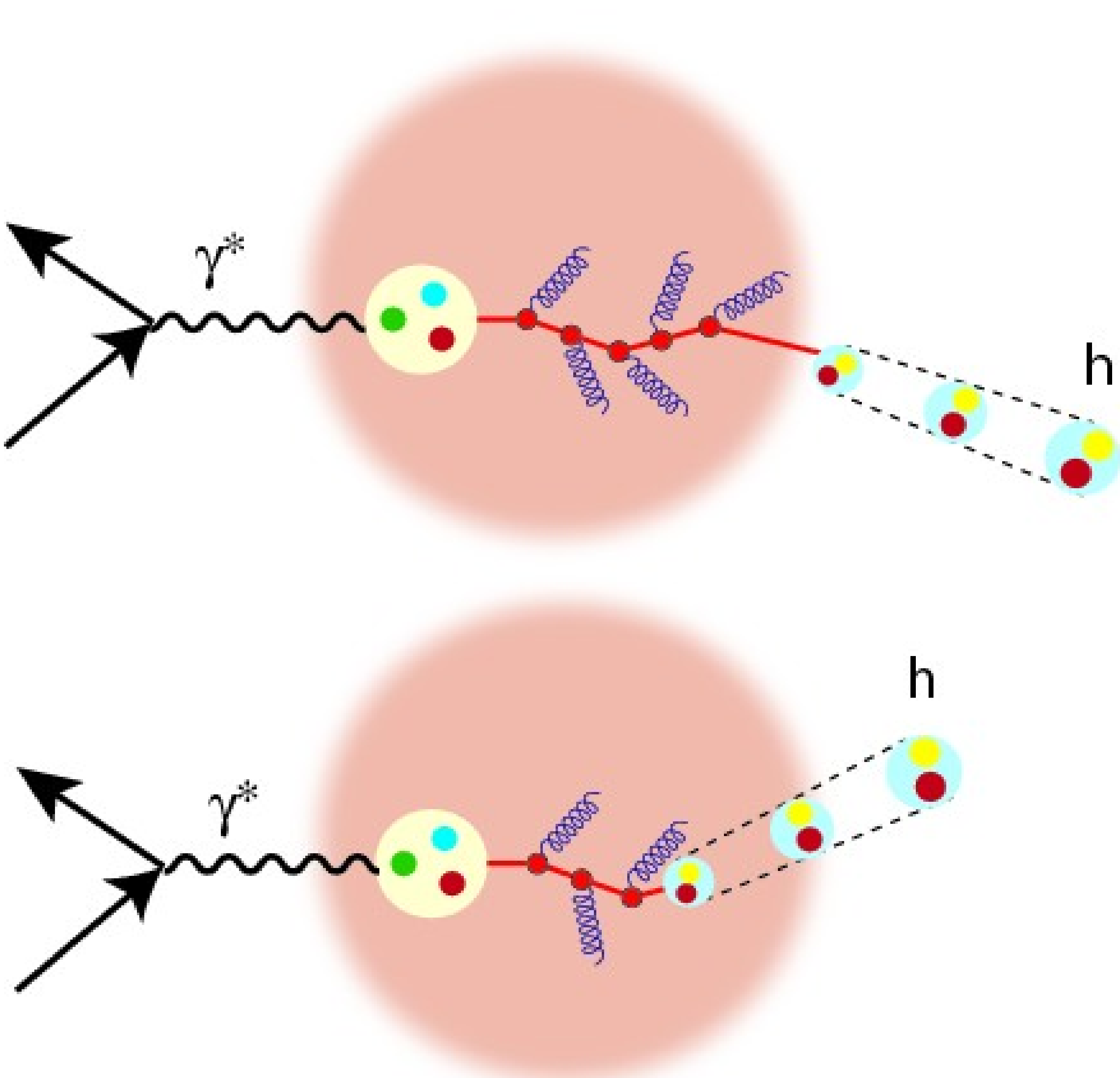


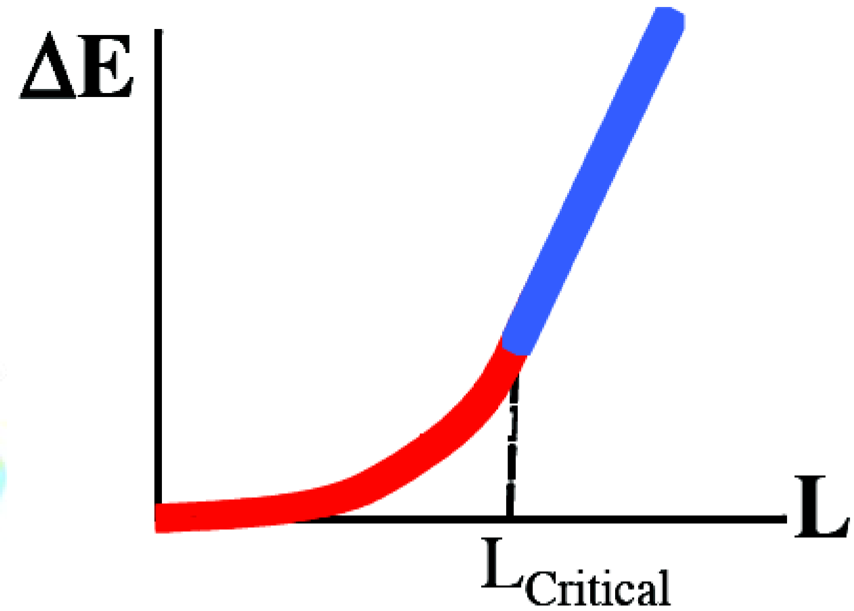
(DIS kinematics)

Hadronic multiplicity ratio:

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

The production and formation of the final hadron, ¿inside or outside?





$$-\frac{dE}{dx} \propto L \qquad L < L_{Critical}$$

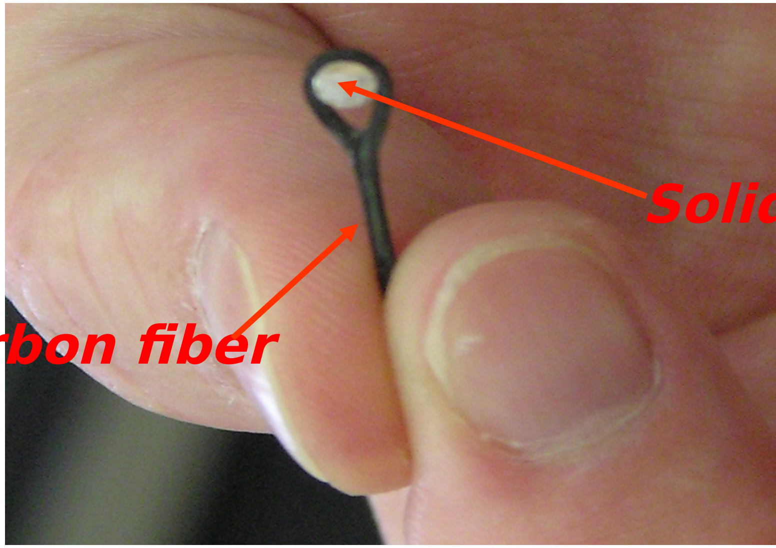
$$-\frac{dE}{dx} \propto \sqrt{E} \qquad L > L_{Critical}$$

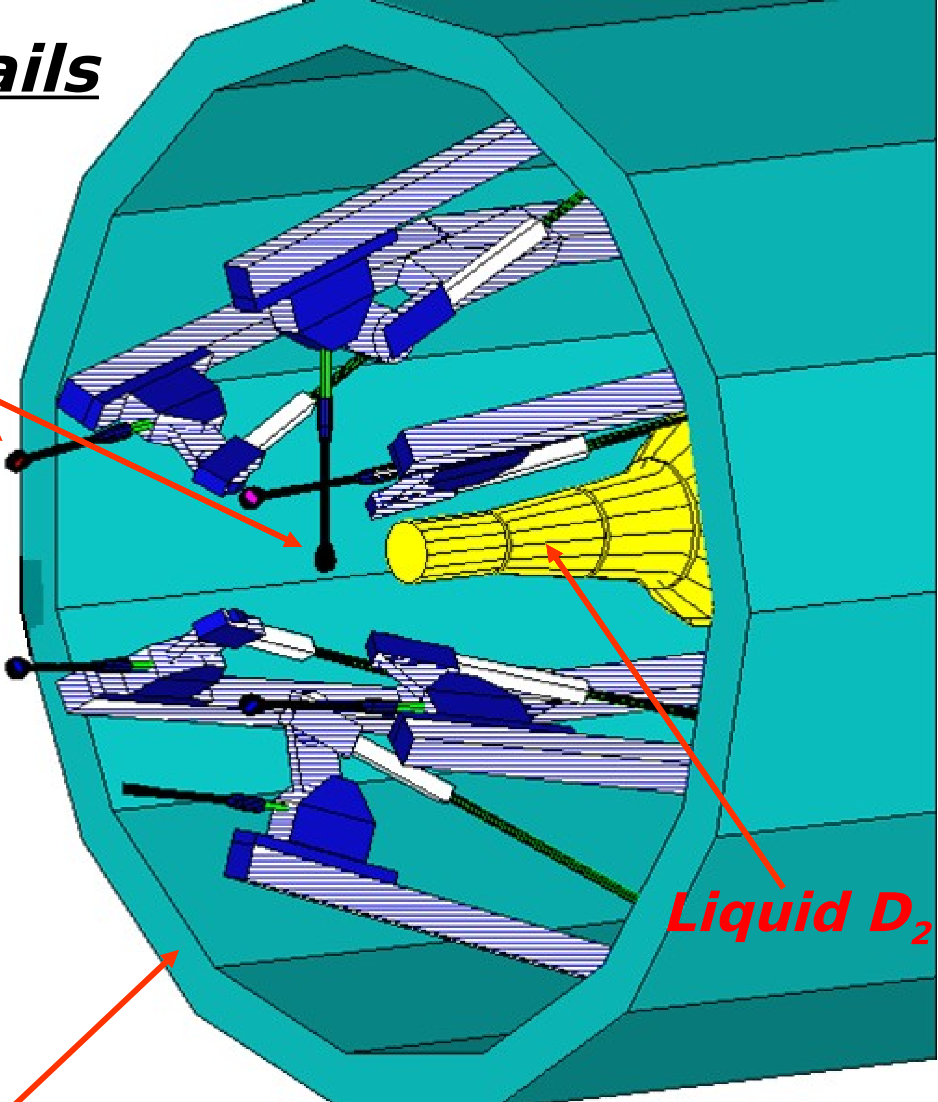
$$\boxed{-\frac{dE}{dx} = \frac{\alpha_s N_c}{4} \Delta k_T^2}$$

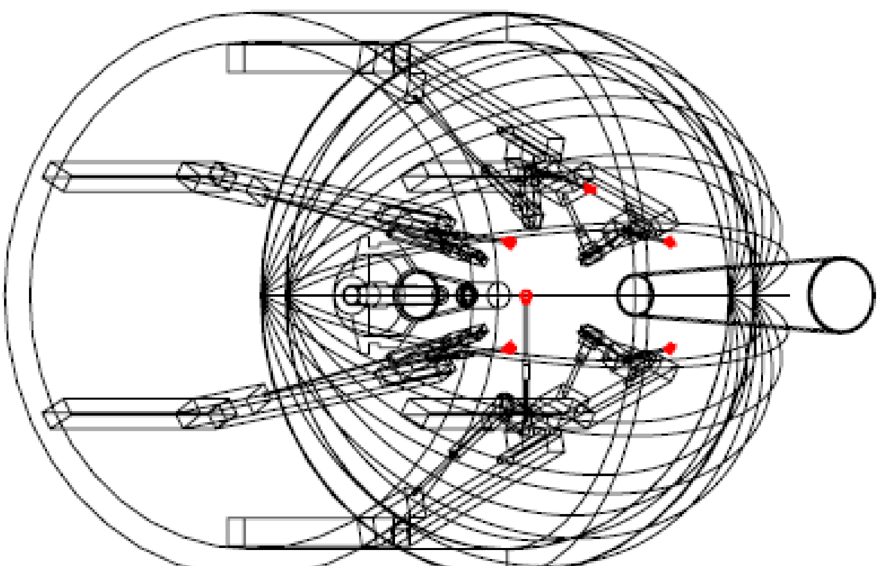
Baier, Schiff, Zakharov, Annu. Rev. Nucl. Part. Sci. 2000. 50:37-69

