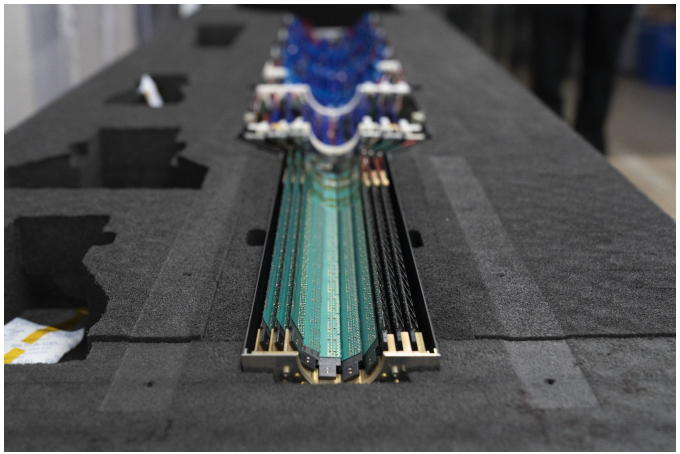
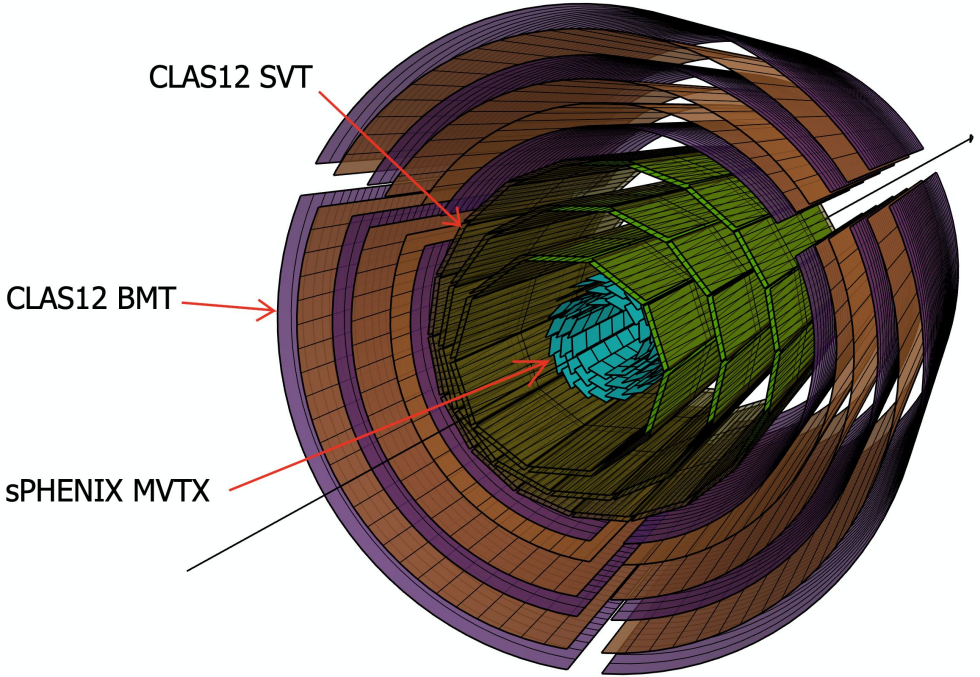
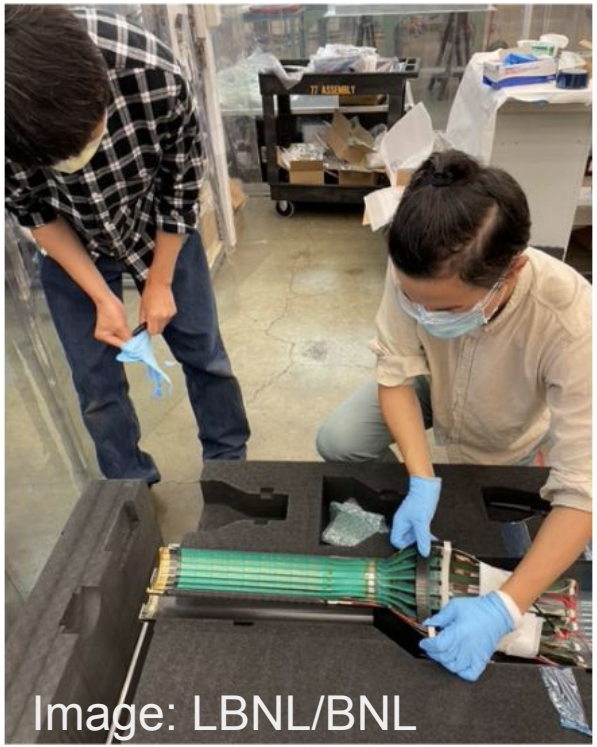
Open Charm Searches with CLAS12 + sPHENIX MVTX

