Double Deeply Virtual Compton Scattering in Hall C

(brief updates on this project)

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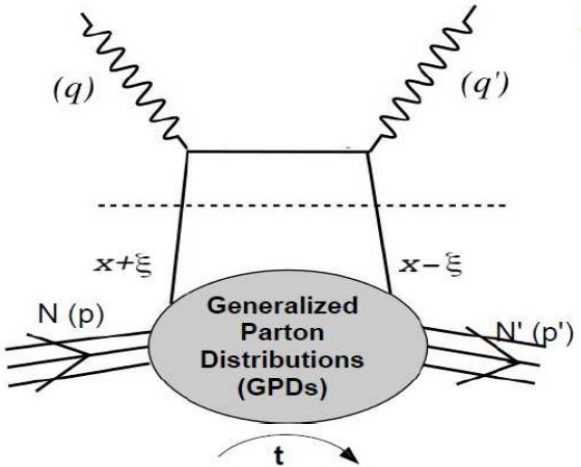
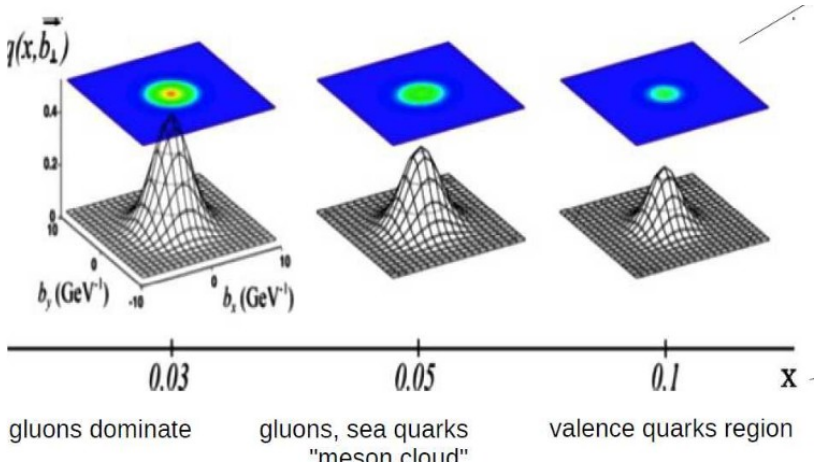
VIRGINIA TECH

PARTONIC STRUCTURE OF THE HADRONS

Motivations



General Compton-like off a quark



Momentum dependent Impact parameter distributions

<u>Accessing nucleon's 2+1 dim structure with hard exclusive processes</u>

DVCS: lot of data, used to parametrize models

TCS: access same kinematic points

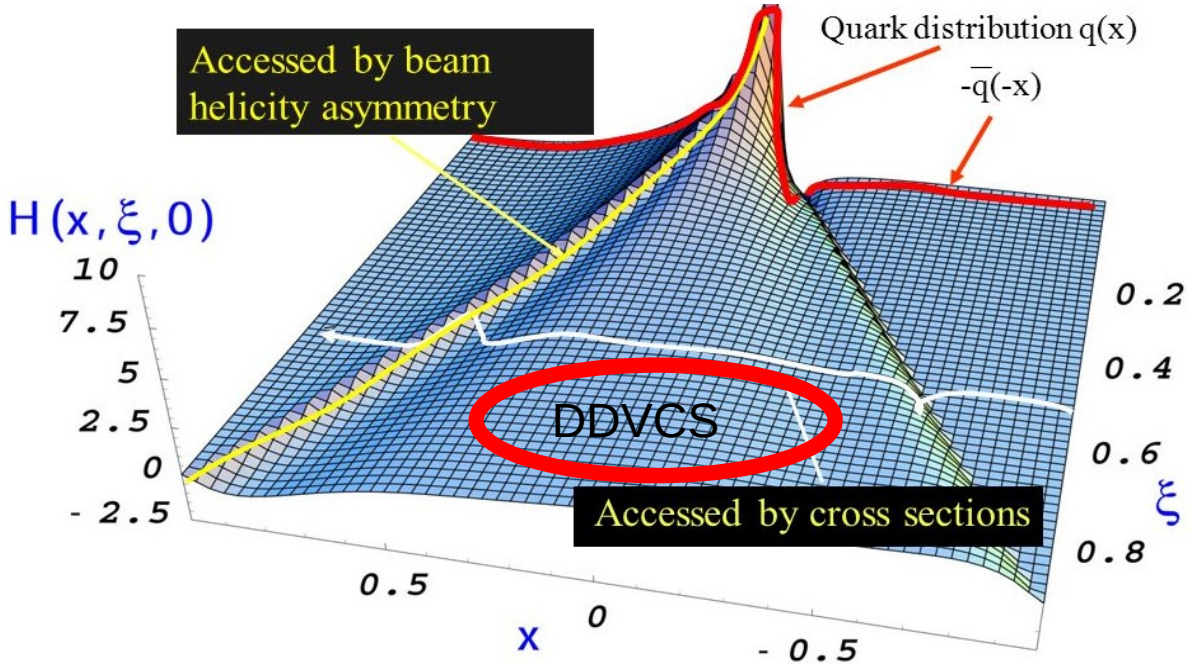
DDVCS: this talk, 2 virtual photons, access other kinematics