CLAS Eg2 experimental target

Experimental details

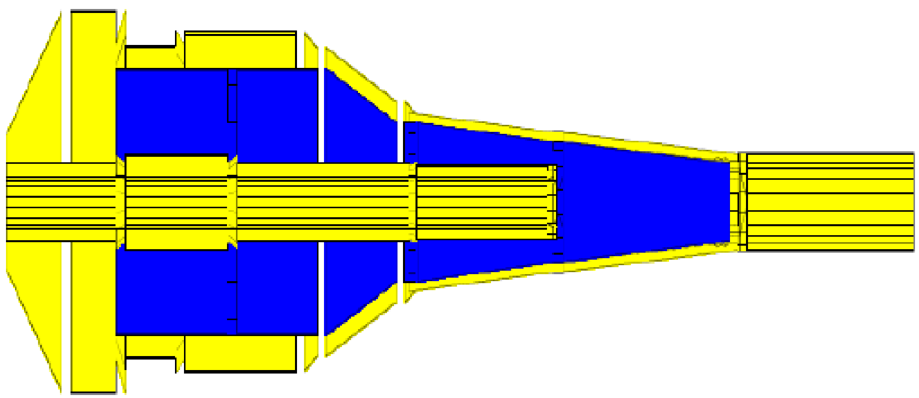






EG2 Experiment target in GEANT3
Solid (C, Al, Fe, Sn, Pb) target simultaneously
with deuterium target

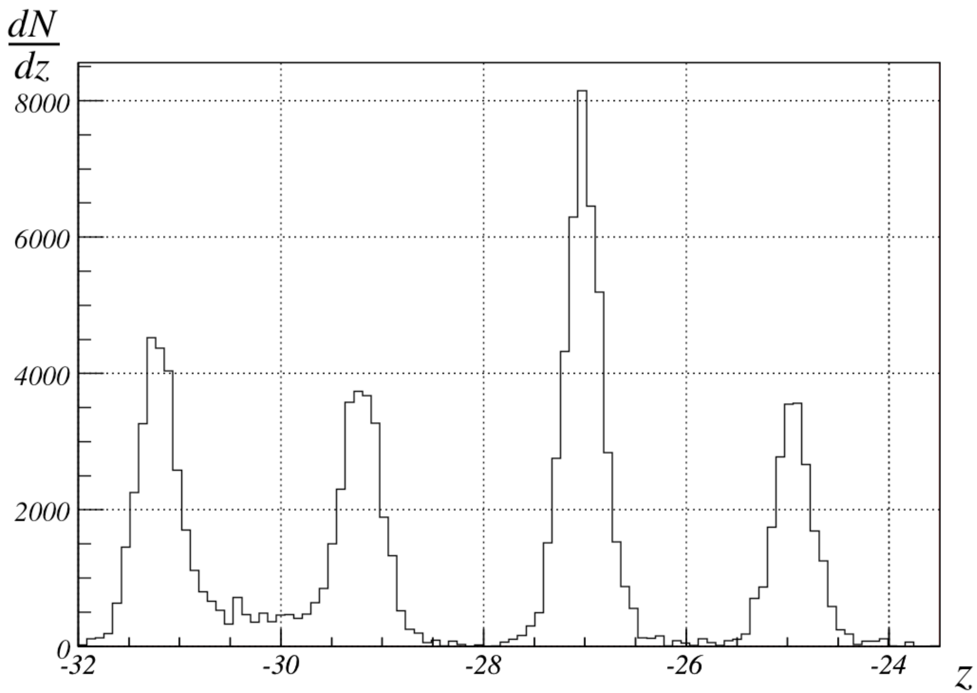
H. Hakobyan, W. Brooks et al, Nucl. Instrum. and Meth. A592:218-223, 2008.



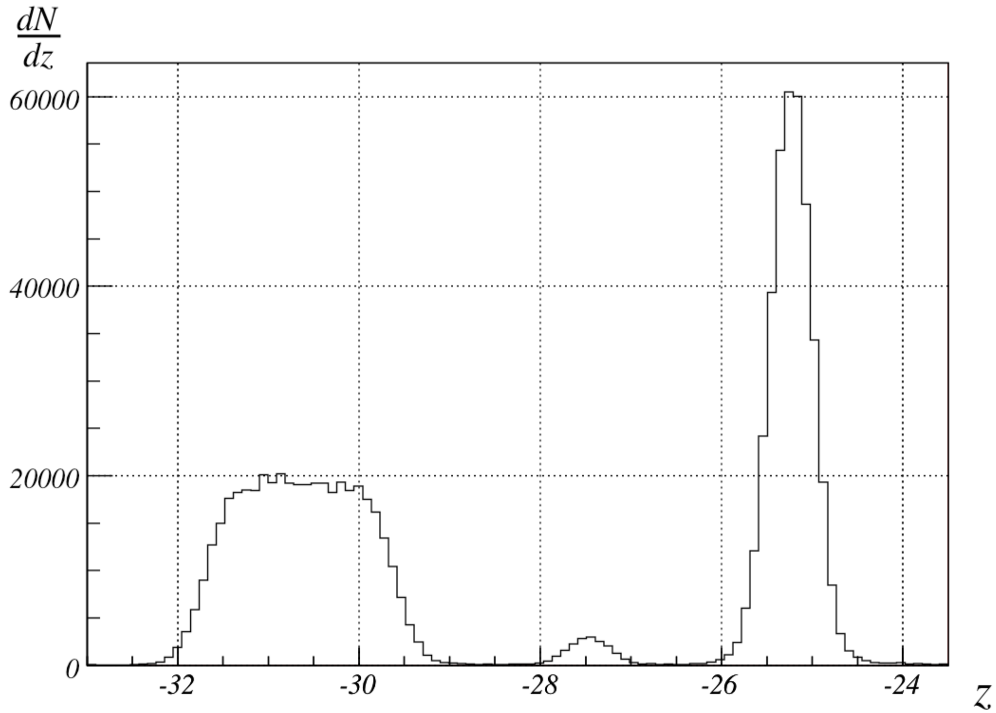
D_2 cell in GEANT

Real CLAS data

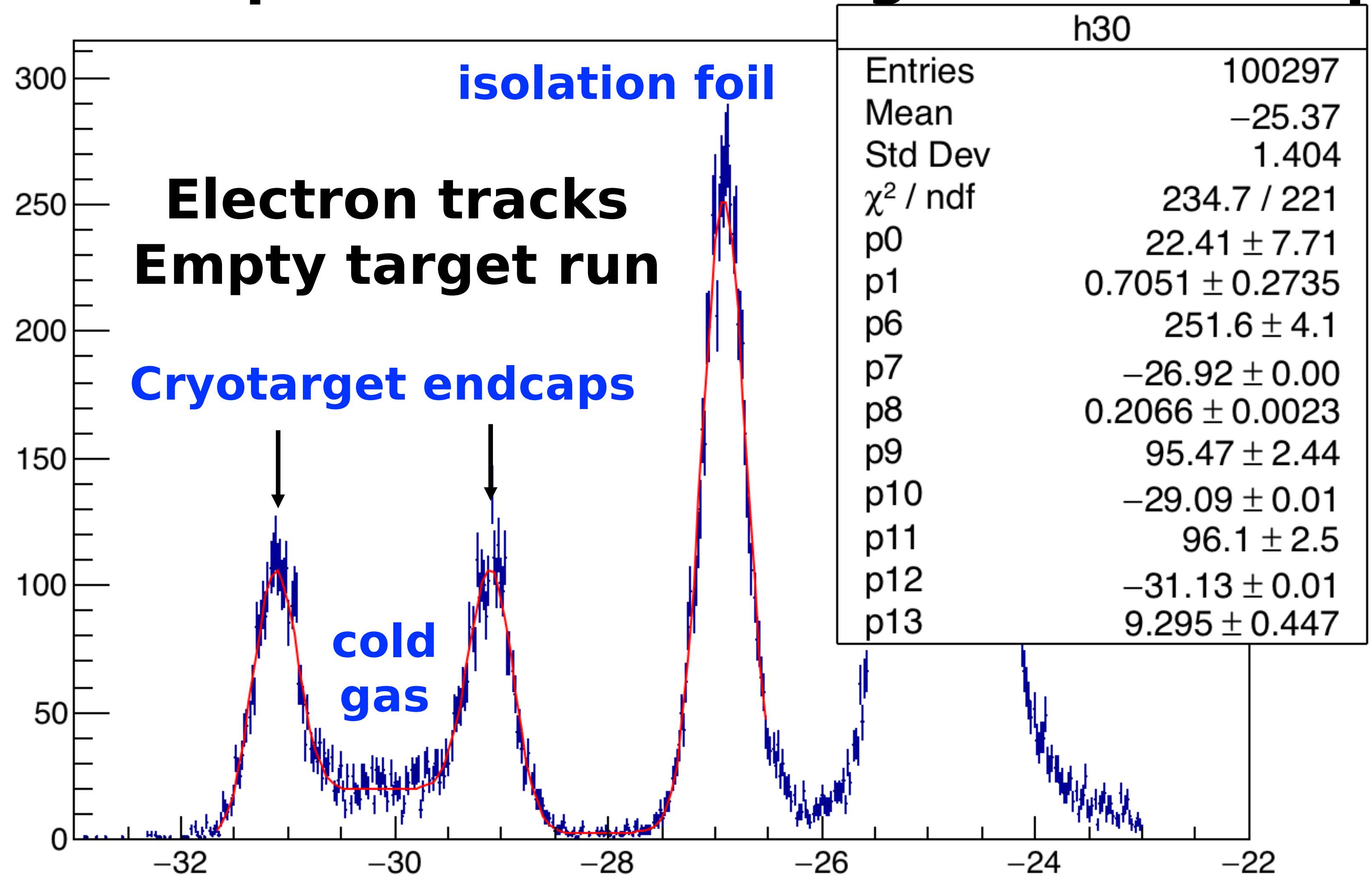
Liquid target empty



Liquid target full



CLAS vertex performance during the EG2 run period



The fit uses Gaussian peaks, vy<1.4 cm, and equal widths for all three peaks. Background parameter is a straight line.