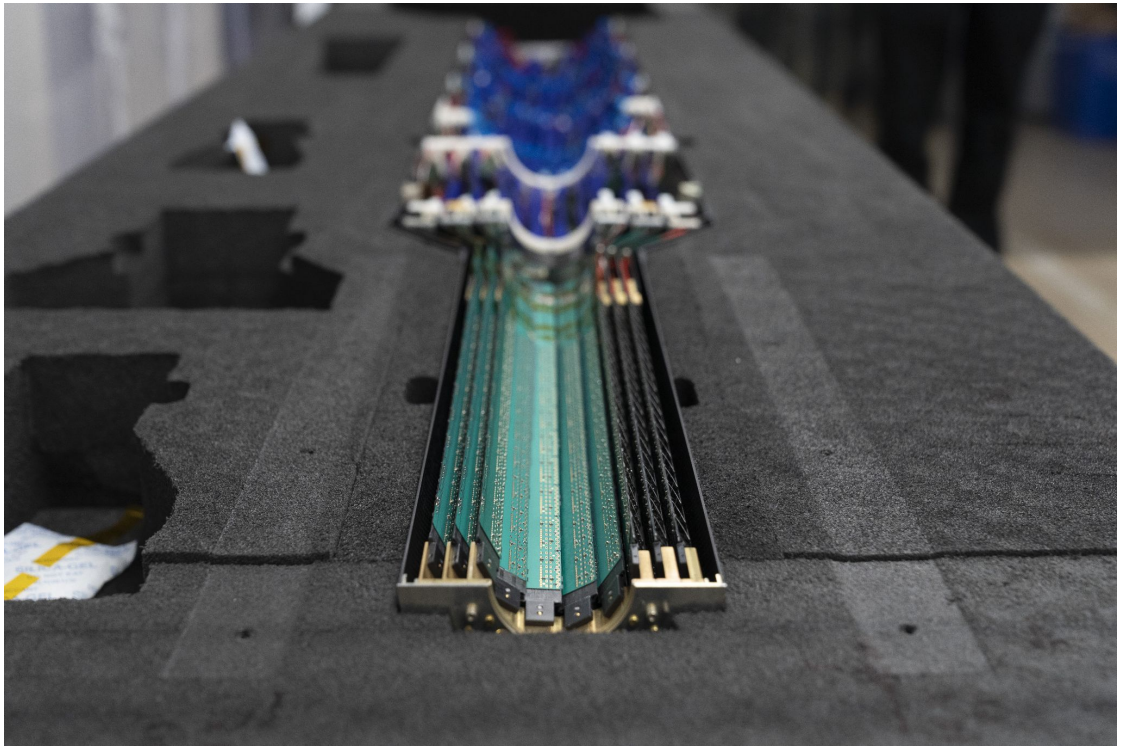
Miguel Arratia, UC Riverside





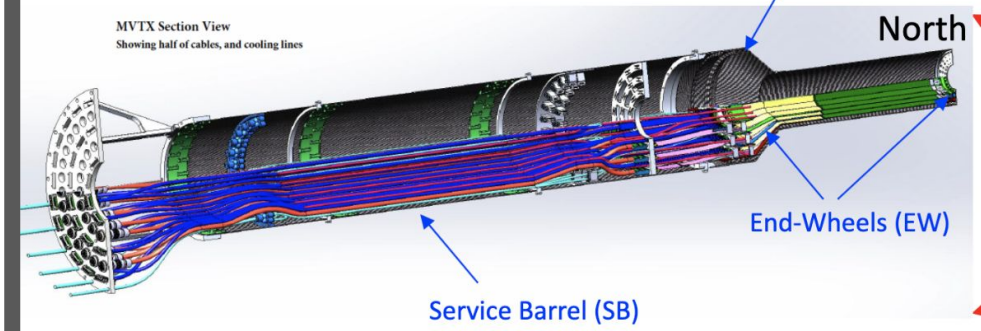
sPHENIX MAPS Tracker

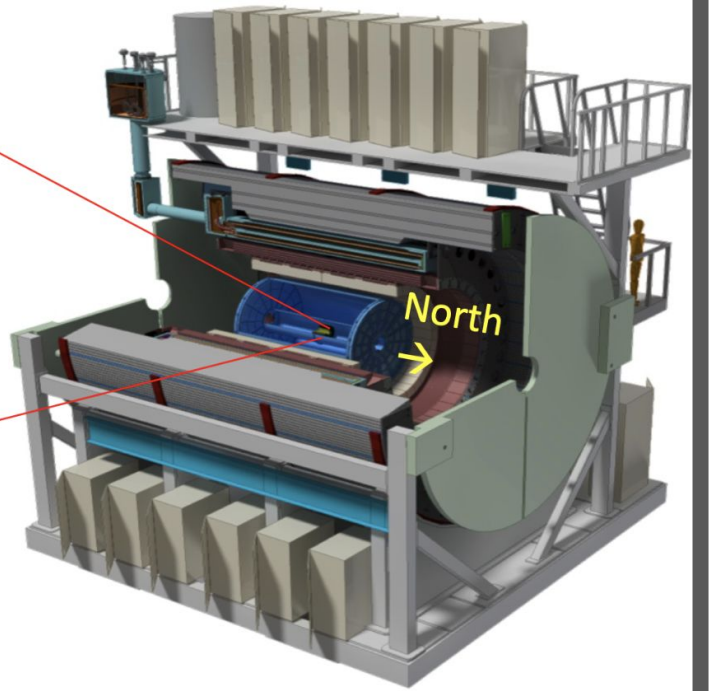




~$5M LRDR (LANL) + ~$5M DOE = ~$12M FY24

MVTX Detector – "Adapted" from ALICE ITS Design

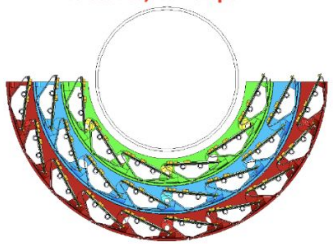




MVTX parameters: L = 271 mm

R (mm)	min	mid	max
Layer 0	24.61	25.23	27.93
Layer 1	31.98	33.35	36.25
Layer 2	39.93	41.48	44.26

3-layer sensor barrel
- 48 staves, 432 chips



Slide from M. Liu

The CLAS12 Central Vertex Tracker (CVT)

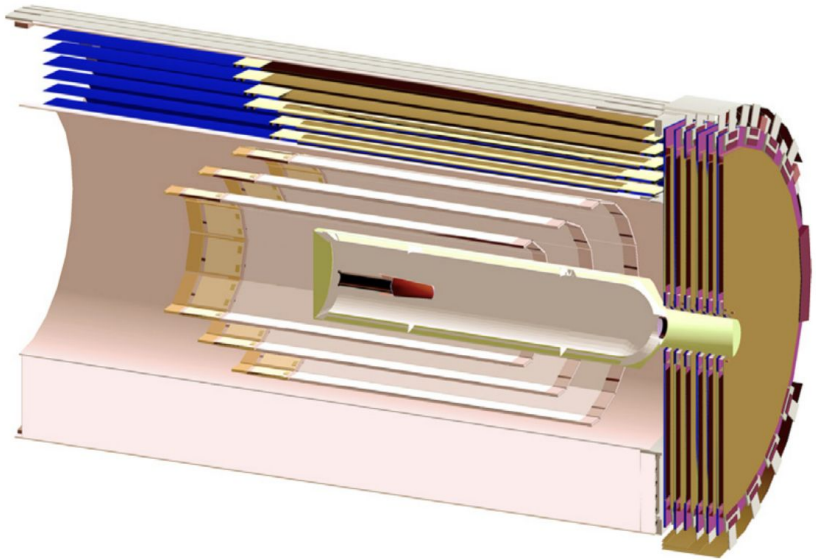


Fig. 27. Central Vertex Tracker schematic, showing (from the inside) the target cell and vacuum chamber, the 3 double layers of the SVT, followed by the 6 layers of the BMT. The beam enters from the left. The six FMT layers are shown at the downstream end at the right.

Space within SVT used by scattering chamber with liquid-deuterium cell

sPHENIX MVTX fits within CVT if vacuum chamber is removed

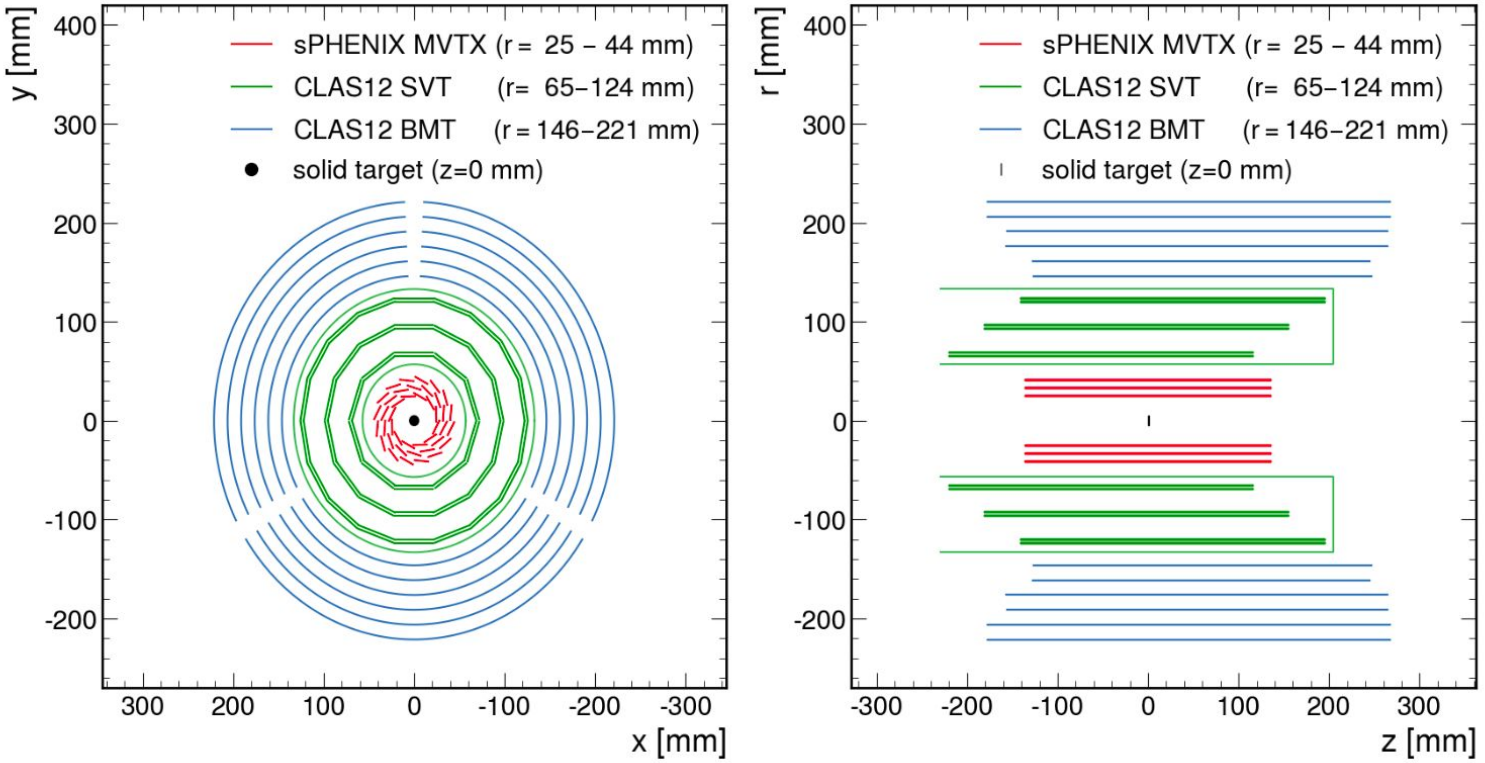
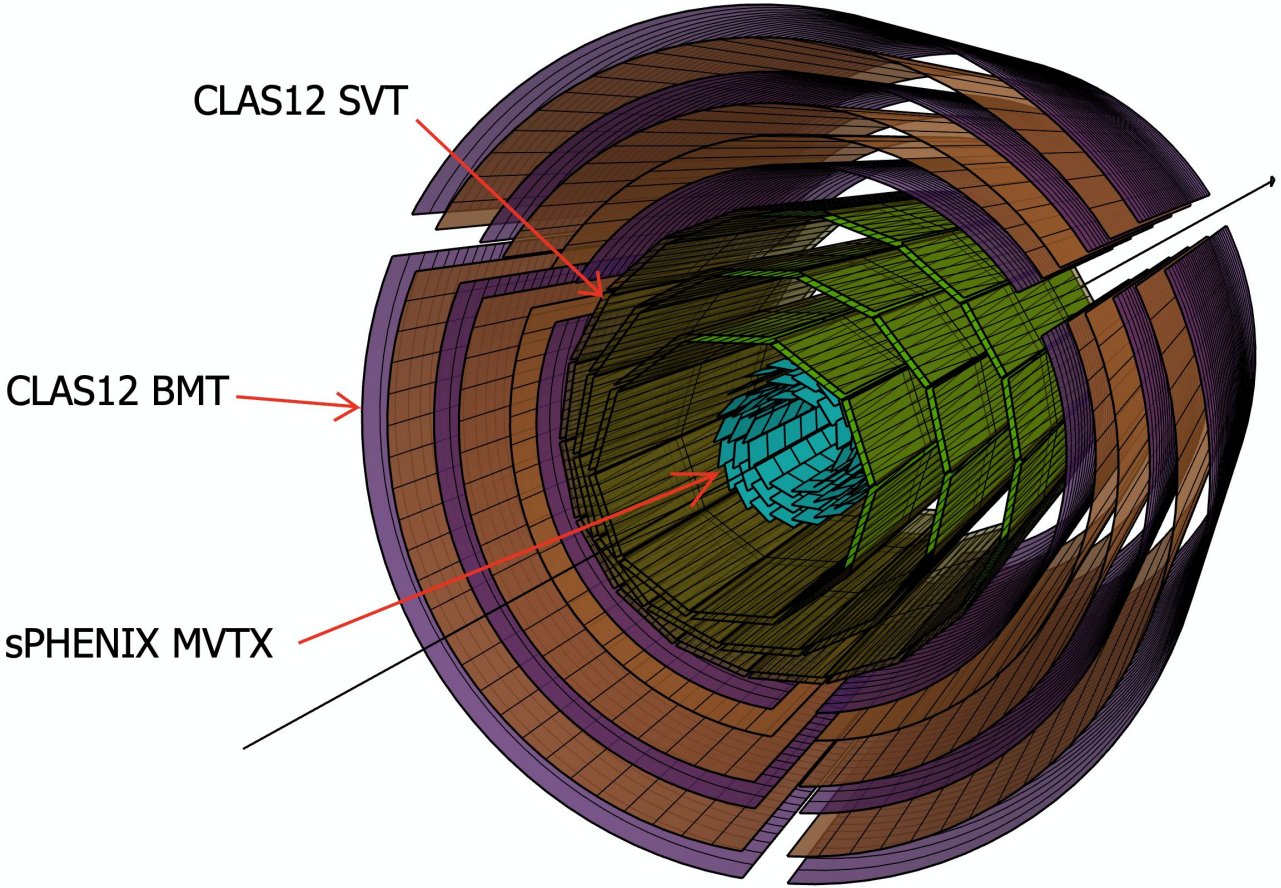