Mesons: flavor separation. Can also access other kinematics

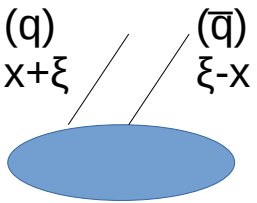
Other processes: 2 photons, meson+photon, multi-mesons...

Independent measurements, universality, "mass" lever arm, ERBL region, flavor separation, interpretation of NLO/higher twist, multi-channel fits...

Motivations



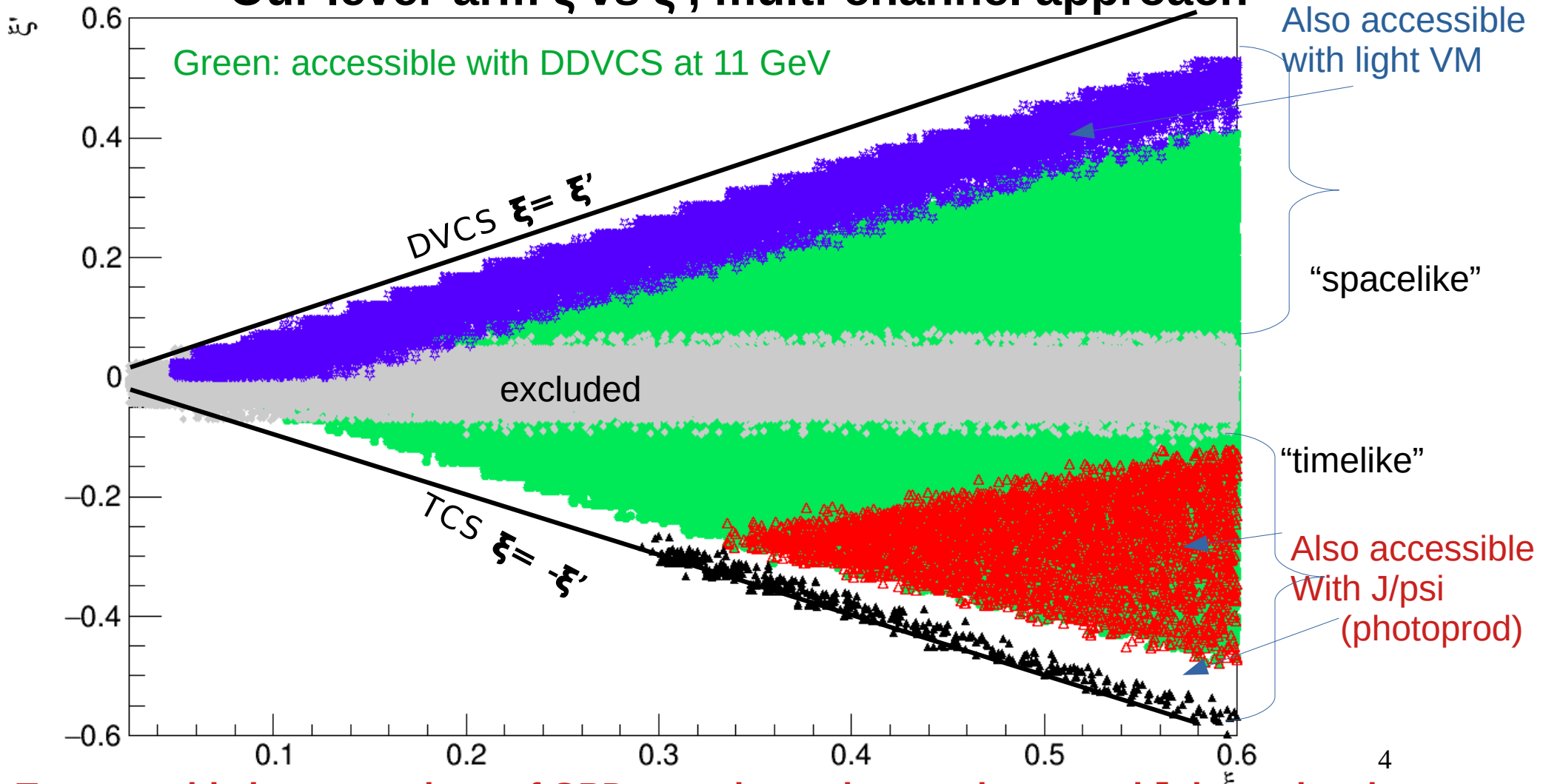
partonic interpretation from M. Diehl in ERBL region