Chisquared/dof = 1.06
Vertex resolution 2.1 mm (parameter 8)
Can resolve targets separated by 1.2 cm - acceptance difference is negligible

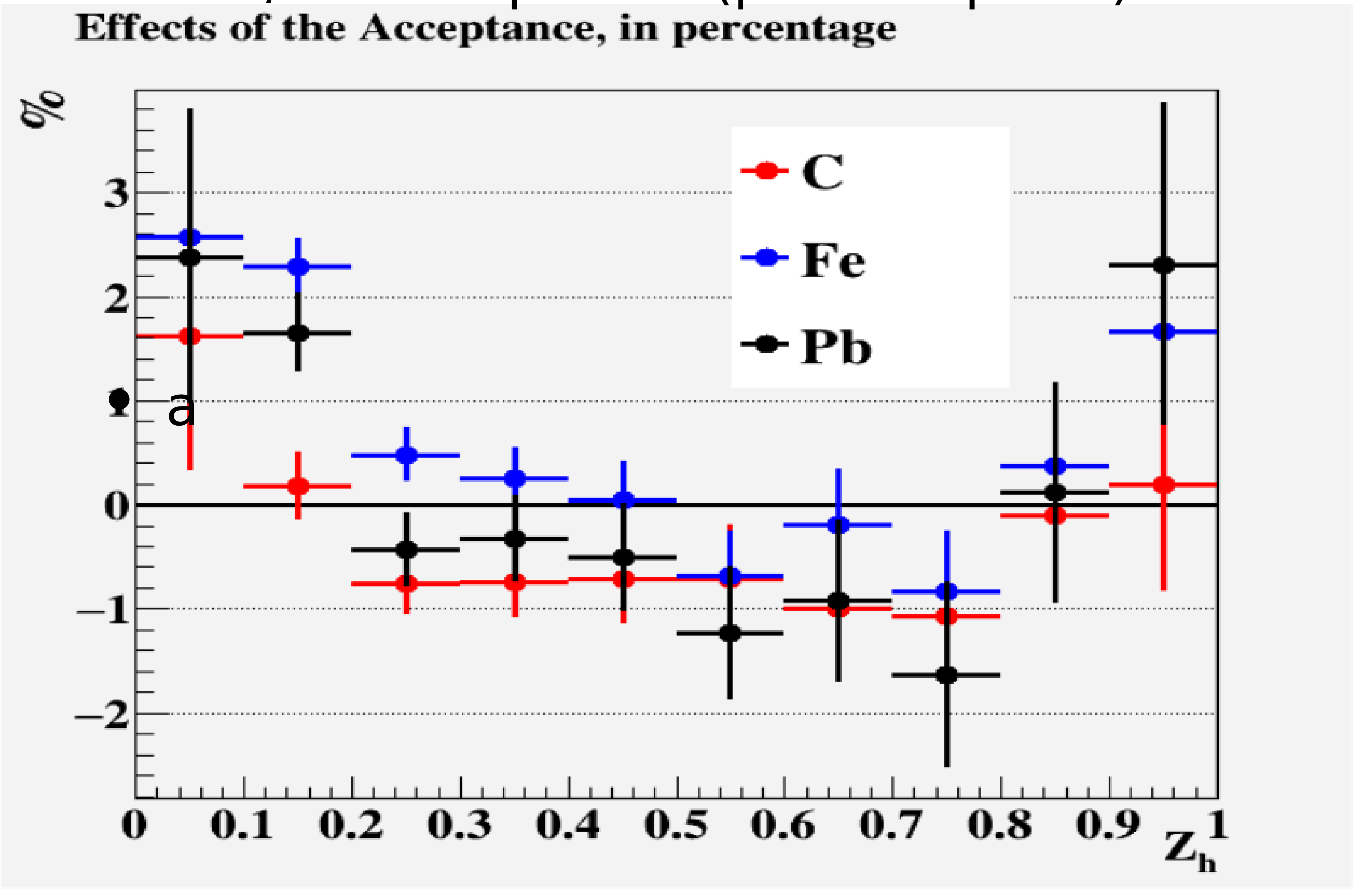
Why we need double-target?

1) Acceptance corrections
2) Trigger efficiency
3) Charged particle reconstruction efficiency
4) Time-dependent modulations of these three based on emergence and disappearance of inoperative channels

And on other factors such as atmospheric pressure variations and drift chamber gas composition variations.

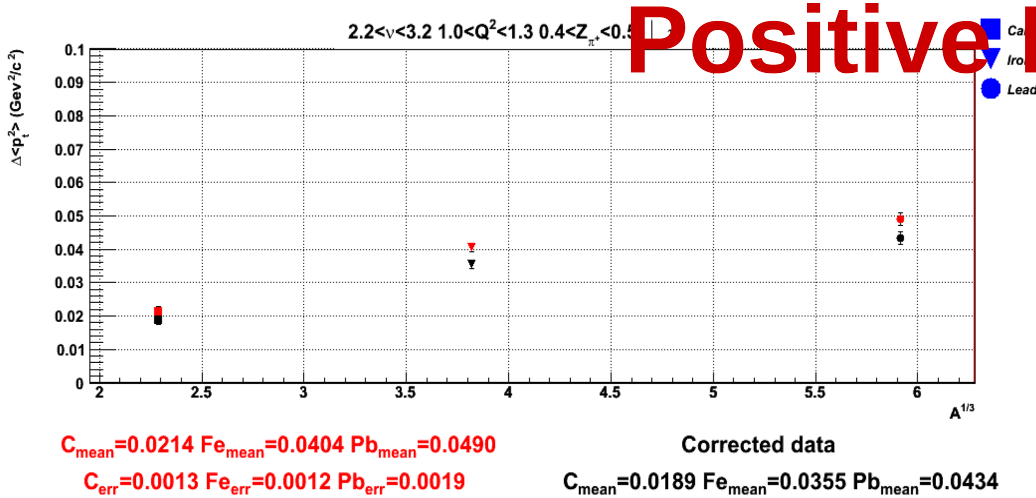
Our requirement is to reach uncertainties competitive with HERMES

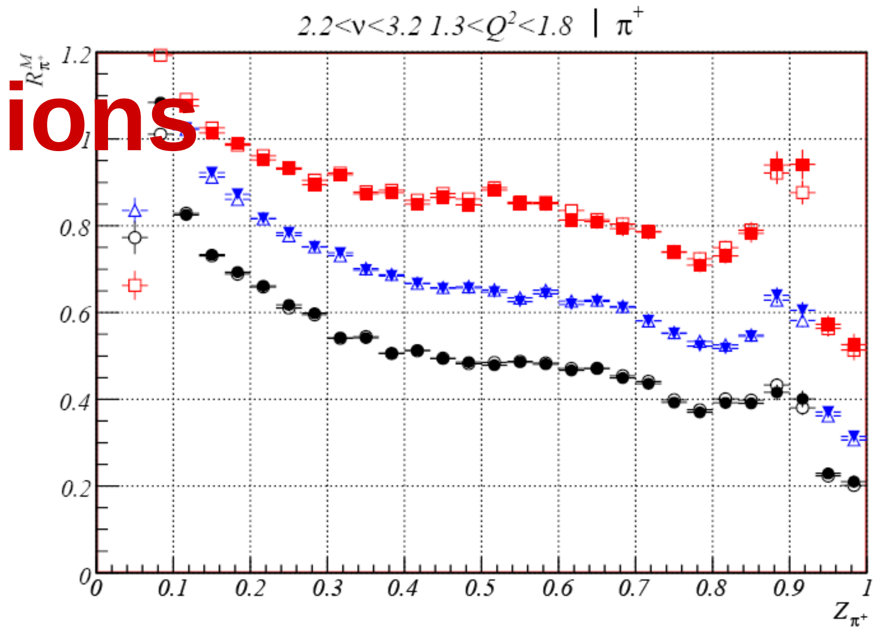
Percent change in multiplicity ratio w/wo acceptance (positive pions)



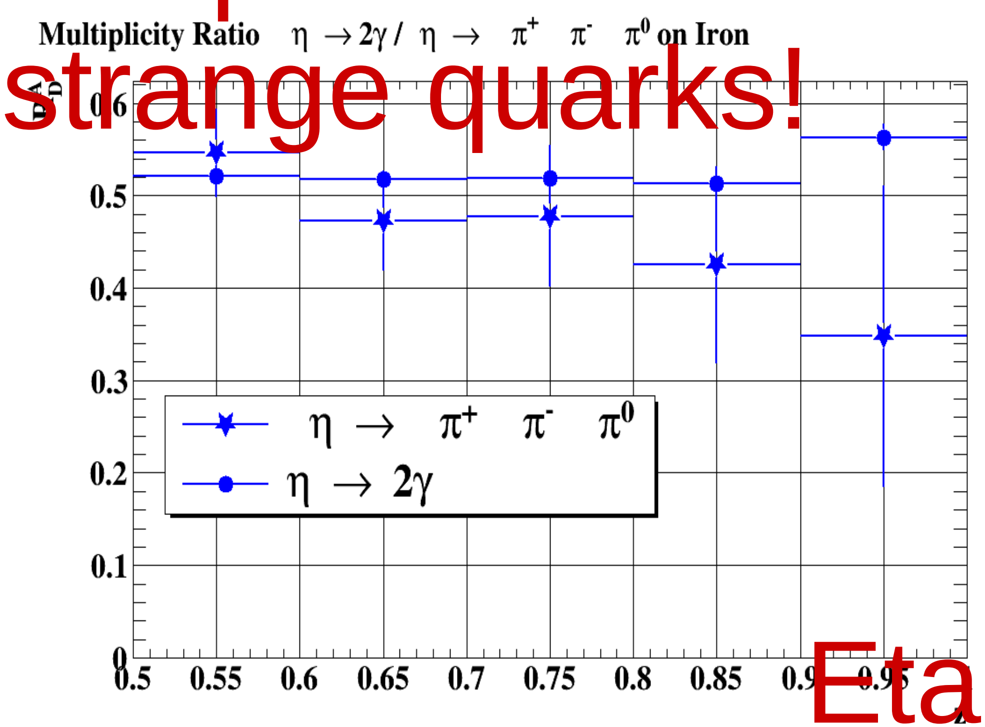
Analysis for π^+, π^-, π^0, K, ω and η hadronization studies