FIG. 5. Possible layout of the sPHENIX MVTX and the CLAS12 SVT and BMT. This configuration would be compatible with a solid-target.



Space of scattering chamber could be used by MVTX instead (with smaller, solid target)

Would it work?

- **Radiation damage:**
  Tested up to 2 Mrad. Will survive sPHENIX basically unscathed

- **Trigger rate:**
  Design to runs at 15 kHz max rate of sPHENIX, should be able to take CLAS12 DAQ rate, even in high-lumi scenario.

- **Occupancy:**
  Much higher in AA collisions than in fixed target experiment

Motivation for a pixel tracker: charm

D^0

$$I(J^P) = \tfrac{1}{2}(0^-)$$

Mass $m = 1864.83 \pm 0.05$ MeV

$m_{D^\pm} - m_{D^0} = 4.75 \pm 0.08$ MeV

Mean life $\tau = (410.1 \pm 1.5) \times 10^{-15}$ s

$c\tau = 122.9\ \mu$m

Hadronic modes with one $\overline{K}$

$K^-\pi^+$	(3.93 ± 0.04) %	S=1.2	861

Motivation for a pixel tracker: charm

Λ_c^+

$I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 2286.46 \pm 0.14$ MeV
Mean life $\tau = (201.5 \pm 2.7) \times 10^{-15}$ s (S = 1.6)
$c\tau = 60.4\ \mu$m

Λ_c^+ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Hadronic modes with a p or n: $S = -1$ final states			
pK_S^0	(1.59± 0.08) %	S=1.1	873
$pK^-\pi^+$	(6.28± 0.32) %	S=1.4	823

I. MOTIVATION FOR OPEN-CHARM PRODUCTION AT THRESHOLD

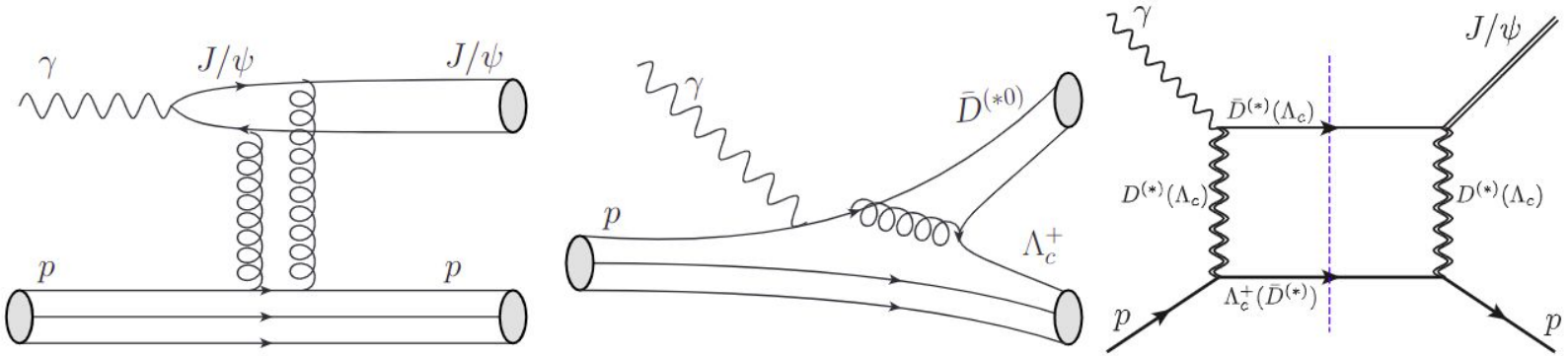
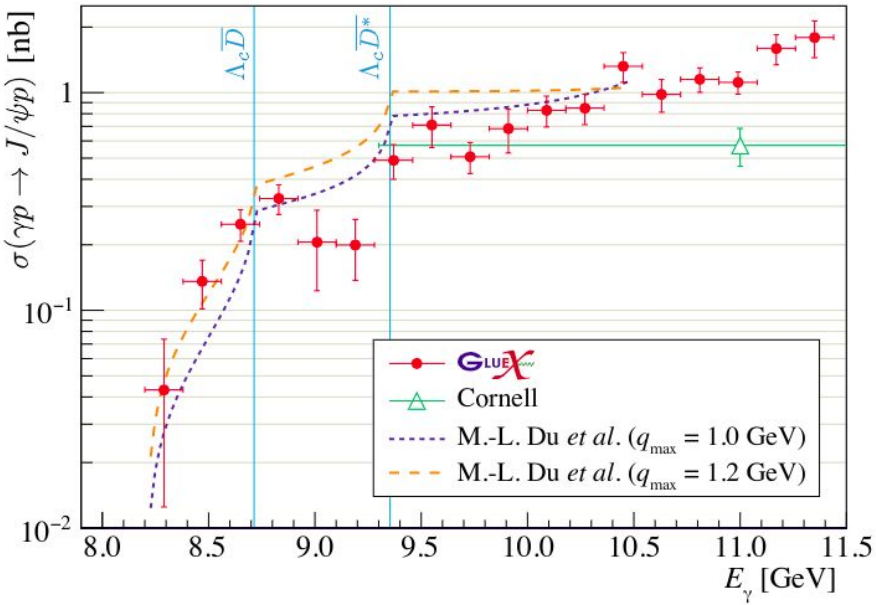


FIG. 1. Left: J/ψ production mechanism as per the vector-dominance model. Middle: Open-charm production mechanism. Right: J/ψ production mechanism through charm-exchange box diagram suggested by Du et al. [1]. Source: Ref. [1].