"diagonal": $$T^{DVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi + i\varepsilon} dx + \ldots \sim \underbrace{P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi} dx}_{\mathrm{Re}\,(\mathcal{H})} \underbrace{- i\pi H(\pm\xi,\xi,t)}_{\mathrm{Im}\,(\mathcal{H})} + \ldots$$

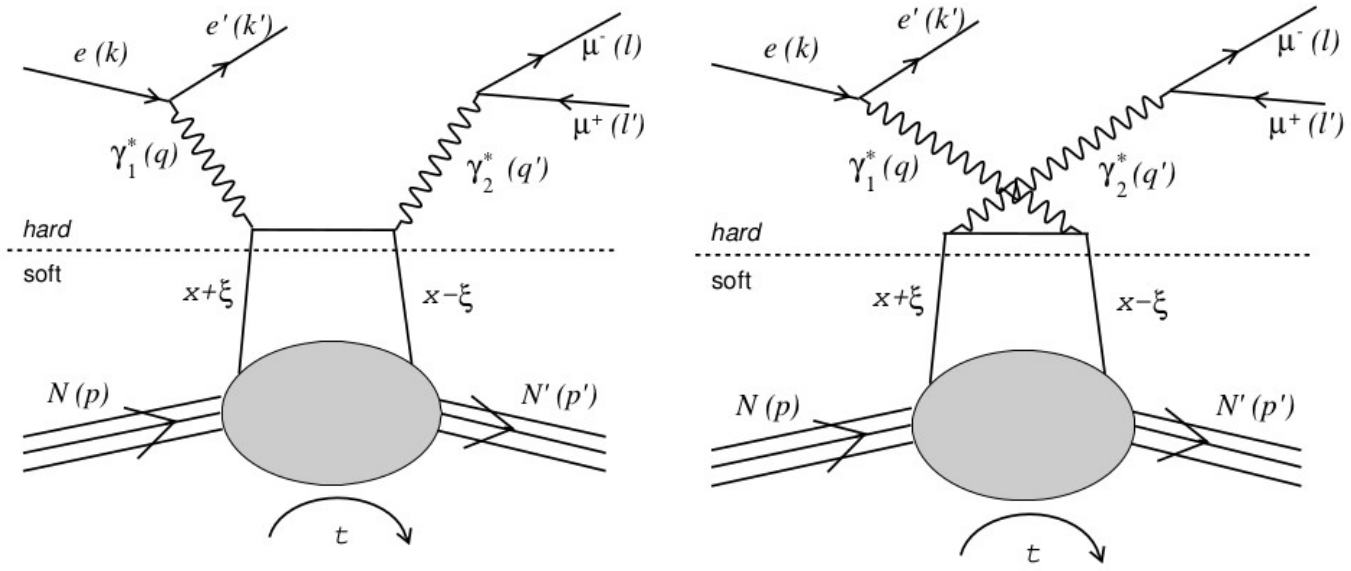
"off diagonal": $$T^{DDVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x - (2\xi' - \xi) + i\varepsilon} dx + \ldots \sim P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x - (2\xi' - \xi)} dx - i\pi H(2\xi' - \xi,\xi,t) + \ldots$$