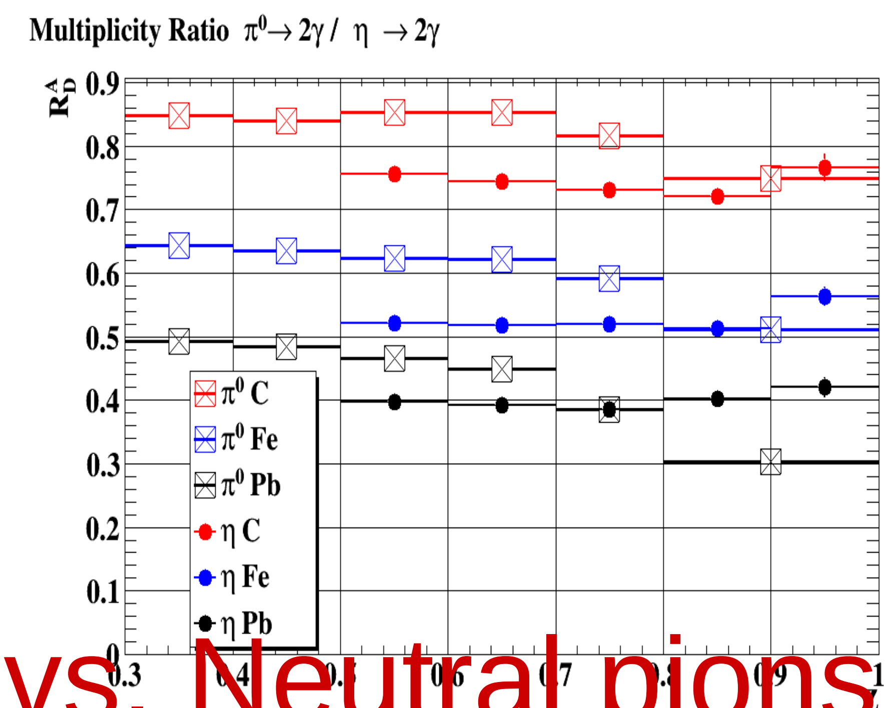
Positive Pions





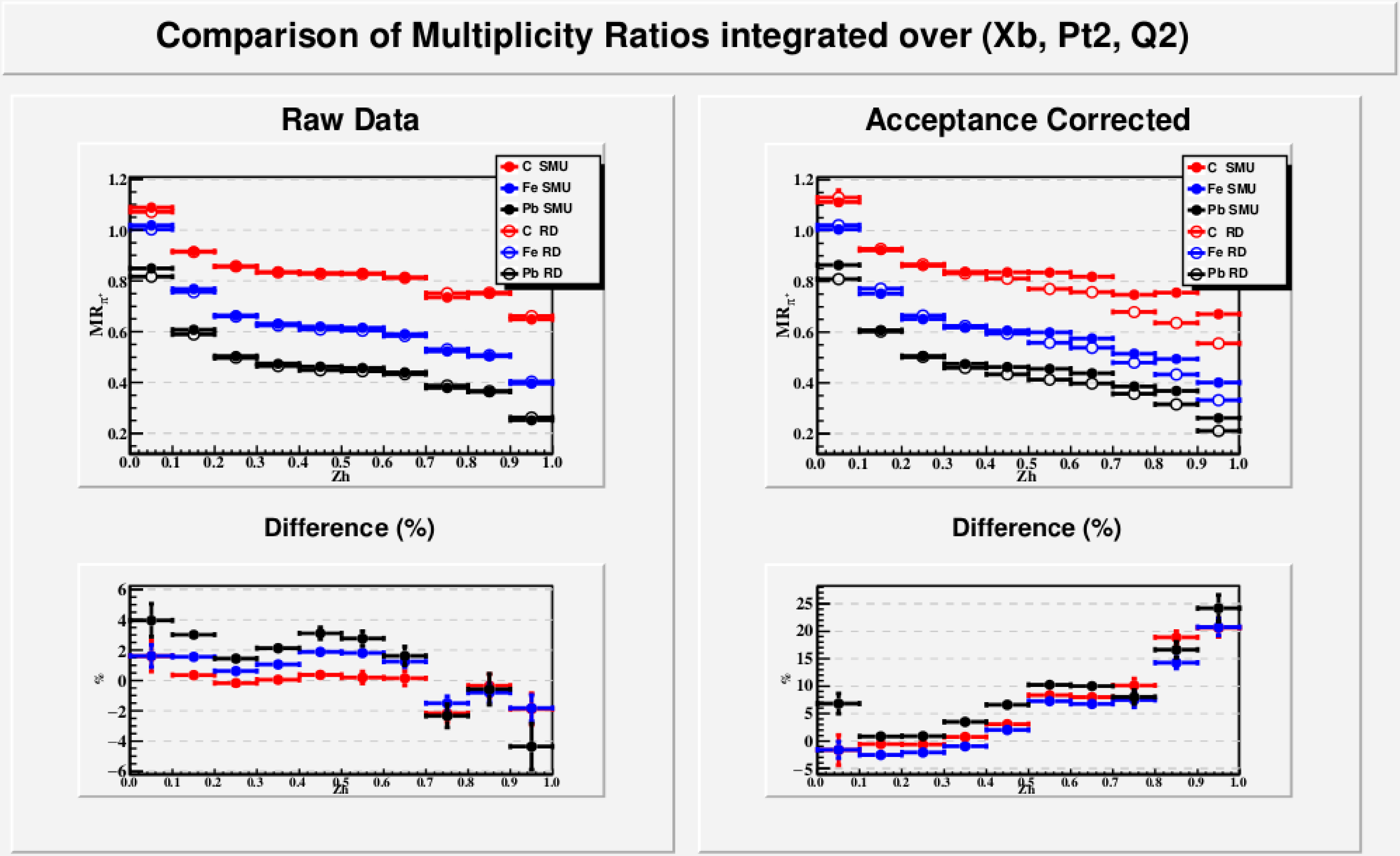
Eta particle contains strange quarks!





Eta vs. Neutral pions

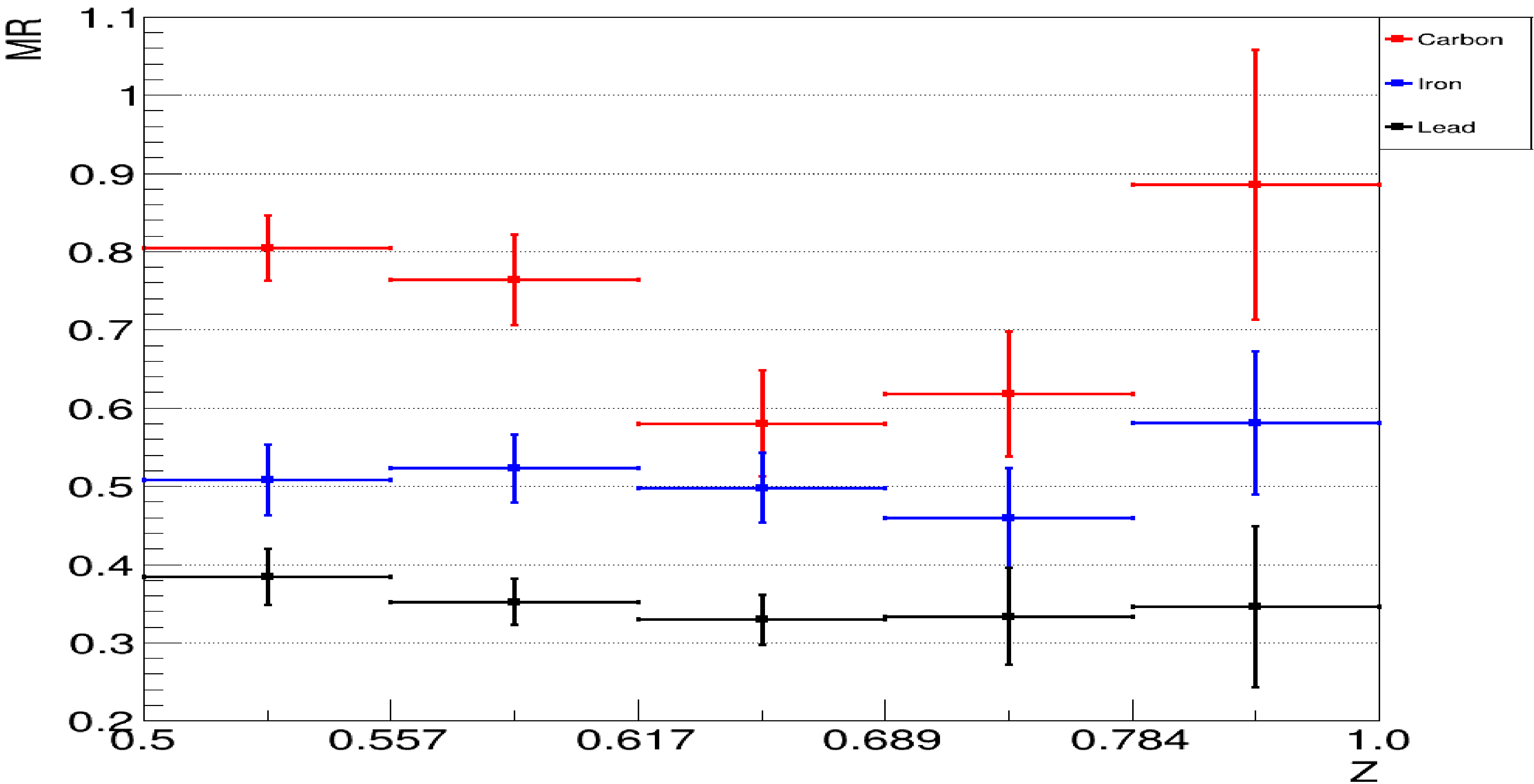
4-D acceptance correction comparison between RD and SMU analysis



See the talk by Sebastian Moran Thursday

CLAS Preliminary – Omega

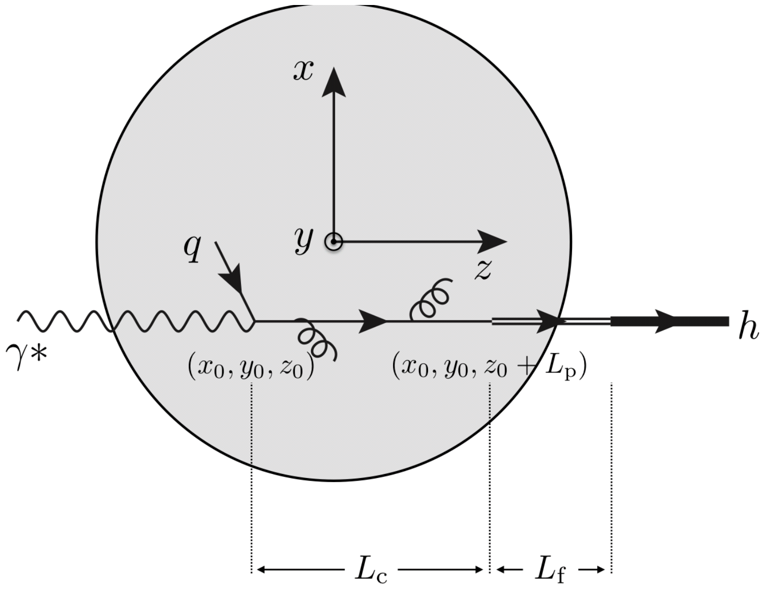
by Andrés Borquez (talks this Thursday)



Studies performed with CLAS Eg2 double-target (including the data mining initiative)

- Nuclear Hadronization and Color Propagation
- Color Transparency
- Short Range Nuclear Correlations
- Two Hadron correlations
- EMC effect measurements
- Hadronic structure functions measurements in nuclei
- Etc.

RG-E: Exploration of subnuclear matter with CLAS12

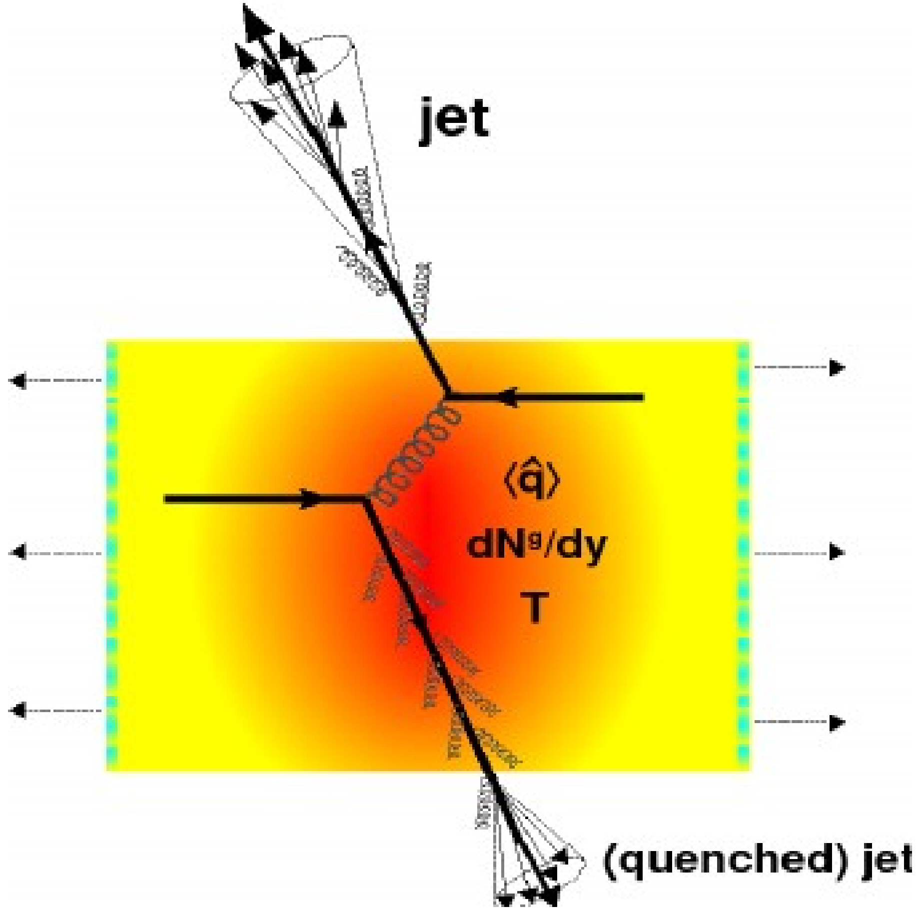


Questions to address:

- How long can energetic quark remain "free"?
- How large is the quark energy loss in the nuclei?
- How do hadrons form from quarks?

Like with CLAS, with CLAS12 as well multidimensional measurements of observables will give access to multivariable dependence to the color lifetime and to quark energy loss. We can do these studies in more dimensions and with small error bars in contrast to HERMES.