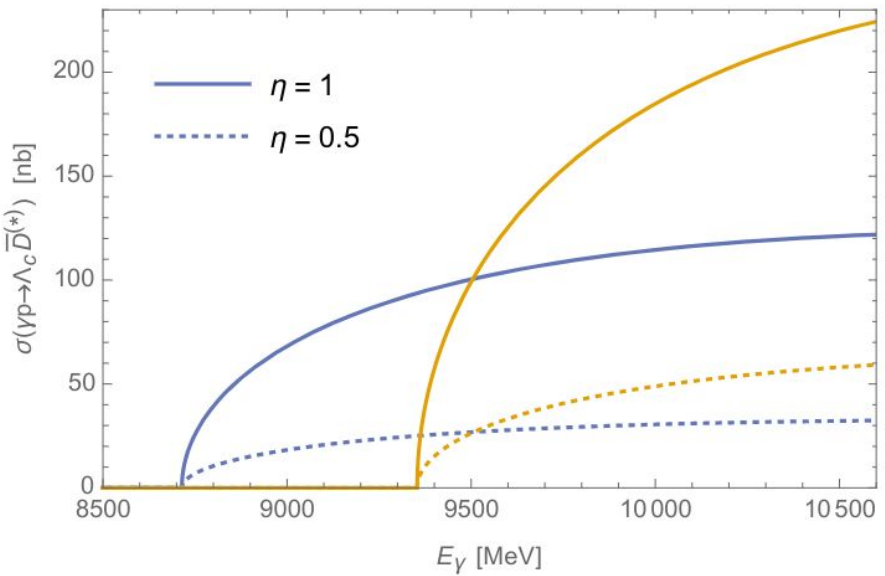
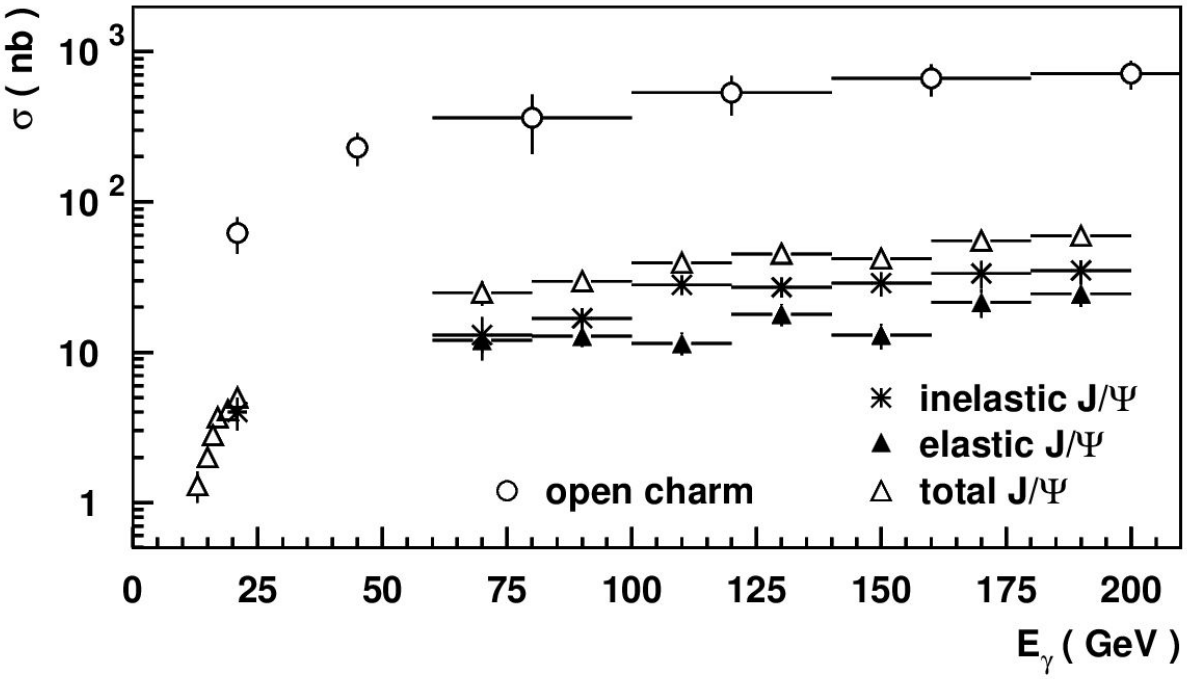


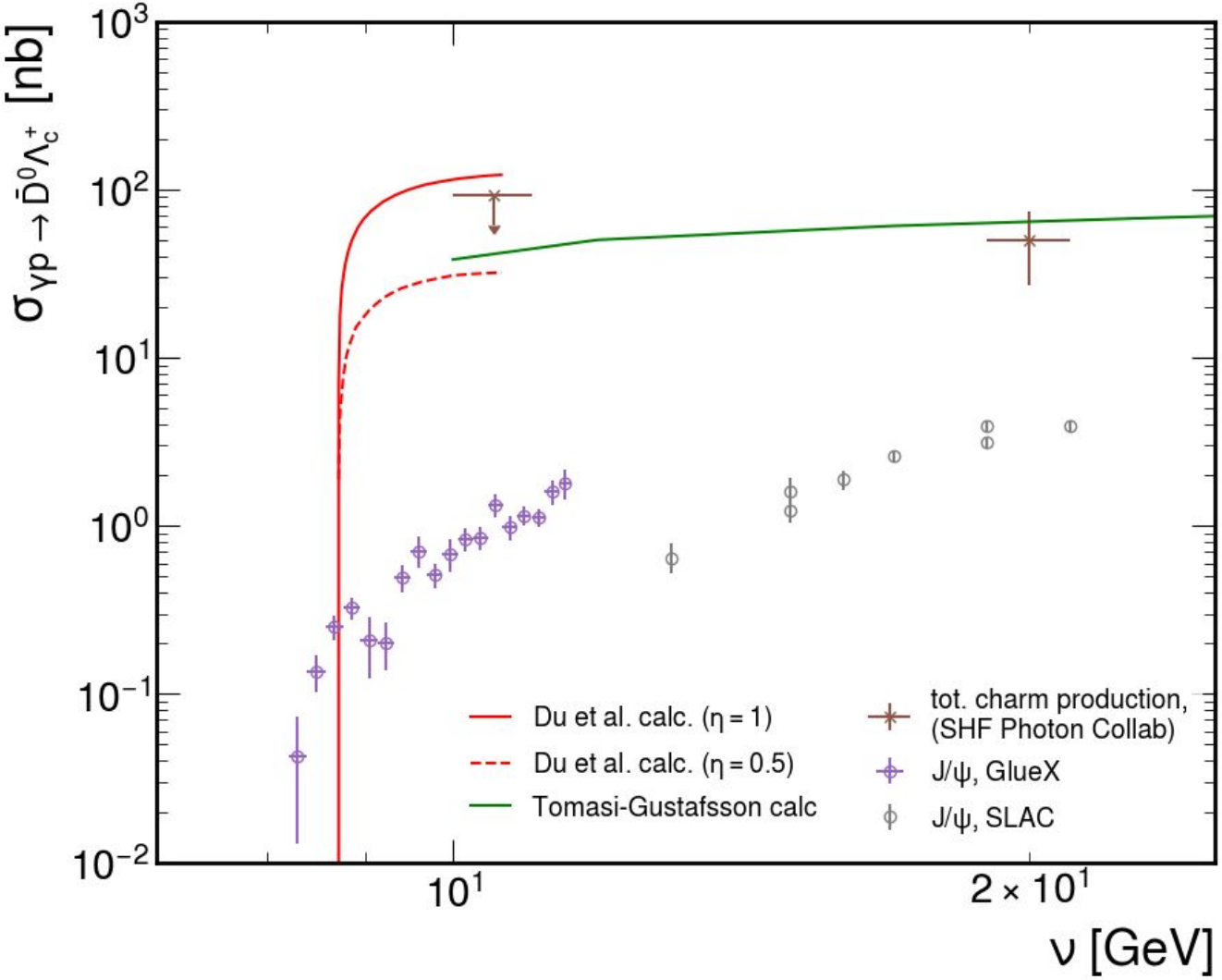
FIG. 2. Left: GlueX measured J/ψ photoproduction near the threshold, with vertical lines indicating the threshold energy for production of $\bar{D}^0\Lambda_c$ and $\bar{D}^*\Lambda_c$. The curves represent predictions by Du et al. [1]. Source: Ref. [2]. Right: Du et al. predictions for open-charm production near the threshold, indicating two scenarios depending on the model parameter η. Note how the open-charm cross-section is predicted to be one or two orders of magnitude higher than the J/ψ cross-section. Source: Ref. [1].