Our lever-arm ξ vs ξ', multi-channel approach



Tomographic interpretations of GPDs require to deconvolute x and ξ dependencies

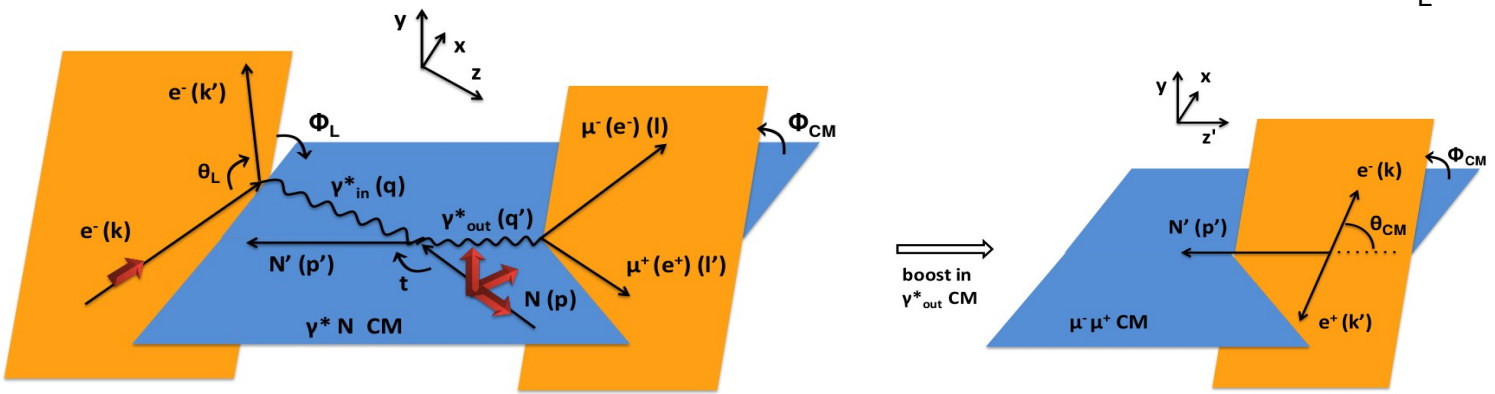
Reaction and what to measure?



e P → e' P' μ+ μ-

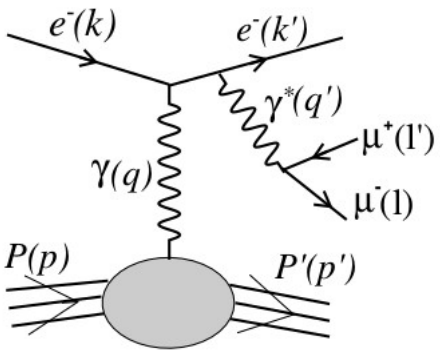
Need to measure a muon pair (antisymetrization, possibility to get the kinematics of 2 forward leptons)

7-independent variables for cross section.
Choice: E_e, ξ (or x_{bj}), t, Q^2, Q'^2, Φ_L, Φ_{CM}, θ_{CM}



Experimental and interpretation challenges

(1)



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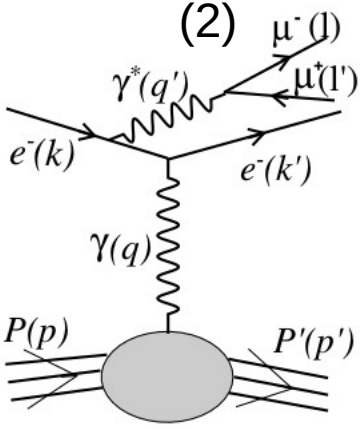
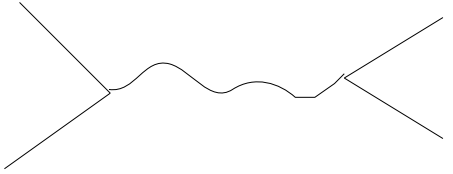


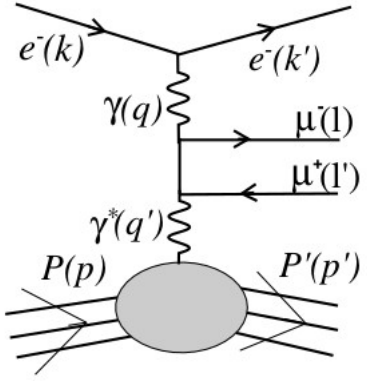
Interference with Bethe-Heitler

equivalent to pair production from e+e- annihilation

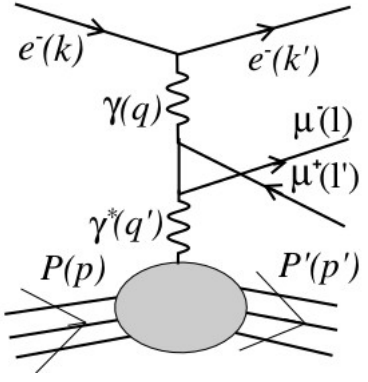


notations: γ1 connected to the beam and pair
and γ2 connected to the nucleon
see BH associated to DVCS when $Q'^2 \to 0$