Connections: Quark and gluon energy loss in-medium is the basis for the Jet Quenching observed in heavy ion collisions in the hot medium



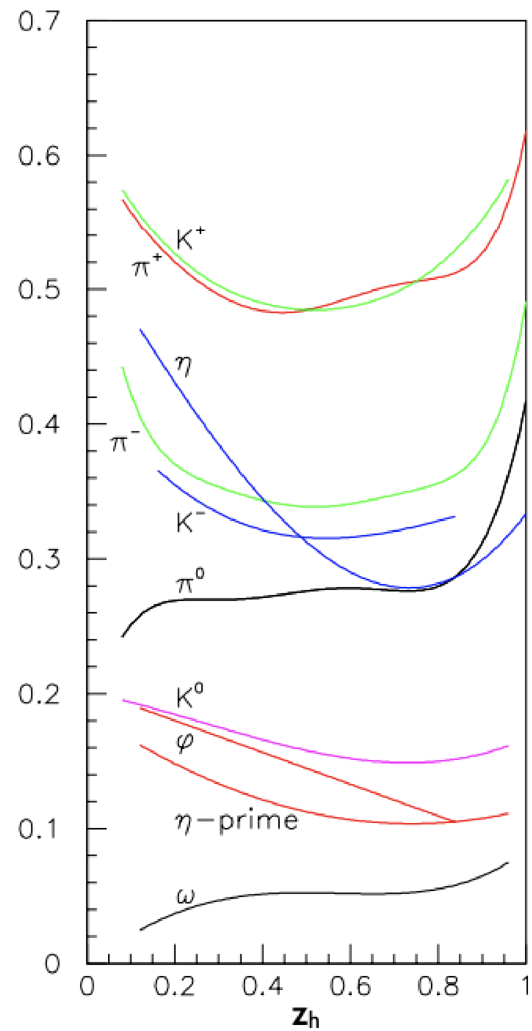
Quark Propagation and Hadron Formation

hadron	cτ	mass	flavor content	limiting error (60 PAC days)
π^0	25 nm	0.13	$u\bar{u}d\bar{d}$	5.7% (sys)
π^+, π	7.8 m	0.14	$u\bar{d}$, $d\bar{u}$	3.2% (sys)
η	170 pm	0.55	$u\bar{u}d\bar{d}s\bar{s}$	6.2% (sys)
ω	23 fm	0.78	$u\bar{u}d\bar{d}s\bar{s}$	6.7% (sys)
η'	0.98 pm	0.96	$u\bar{u}d\bar{d}s\bar{s}$	8.5% (sys)
ϕ	44 fm	1.0	$u\bar{u}d\bar{d}s\bar{s}$	5.0% (stat)*
f1	8 fm	1.3	$u\bar{u}d\bar{d}s\bar{s}$	-
K^0	27 mm	0.50	$d\bar{s}$	4.7% (sys)
K^+, K^-	3.7 m	0.49	$u\bar{s}$, $\bar{u}s$	4.4% (sys)
p	stable	0.94	ud	3.2% (sys)
$\bar{p}$	stable	0.94	$\bar{u}\bar{d}$	5.9% (stat)**
Λ	79 mm	1.1	uds	4.1% (sys)
$\Lambda(1520)$	13 fm	1.5	uds	8.8% (sys)
Σ^+	24 mm	1.2	us	6.6% (sys)
Σ^-	44 mm	1.2	ds	7.9% (sys)
Σ^0	22 pm	1.2	uds	6.9% (sys)
Ξ^0	87 mm	1.3	us	16% (stat)*
Ξ^-	49 mm	1.3	ds	7.8% (stat)*

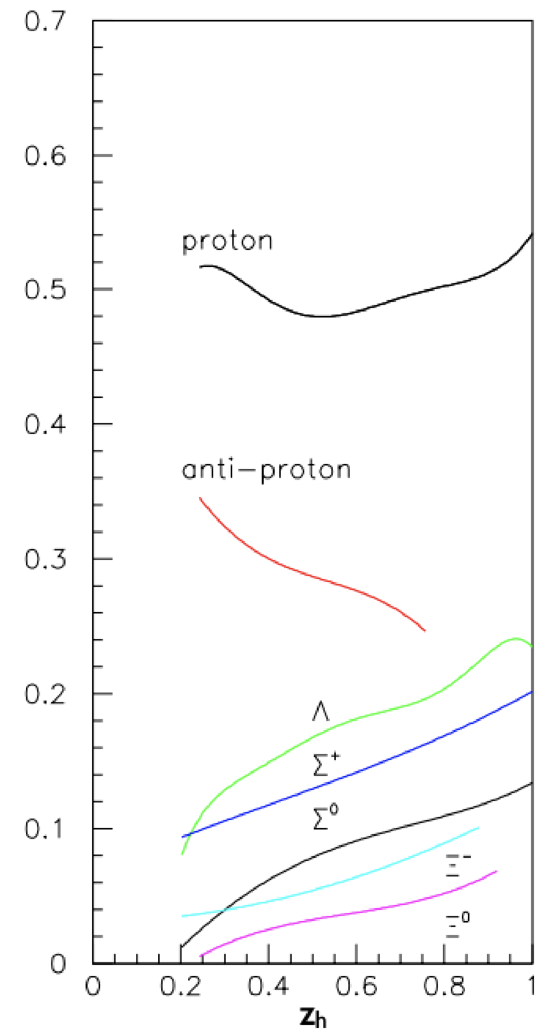
*in a bin in z from 0.7-0.8, integrated over all ν, p_T, ϕ_{pq}, and Q^2>5 GeV^2

**in a bin in z from 0.6-0.7, integrated over all ν, p_T, ϕ_{pq}, and Q^2>5 GeV^2

Dependency of observables (and thus derived quantities, such as production time, formation times, transport coefficient, in-medium cross section, etc.) on mass, flavor, and number of valence quarks



CLAS12 Acceptance for Mesons



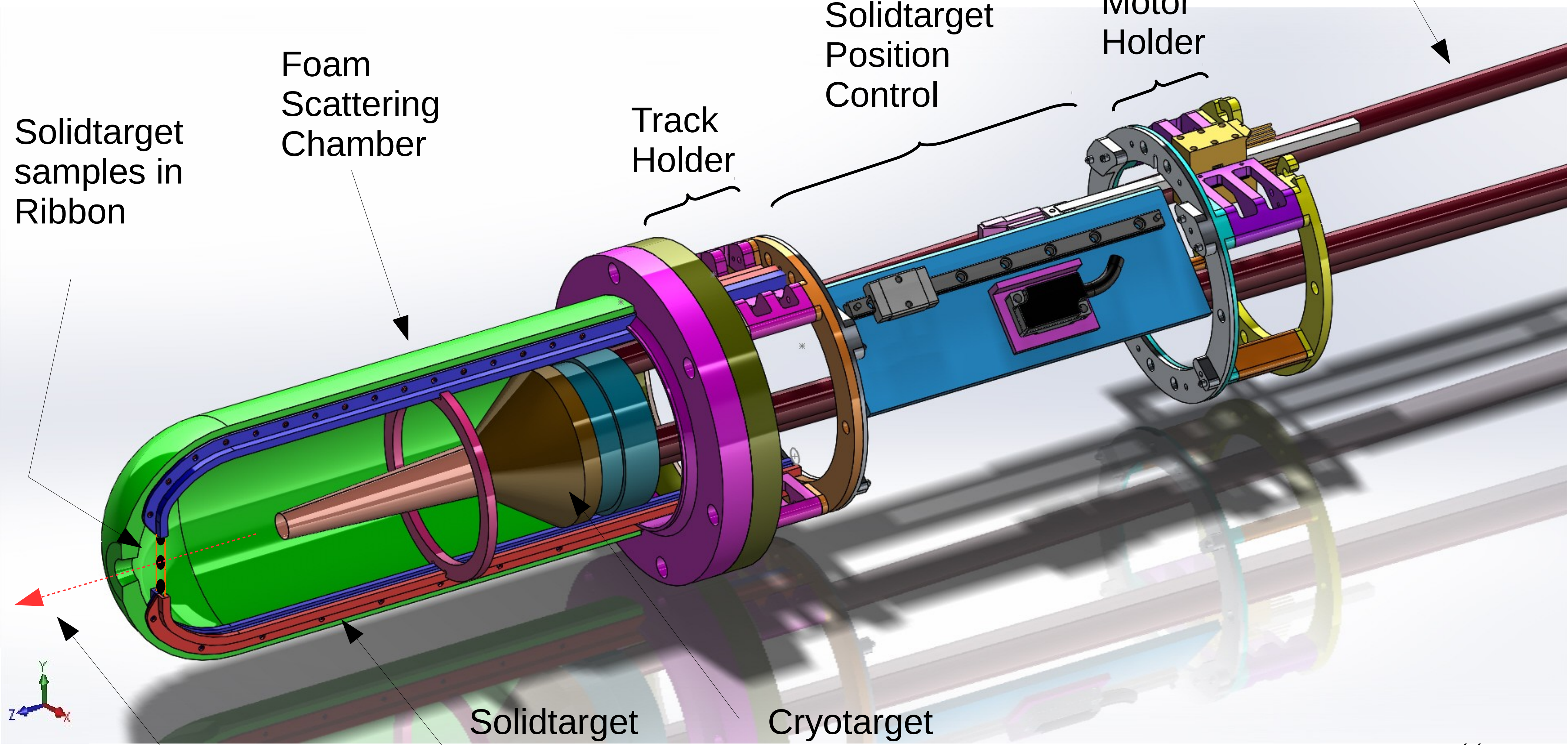
CLAS12 Acceptance for Baryons

Extreme Conditions for the New Target

- High Vacuum (6x10E-6 mbar) → low gas loads materials
- Magnetic Field (5 Tesla) → Non-magnetic materials
- Cryotarget (30 °K) → Low temperature resistant
- Radiation Hardness
- Reduced space

The problem to solve is to generate precise movement (<u>to exchange targets in a short period of time</u>) in these extreme conditions.

Full Assembly



USM Target Assembly

From RGM ERR: “It is believed that the present optical encoder design will not sustain the radiation environment” Changed to a resistive encoder

Position Control
Resistive encoder

Constant Tension spring
Included in the new resistive encoder

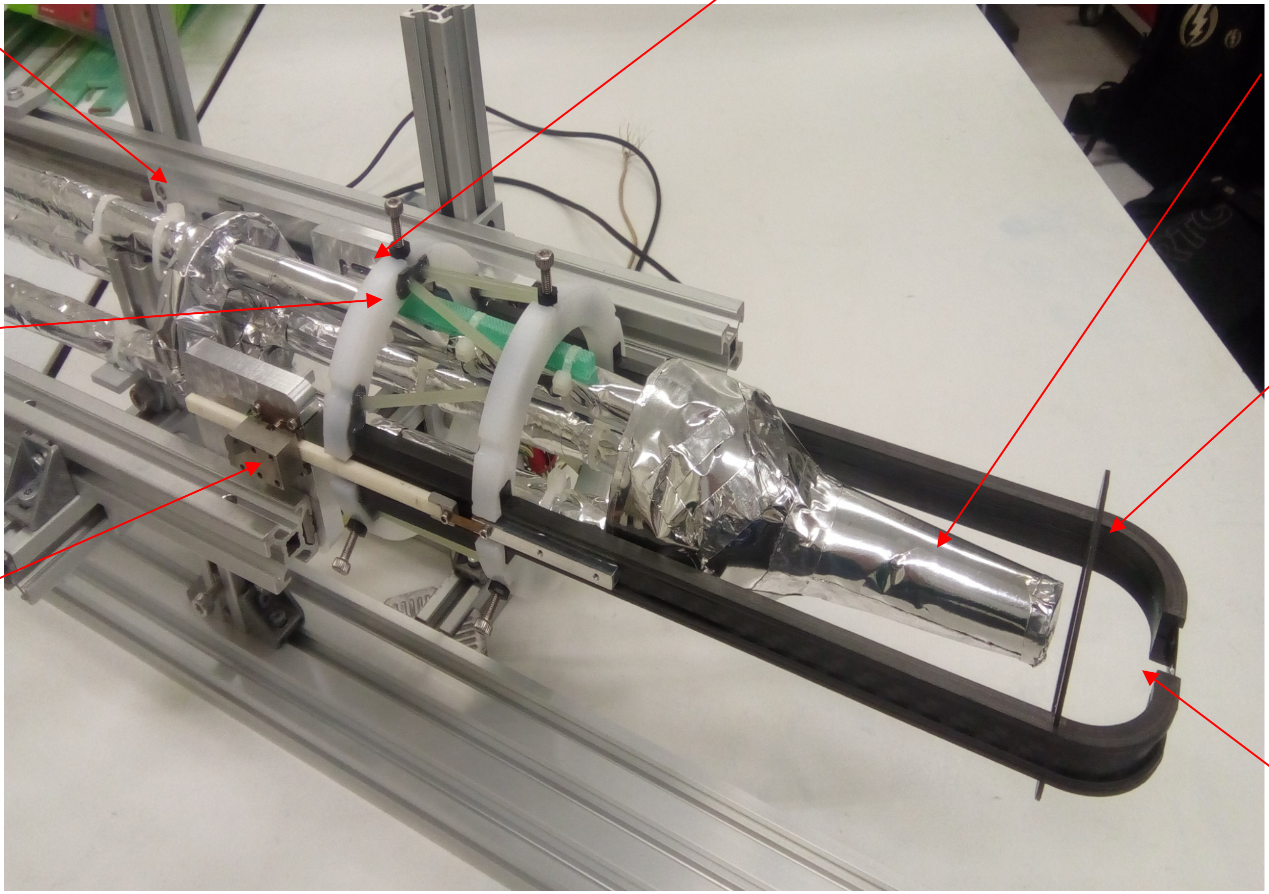
Hall-B cryo Target (1:1 model)