Cross-section for open charm is much larger than for J/psi



https://inspirehep.net/literature/553290

Figure 3.1: *Cross-sections for the photoproduction of charm quark pairs as a function of the photon energy E_γ separately for particles with open and hidden charm. Shown are data from* EMC *[*EMC*:83a,* EMC*:83b],* SLAC *[A⁺:86, C⁺:75a], and* PEC *[A⁺:87].*


$\sigma_{\gamma p \to \bar{D}^0 \Lambda_c^+}$ [nb]
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^1
2×10^1
ν [GeV]
Du et al. calc. ($\eta = 1$)
Du et al. calc. ($\eta = 0.5$)
Tomasi-Gustafsson calc
tot. charm production, (SHF Photon Collab)
J/ψ, GlueX
J/ψ, SLAC

Vox Populi

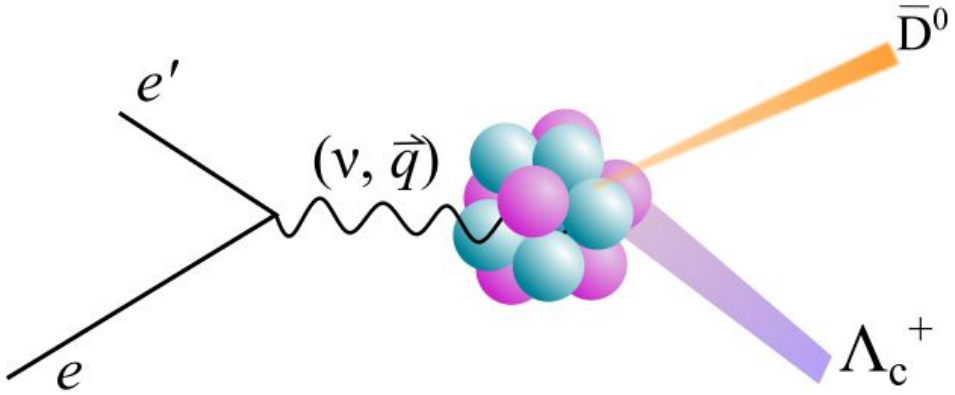
"Since the strength of the cusps is connected to the rate for $\gamma p \to \bar{D}^0 \Lambda_c$, we also provide an estimate for the expected rate into the open-charm channels....measurements of the $\bar{D}\Lambda_c$ production will provide crucial information". Du et al. [21].

"It is thus crucially important to constrain model parameters with further measurements in order to disentangle the possible physics scenarios and their implications...the measurement of open-charm photoproduction is needed to assess the role of coupled channels. A simultaneous analysis of the $\gamma p \to J/\psi$ and $\gamma p \to \bar{D}^0 \Lambda_c$ cross sections would provide a stringent constraint on the coupled channel dynamics. Based on the best fit parameters extracted here, we expect a large open-charm cross-section $\gtrsim$ 10 nb. Furthermore, studies of photoproduction off nuclear targets may give further constrain on the total J/ψ-nucleon cross-section." Winney et al. (JPAC Collaboration) [22].

Motivations, for Open-Charm in heavy nuclei

- *What are the differences in hadronization of quarks versus gluons and of light quarks versus **heavy quarks**?*
- *How does hadronization change in a dense partonic environment?'*

2023 LRP



Moreover, D+/D- pairs ***subthreshold*** should be possible for nuclei, probing gluon SRC
In analogy to https://arxiv.org/abs/1911.11706

HERMES studies

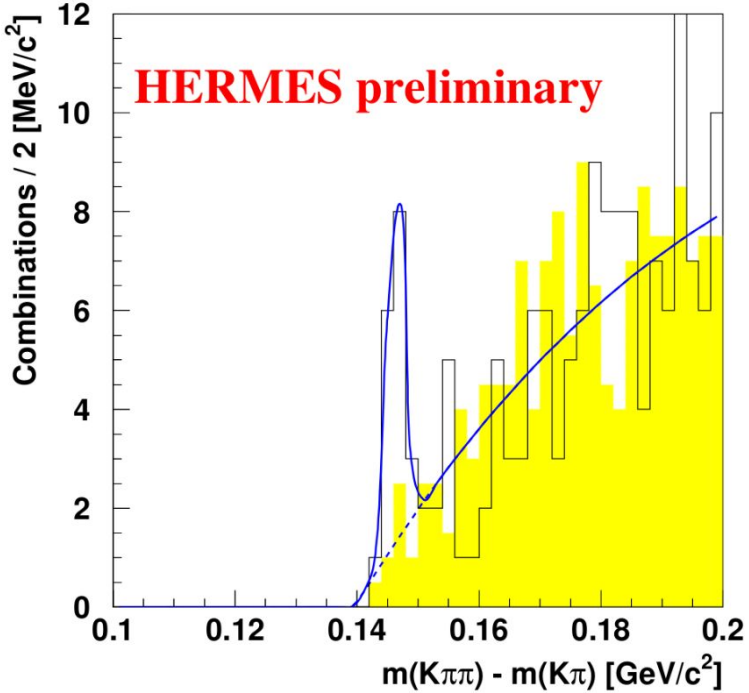


FIGURE 6. Missing mass spectrum $M(K\pi\pi) - M(K\pi)$ for the process $D^\star \to D^0(\to K\pi)\ \pi$ together with a background estimate (shaded) from the D^0 side bands.

DESY-THESIS-2001-002 (UNPUBLISHED)

been performed. To allow a comparison with these measurements, the electroproduction cross-section has been converted into a total open charm photoproduction cross-section for a photon energy of $E_\gamma = (15.5 \pm 1.0)$ GeV

$$\sigma^{\gamma p \to c\bar{c}X} = \left(87.9\ ^{+40.7}_{-32.1}\,\text{stat} \pm 9.2\,_{\text{syst/exp}} \pm 17.6\,_{\text{syst/frag}}\right)\ \text{nb}\,.$$

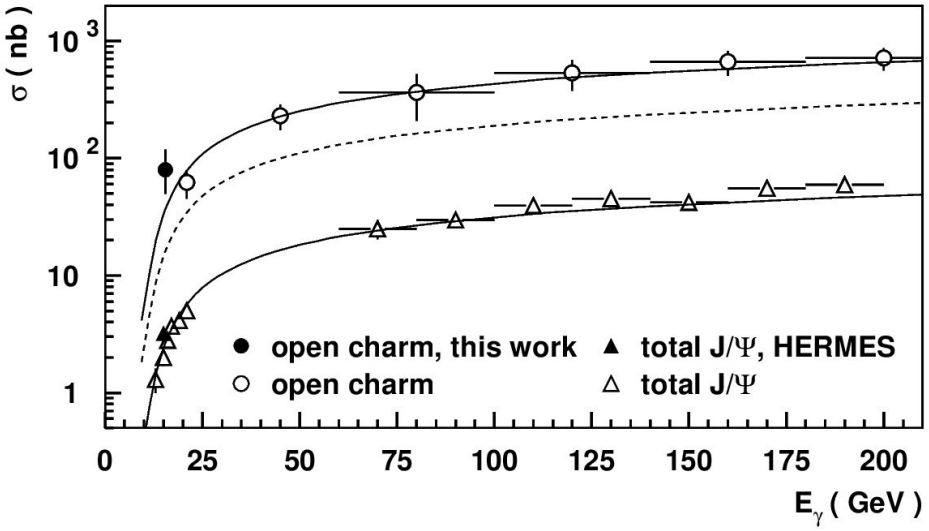
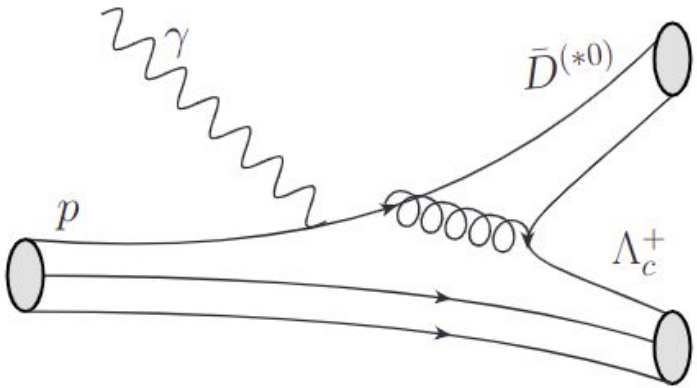