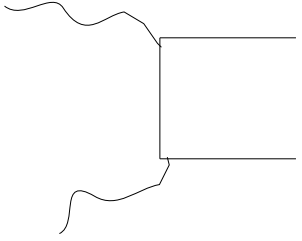
(3)



(4)

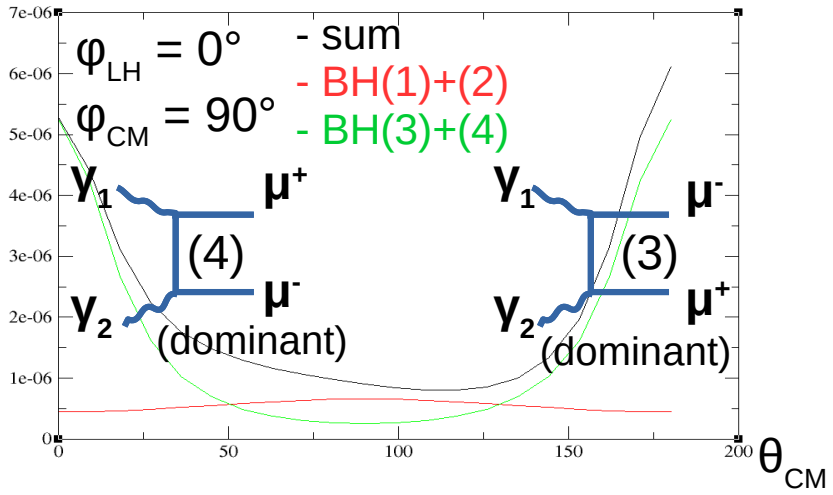


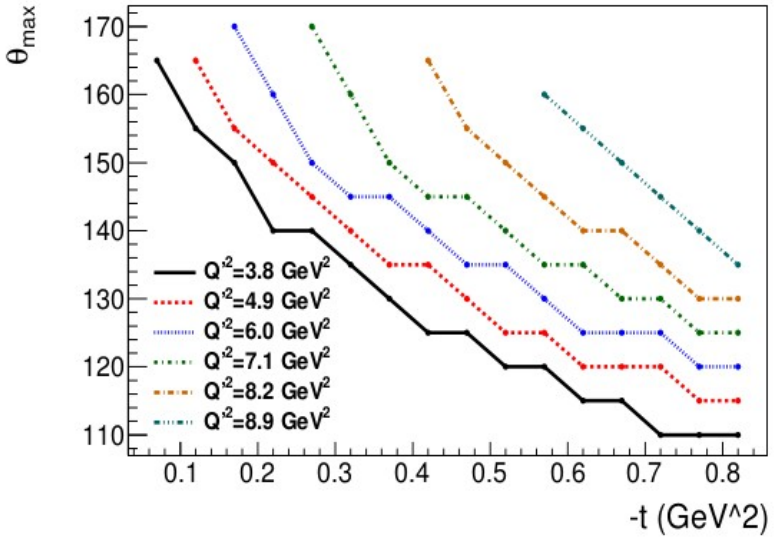
pair production from 2 virtual photons interaction



notations: γ1 connected to the beam
and γ2 connected to the nucleon
see "BH" associated to TCS when $Q^2 \to 0$