Ring Holders (spider)

Ribbon Track

Piezo Motor

Target holder (ribbon)



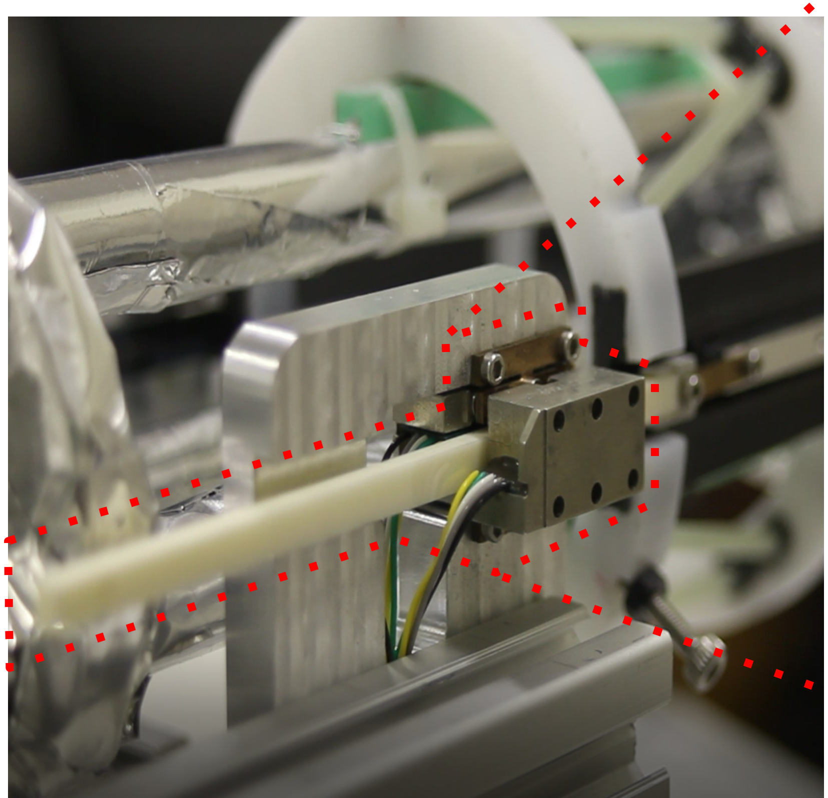
Solid Target System attached to the 1:1 model of the existing cryo target at Hall-B.

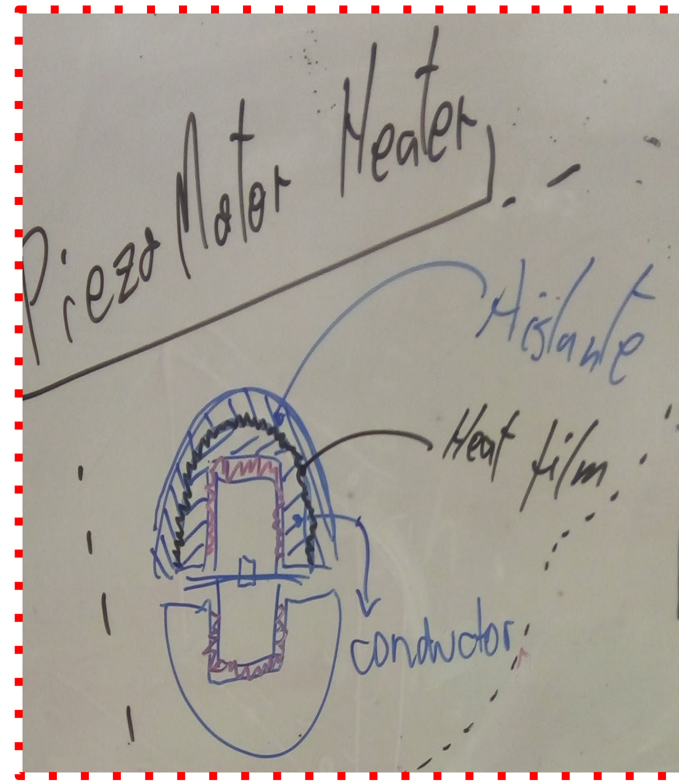
Piezo Motor

From RGM ERR: “Test how the Piezo motor and encoder are affected by in radiations and low temperatures”

Specs:

- Non magnetic materials
- Previously used at 5 Tesla
- For vacuum up to 10E-7 torr
- Operating temperature {-20 to +70°C}





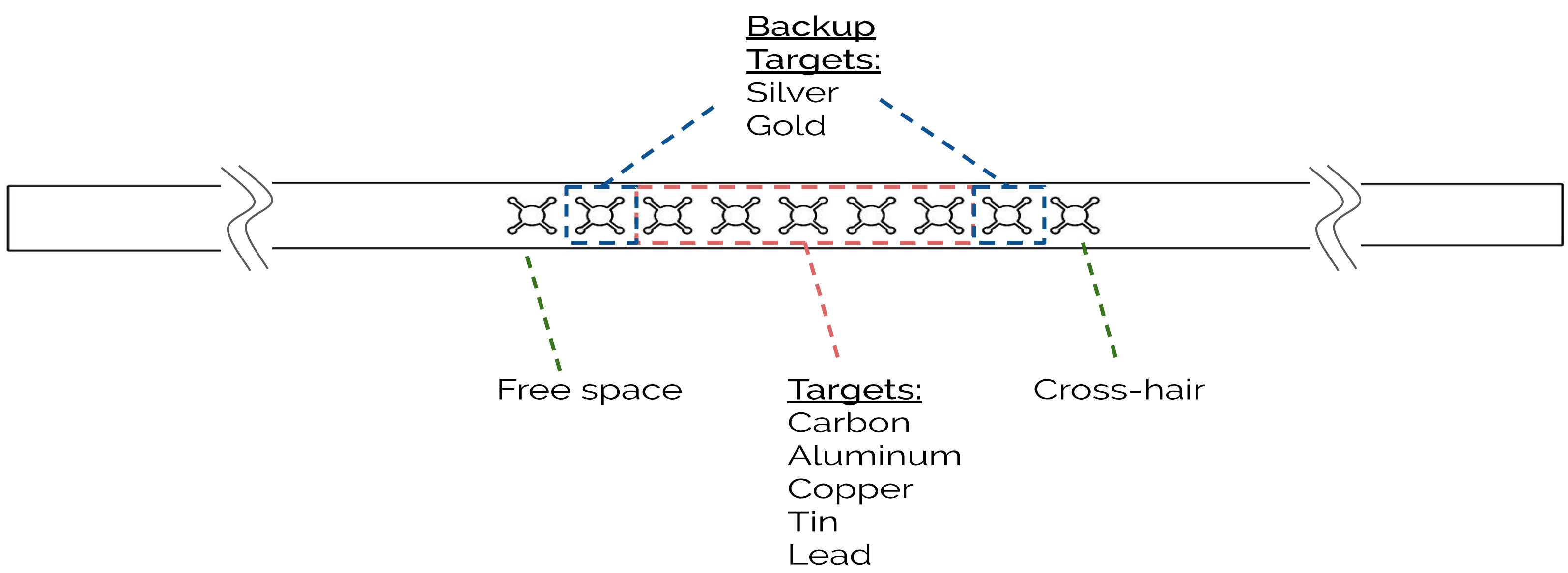
Film heater as option

Radiation hardness test

The solid targets are glued into the holes on this band. The band slides in a channel in the black outer holder, positioned by a piezoelectric motor. The radiation dose to that motor has been calculated by Lorenzo Zana, and it is well below the levels to which similar motors have been tested and found to continue operating, in published studies:

Radiation hardness tests of piezoelectric actuators with fast neutrons at liquid helium Temperature, CNRS-IN2P3-IPN Orsay, France

Target holder distribution



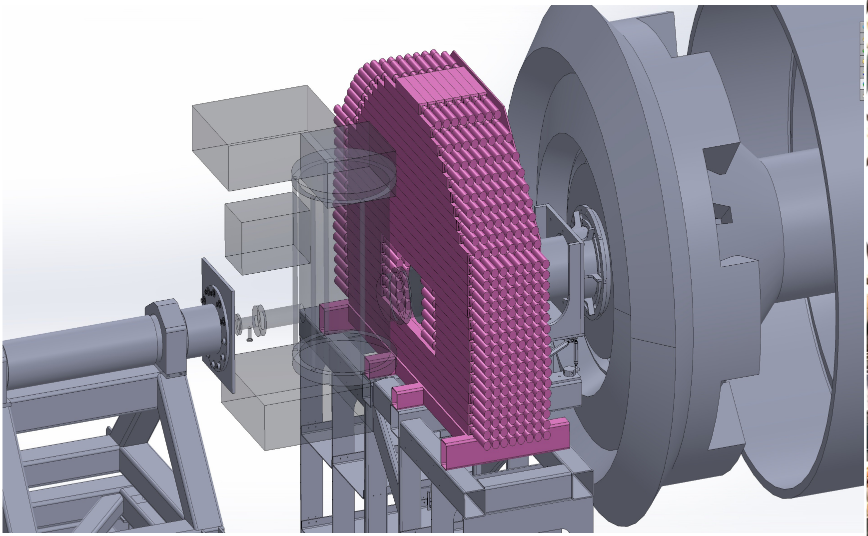
Radiation Hardness Test in the Hall-A

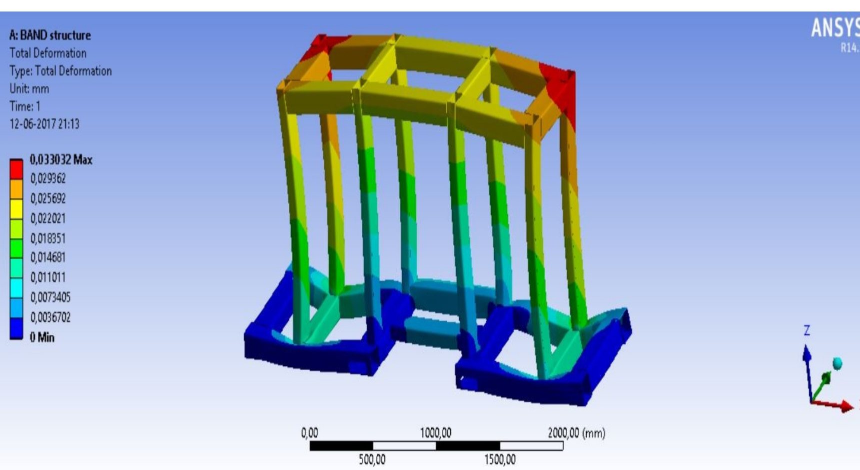
Double-Target

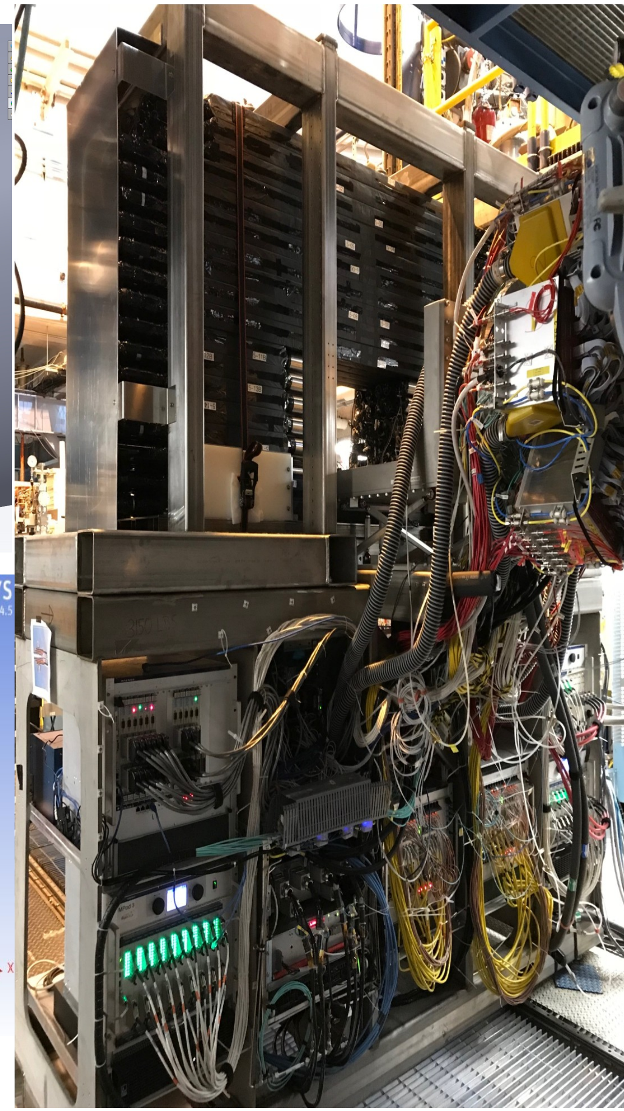
BAND (Back Angle Neutron Detector)