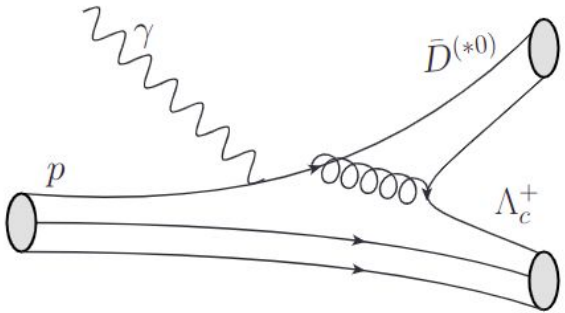
Figure 7.1: *Cross-sections for the photoproduction of charm quark pairs as a function of the*

Studies with CLAS12



Kinematics of D→Kπ

Estimated from phasespace generator



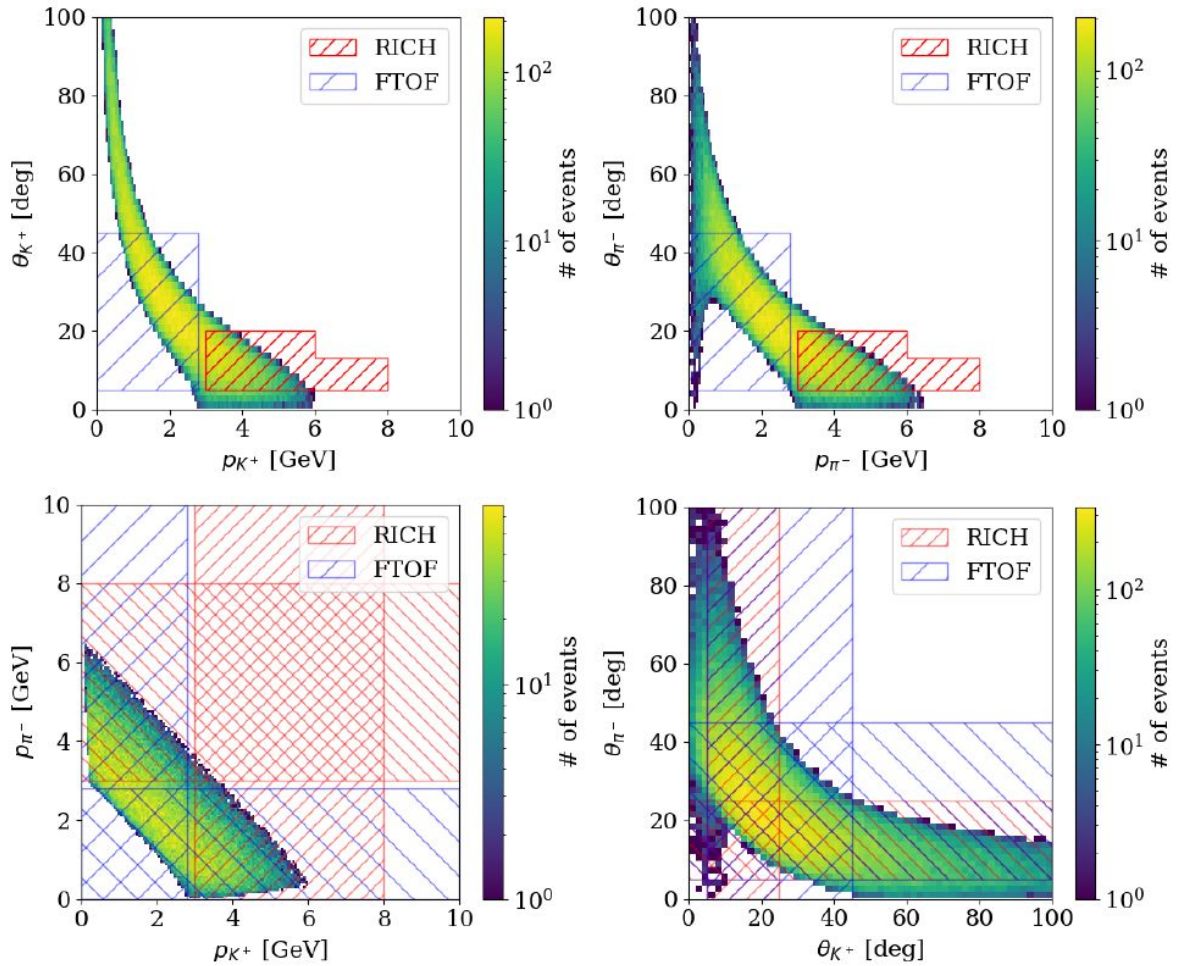
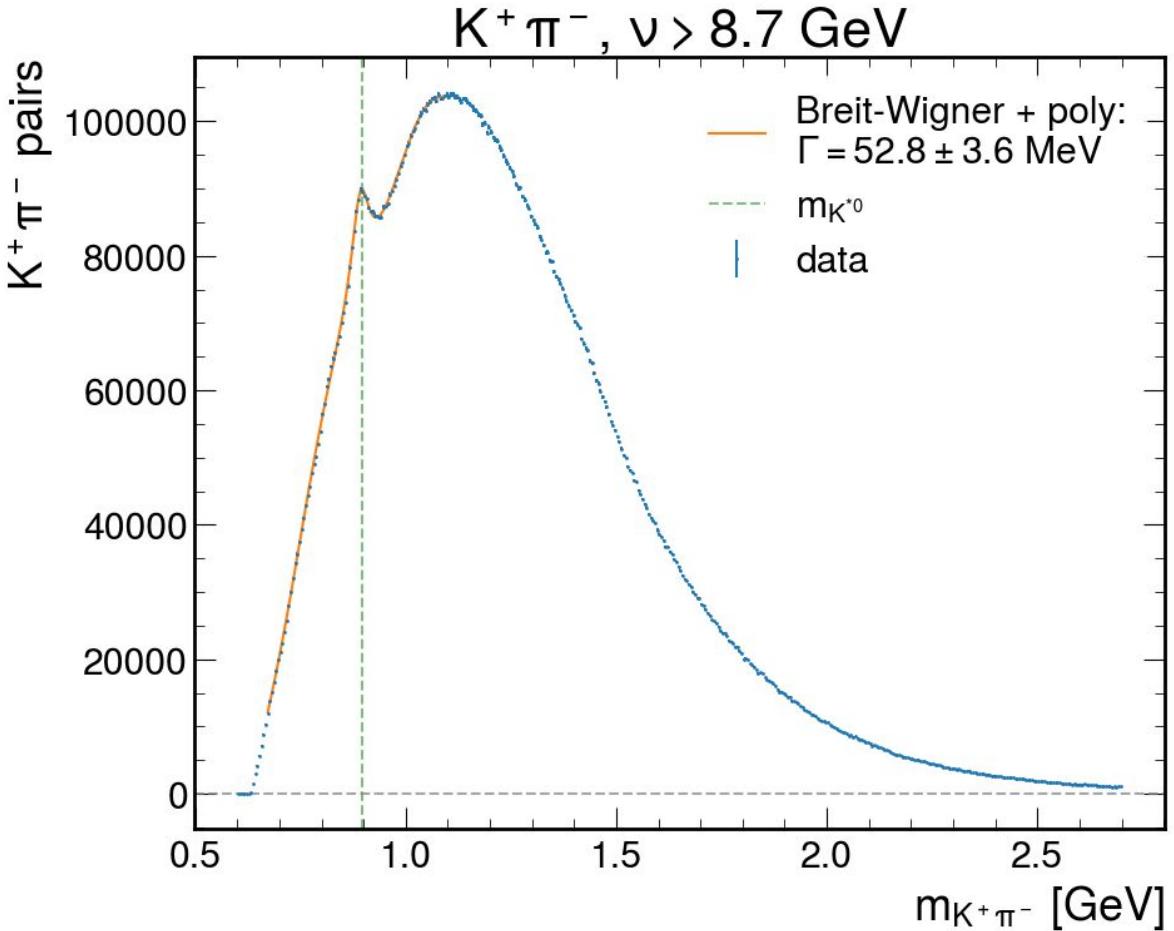


FIG. 3. Kinematics of the generated decay products of the $\bar{D}^0$. Top left: p_K vs θ_K. Top right: p_π vs θ_π. Bottom left: p_K vs p_π. Bottom right: θ_K vs θ_π. The acceptances of the RICH and FTOF are shown in red and blue respectively.