Analysis methods

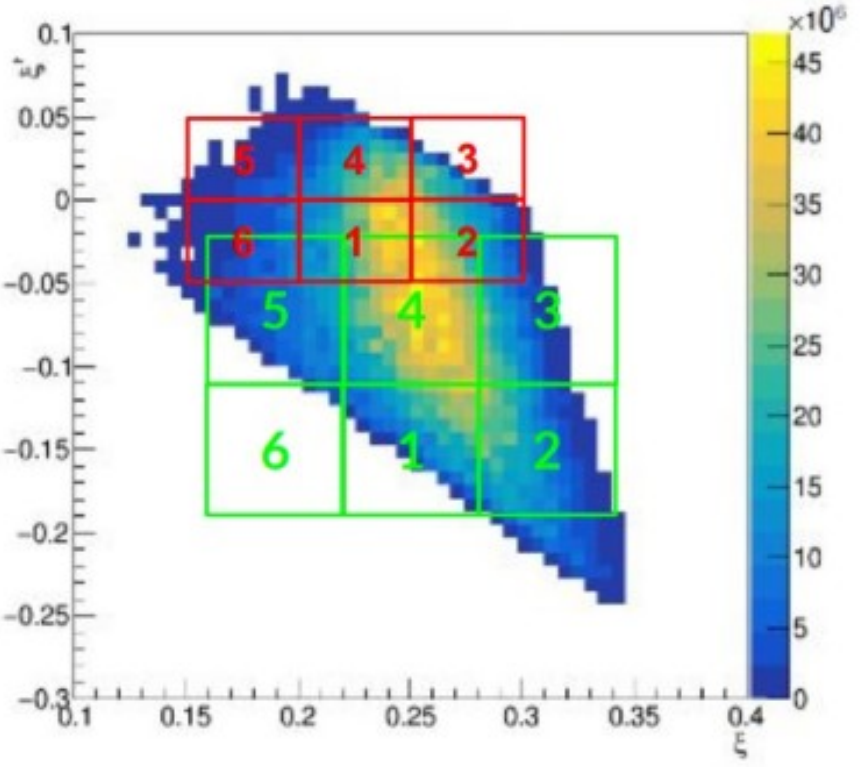


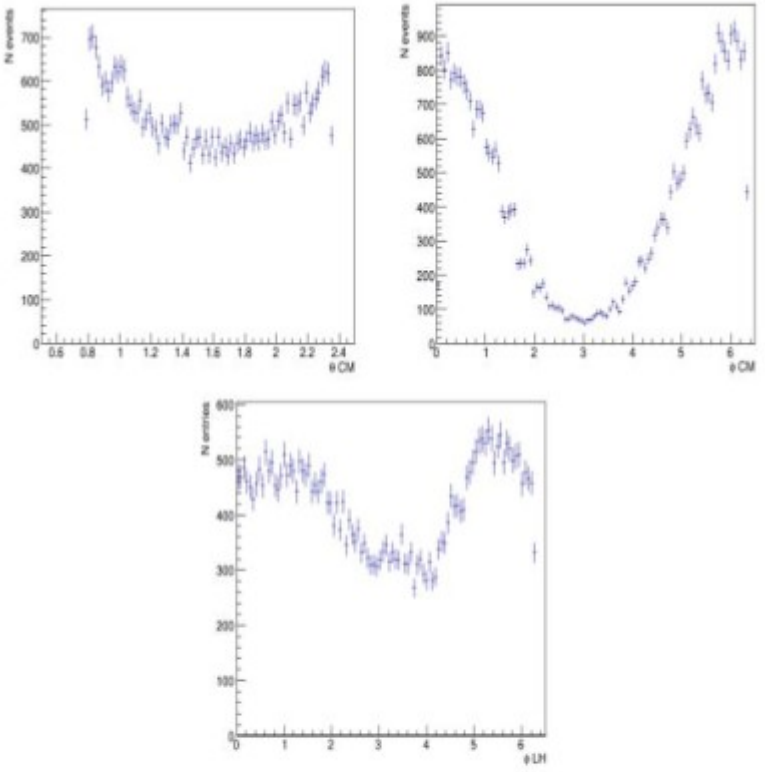


- based on TCS methods, due to BH peaks

- less “risky” than TCS, but not taking into account angular correlations or BH dominance and its fast cross section evolution will lead to big mistake in interpretation; essential to do it at the stage of developing the experiment to not place detectors at the wrong place where physics is not so interesting or no interpretation can be made

Physics and analysis studies





- still in progress
- these plots are studies by undergraduate students in summer of 2022 with simulations (v. 2019 of DEEPGen)

Credit: Jocelyn Robbins, Melinda Yuan

Figure 5: θ_{CM} (upper left), ϕ_{CM} (upper right), and ϕ_L (lower)

Physics case and analysis challenges

- Clear and strong motivations: off diagonal region of GPDs, tomographic interpretation. Essential and unique measurement. Cleaner and no extra-step compared to using meson mass in multi-channel approach (mesons have other advantages)

- BH interference and angular correlations are complex: need of good understanding for a “limited acceptance” experiment, where do we have more impact, choice of region to focus Can absolutely impact the interpretation of a DDVCS experiment

- Why in Hall C: projects in Hall A (SoLID) and Hall B (dedicated) [both in progress]

With larger acceptance, probing a wider kinematic region

(note that we work on SoLID too, the experiments are complementary and both are important)