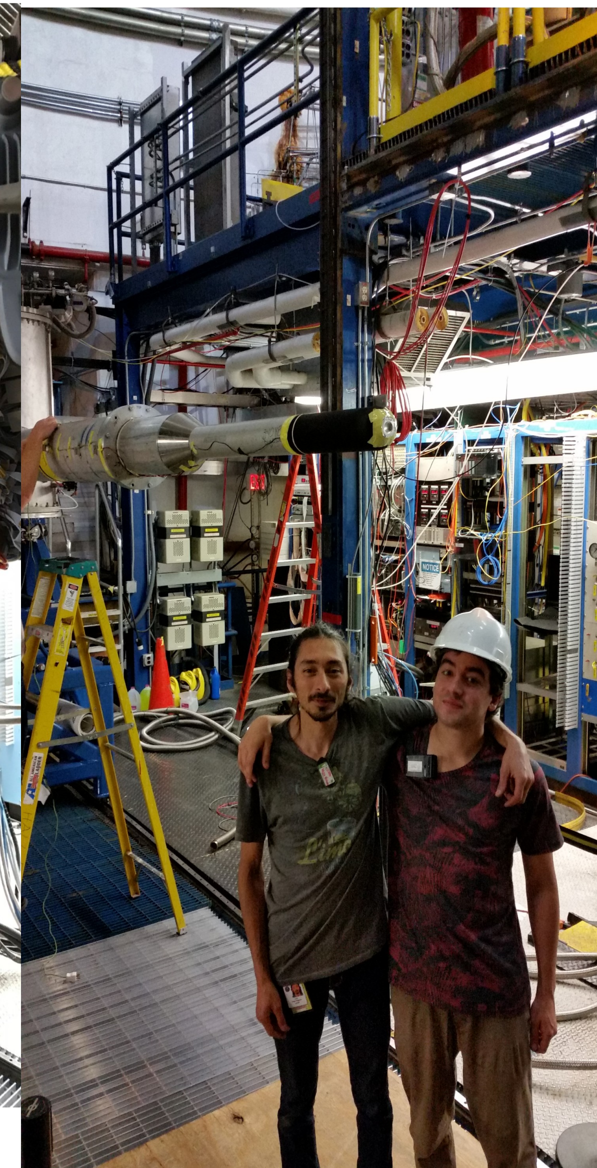
(Mechanical design by Iñaki Vega, Milan Ungerer)