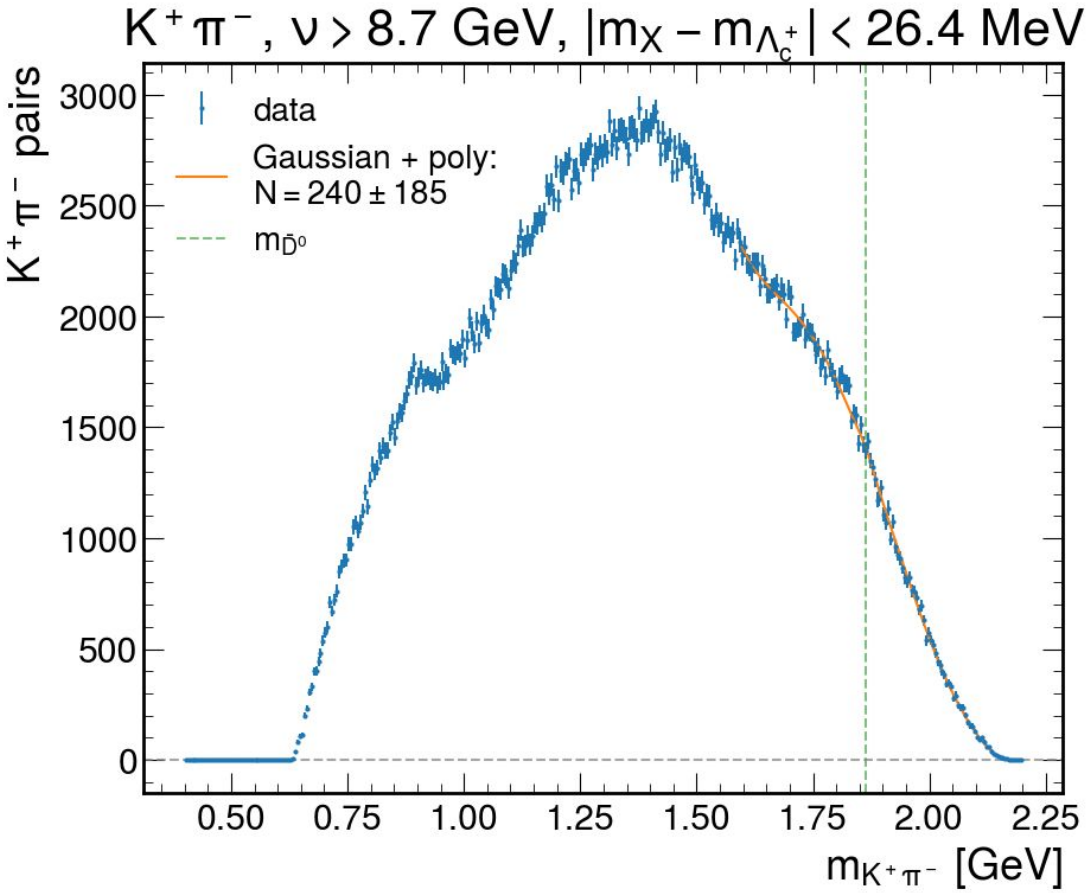
A peek at RGA data with FT



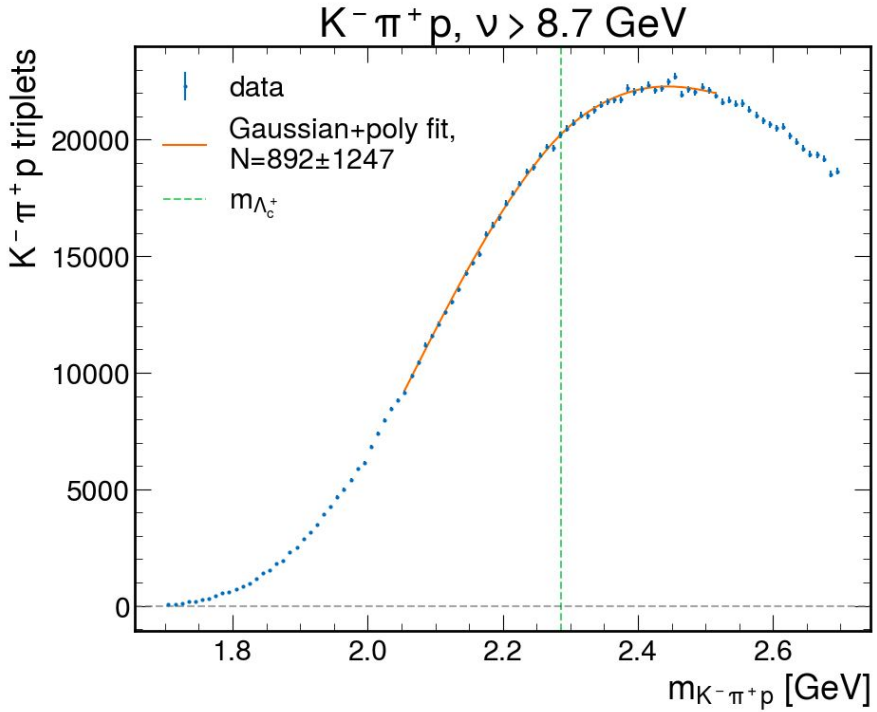
From K*0 pdg:

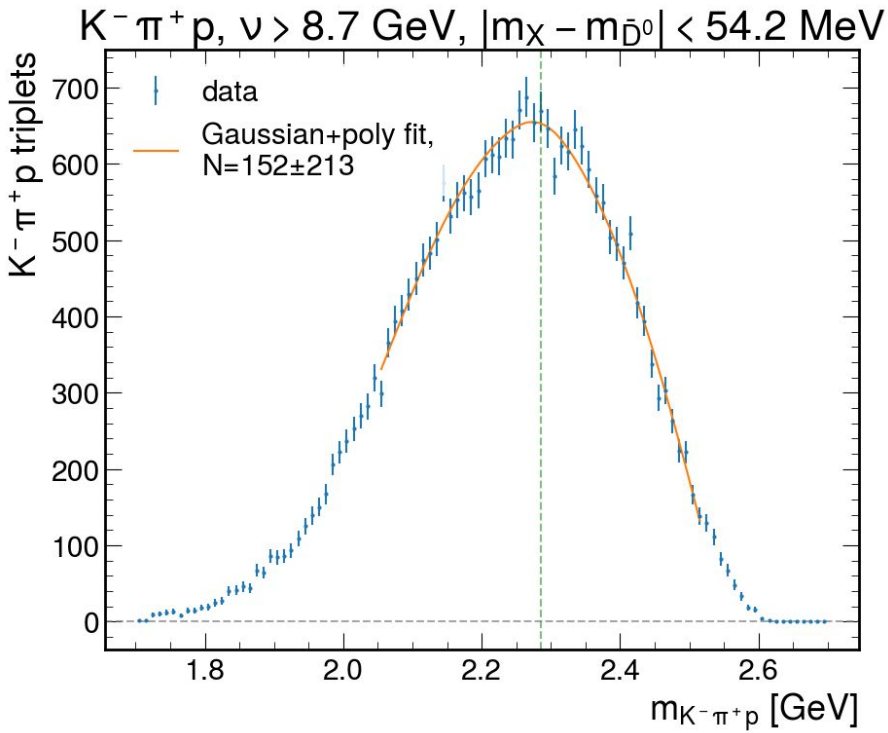
- M=895.81±0.19 MeV
- width=47.4 ±0.6 MeV