- We can target specific kinematics, at least one in “timelike” and “spacelike” regions
- We can have much higher intensity
- We can have a dedicated setup
- We can detect 4 particles: important for t resolution and interpretations
- Other: high precision measurement of unpolarized TCS in parallel… complement other experiments (meson channels as well, but depending phase-space)

Our progress with simulations

Unfortunately not as much as we wanted by this meeting…
After “toy MC” and projections with not so realistic setup, we are now starting full Geant4

Excluded: use of HMS+SHMS or SBS, due to too low acceptance
Common:
addition of a muon detector, need of a dipole magnet (min. 3 T?), better to detect the proton
10 cm LH2
60 µA, 100 days (hopping to go higher)

- Starting from DVCS setup:
  - with addition of (SBS?) magnet
  - addition of shielding and hodoscopes behind NPS
  - need to know if we can/decide to detect the proton

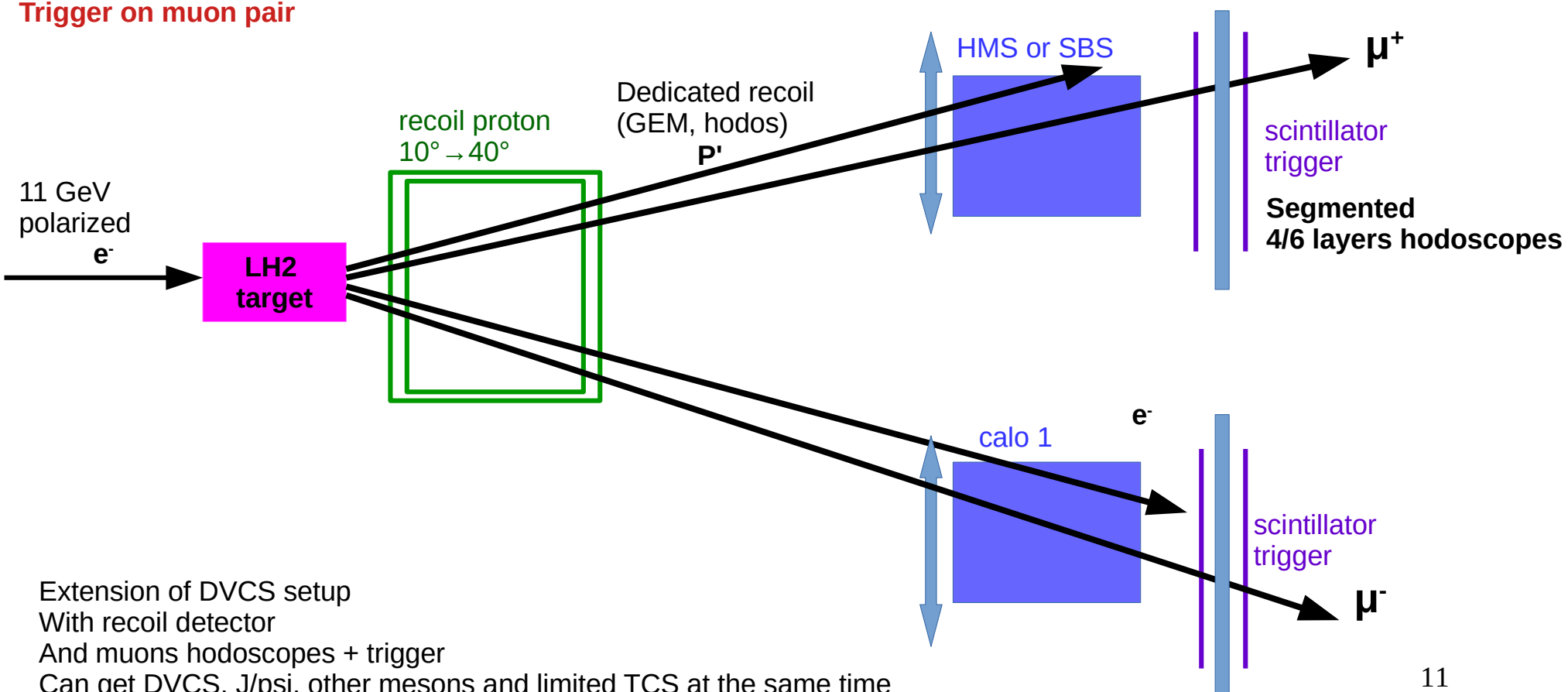
DVCS and some mesons can be measured simultenaously
Simpler setup

- Starting from TCS setup:
  - replacing target and adding magnet
  - shielding behind calorimeter, and hodoscope