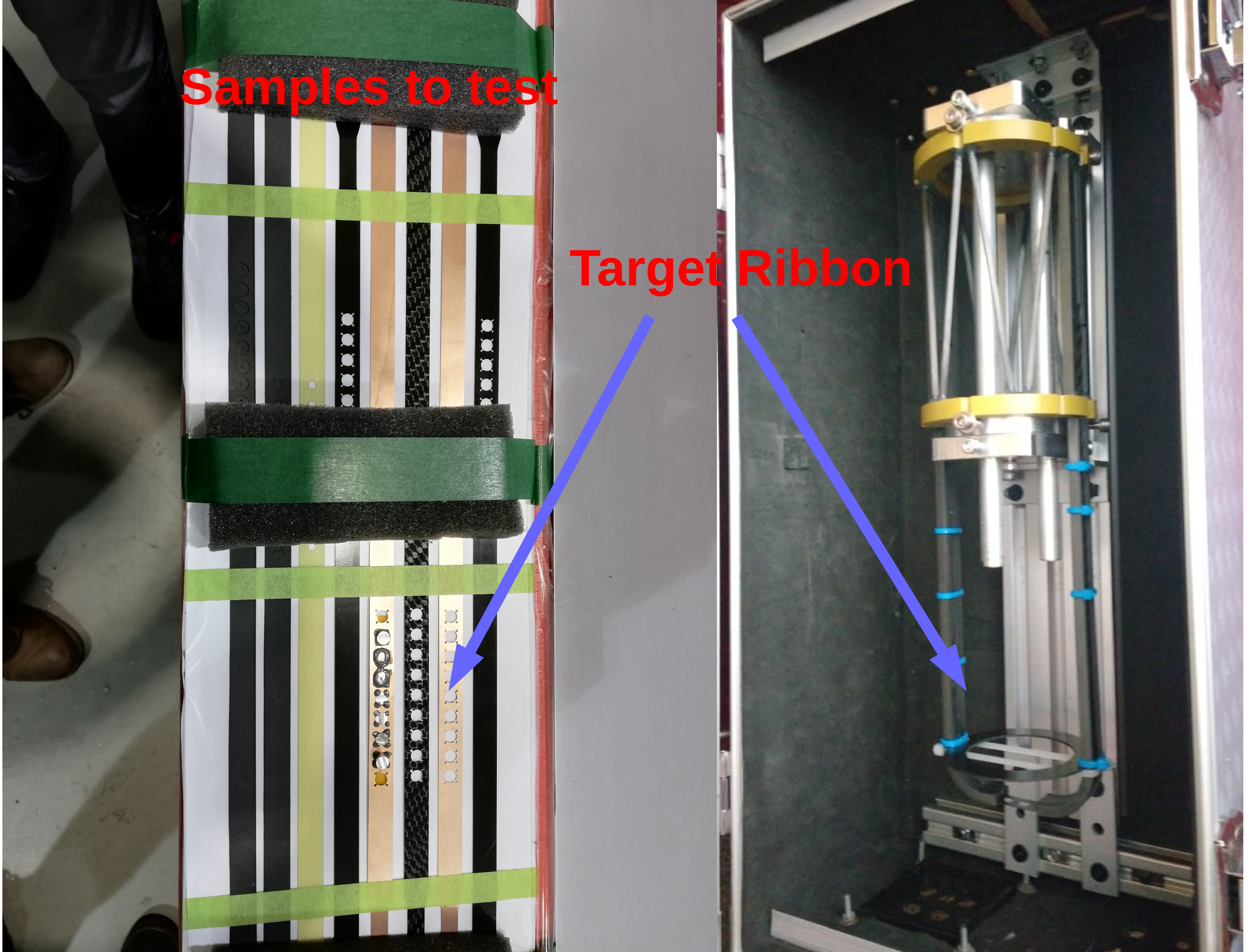
With colleagues from MIT, TAU & ODU



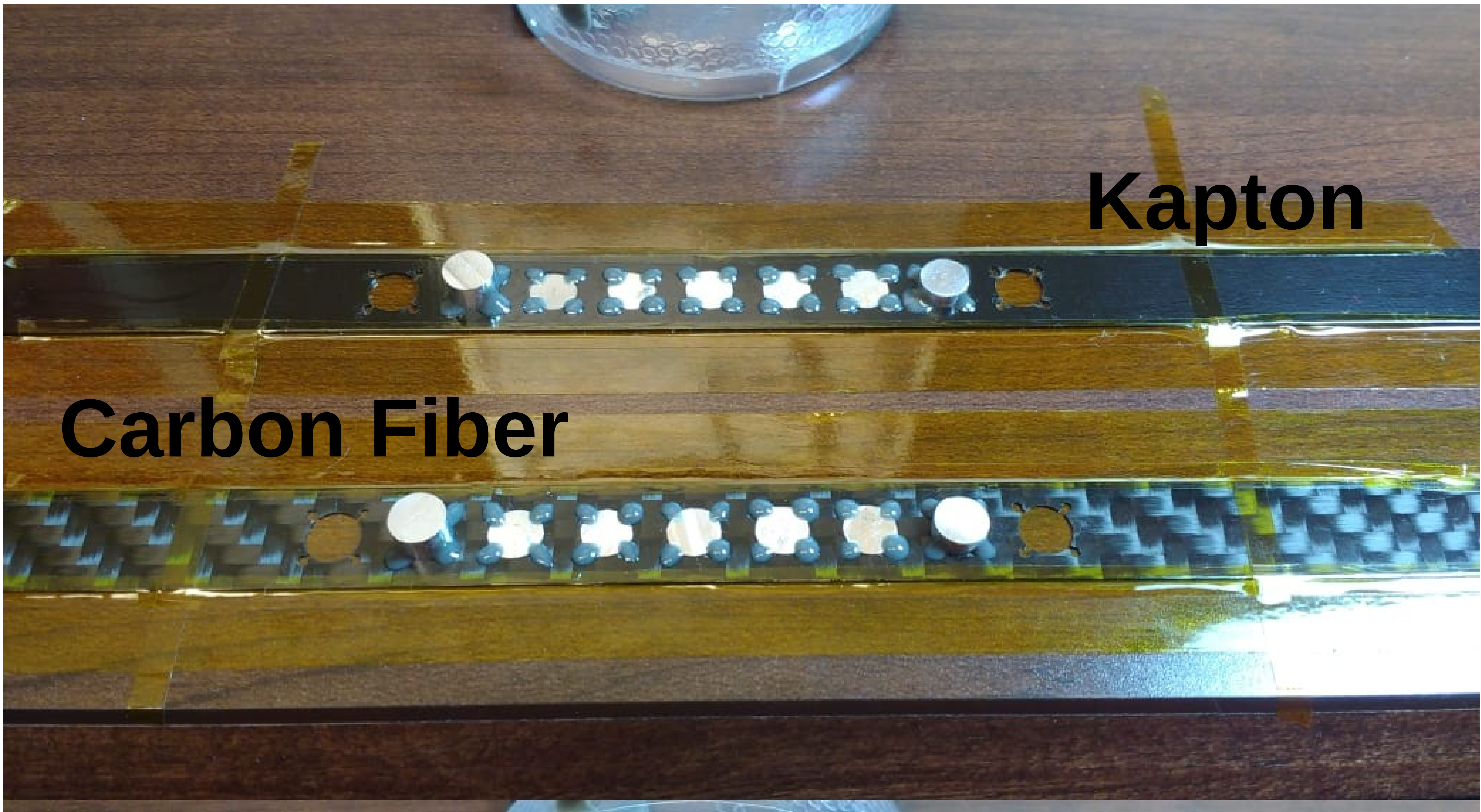







Samples to test
Target Ribbon

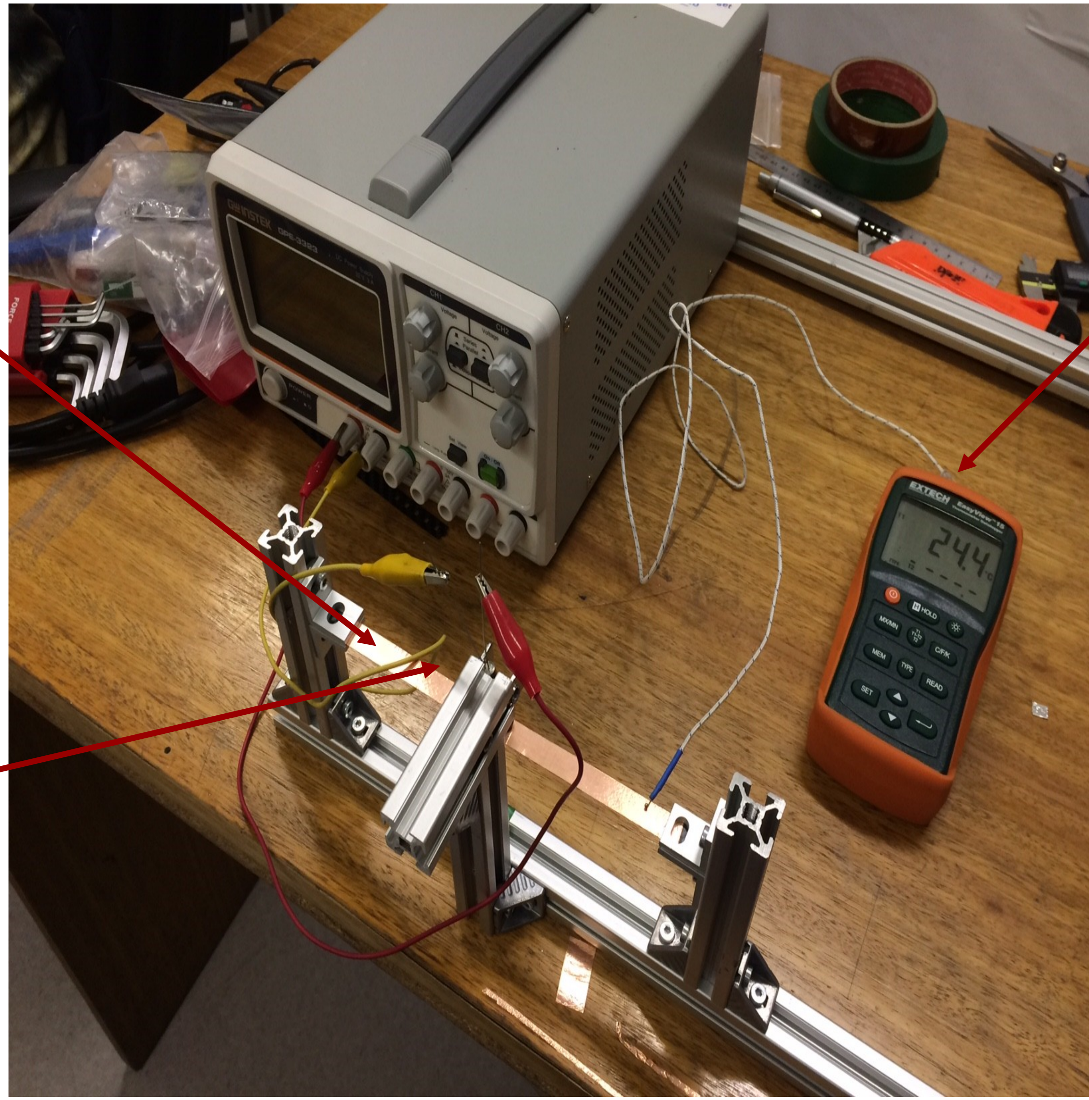
Target Ribbons with different size solid targets on



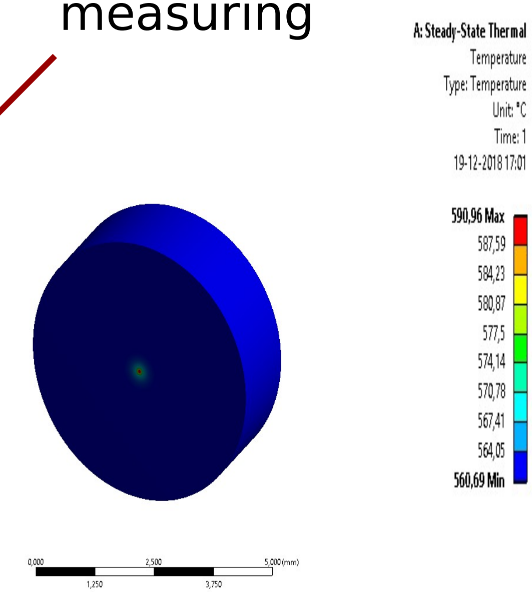
Thermal study-experimental setup

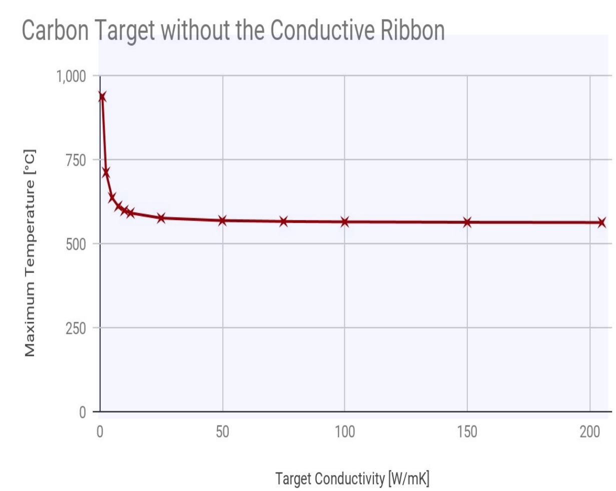
Bi-material Ribbon sample (Copper Polished)

Heater

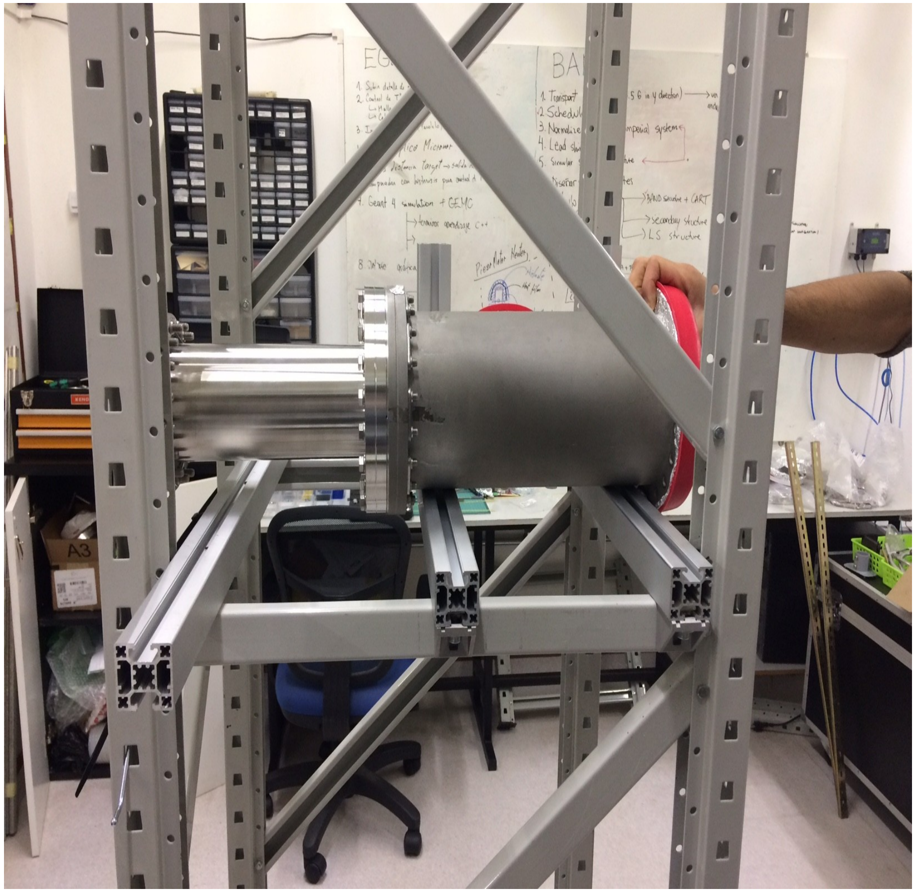


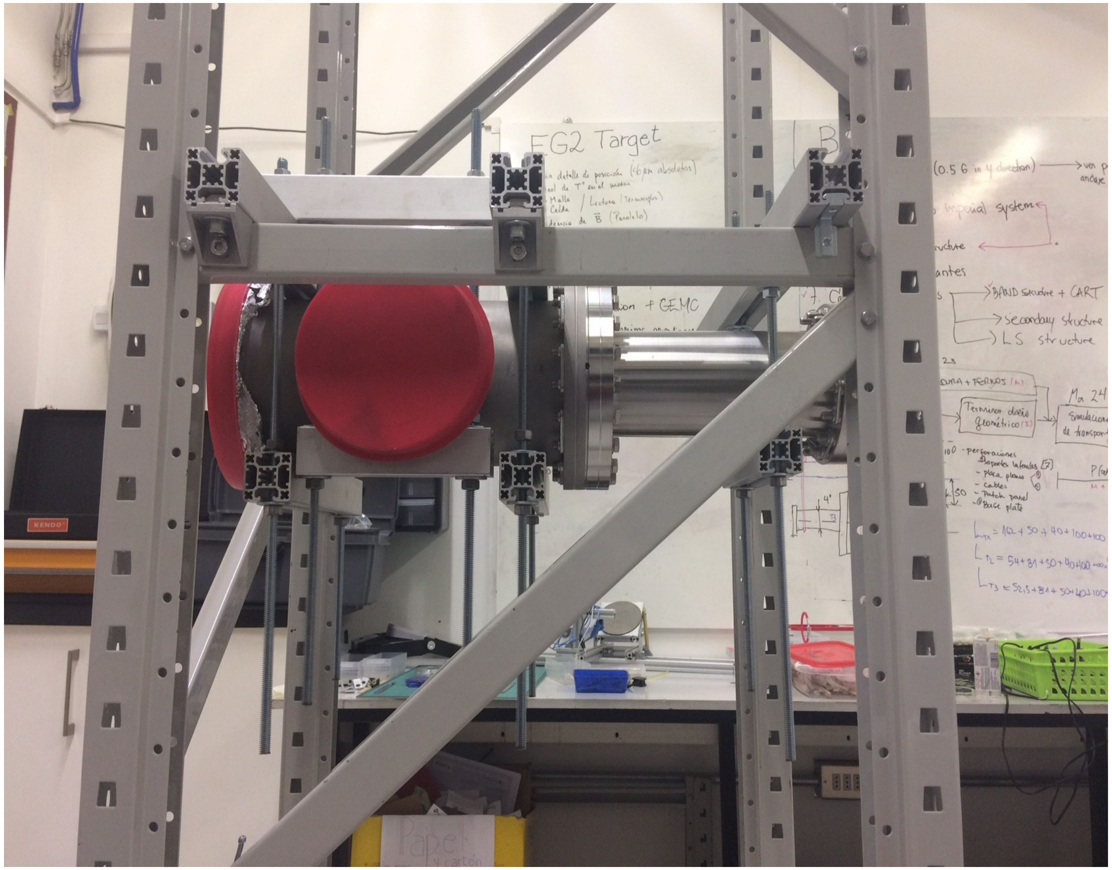
Temperature measuring





Vacuum test





Run Plan: (1-cm long deuterium cell)

Target	PAC days	Beam current (nA)	Luminosity ($/cm^2s$)	Backup target in case of melting
Commission	3	-	-	
Deuterium	4	32	1.00E+35	
Carbon	6	31	1.00E+35	
* Aluminum	7	45	1.00E+35	
Copper	8	83	1.00E+35	
Tin	15	72	6.00E+34	Ag; 83*0.60 = 50 nA
Lead	17	108	6.50E+34	Au; 99*0.65 = 64 nA
Magnets	60% field inbending electrons 90% of the time 60% field outbending electrons 10% of the time			

* to run the aluminum target days (7 PAC days) with RGD.

Conclusions!

CLAS experiment with double-target opened a large spectra of studies like:

- Nuclear Hadronization
- Color transparency
- Short range nuclear correlations
- Two hadron correlations
- EMC effect measurements
- Hadronic structure function measurements in nuclei
- Etc.

More is coming with new CLAS12 and new double-target!