Adding missing mass selection

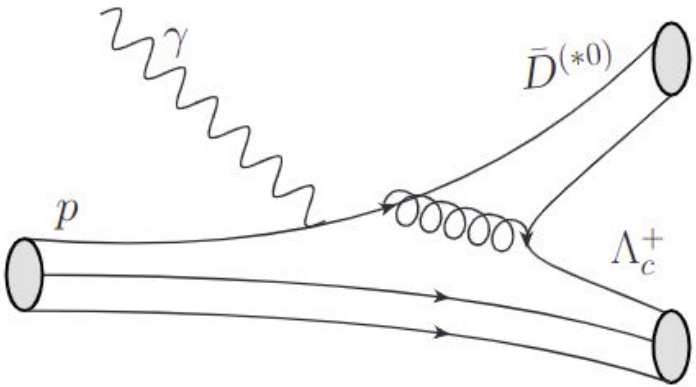


Seach for Lambda_c -> Kppi





Thoughts after initial peek at CLAS12 data



No visible peak using PID only, so far.

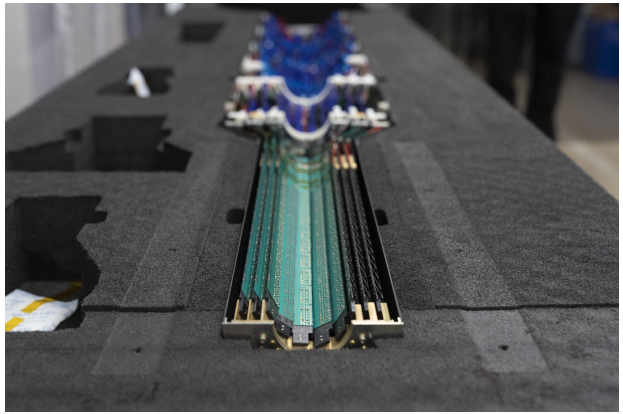
Perhaps signal is overwhelmed by background

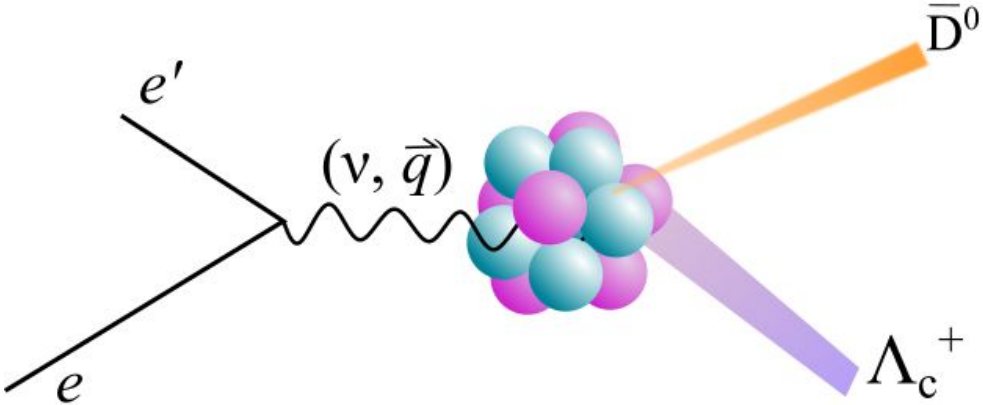
Perhaps displaced vertex analysis with MVTX could help

Summary:

Proposal: Reuse PHENIX MAPS tracker to open new “open-charm” program at CLAS12
- Science case is compelling and timely for multiple reasons
- No technical showstopper identified so far.
- Key stakeholders are onboard and interested, including PI M. Liu (LANL)
- Some work would be needed to adapt services, integrate readout.

Plan: This year we will submit a LOI.
Next year will include GEMC simulations and refined projections.



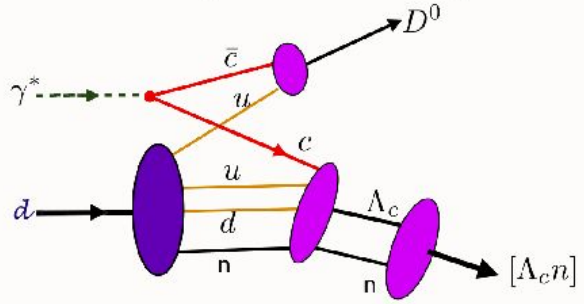


Backup

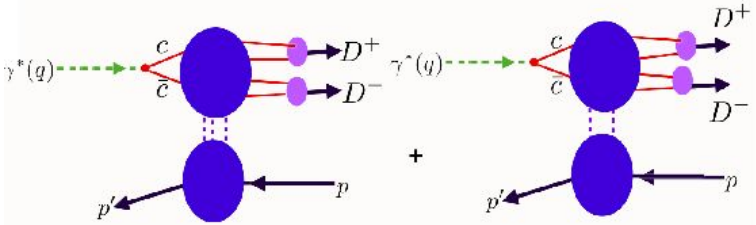
Brodsky

Open Charm Production at Threshold

Nuclear binding at low relative velocity



$$\gamma^* d \to \overline{D}^0(\bar{c}u)[\Lambda_c n](cududd)$$



Odderon-Pomeron Interference leads to D^-D^- and B^+B^- charge and angular asymmetry

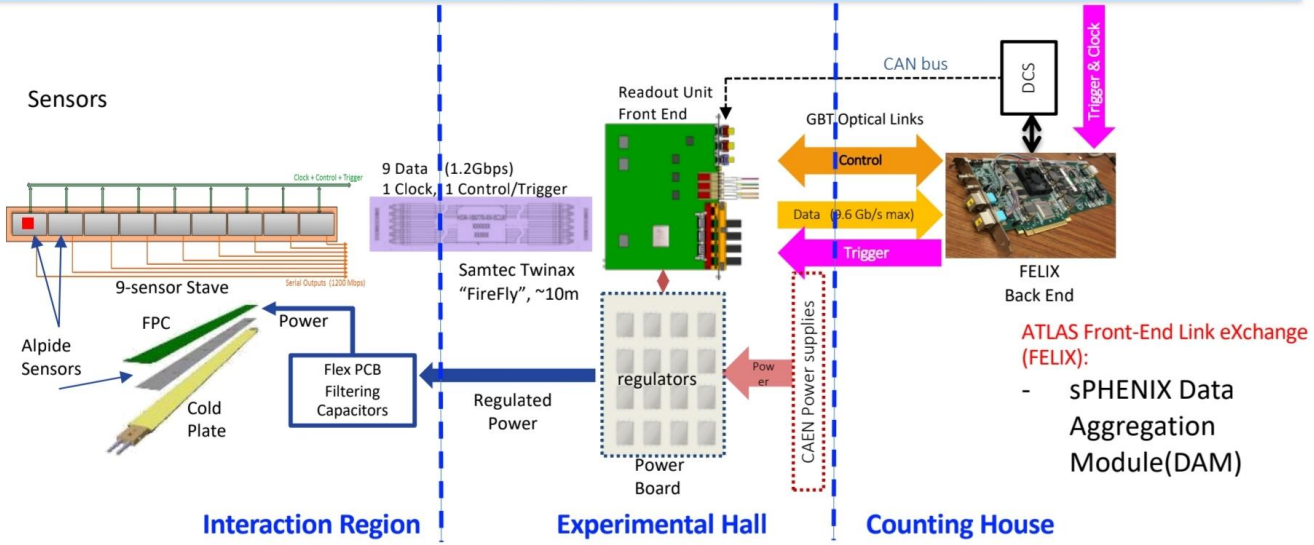
Odderon at amplitude level

Strong enhancement at heavy-quark pair threshold from QCD Sakharov-Schwinger-Sommerfeld effect

$$\frac{\pi\alpha_s(\beta^2 s)}{\beta}$$

enomenology measureable at JLAB-12 GeV

All Sensors and Readout Electronics Tested



84 staves in production at CERN complete in 2020

60 RUs produced; PUs ready for production

8 FELIX to be produced with TPC in 2020

Slide from M. Liu