Quasi-real photon TCS can be measured,
With advantage of comparison of ee and µµ and “discriminator” for pions in ee,
Can measure some mesons

ideal detector position for different bins, assuming previous distributions "at vertex" are similar to the one with magnetic field
symmetric configuration for μ+ and μ- ⇒ better for interpretation and treatment of BH2

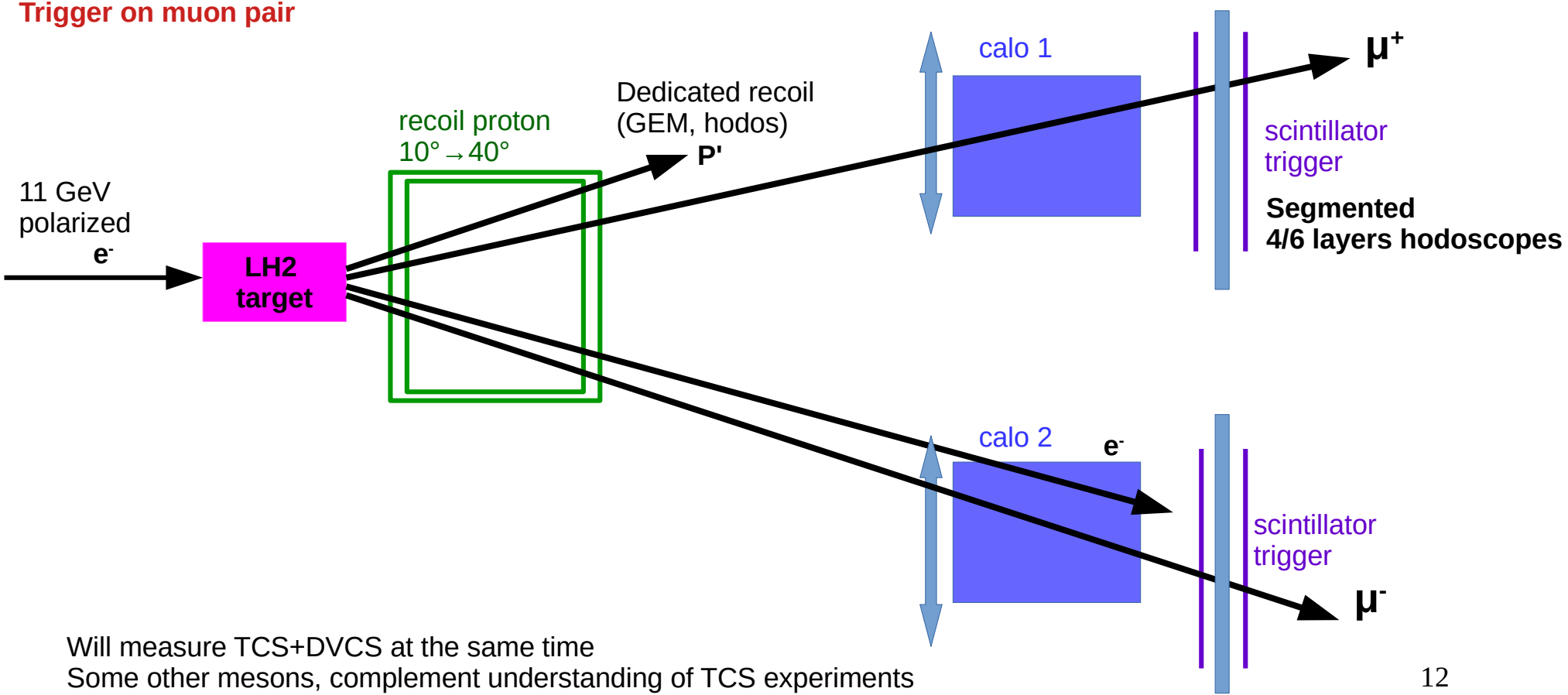
We need to detect all final particles for resolution in t
Trigger on muon pair



Extension of DVCS setup
With recoil detector
And muons hodoscopes + trigger
Can get DVCS, J/psi, other mesons and limited TCS at the same time

ideal detector position for different bins, assuming previous distributions "at vertex" are similar to the one with magnetic field
symmetric configuration for μ+ and μ- ⇒ better for interpretation and treatment of BH2

We need to detect all final particles for resolution in t
Trigger on muon pair



Will measure TCS+DVCS at the same time
Some other mesons, complement understanding of TCS experiments
Extension of TCS setup

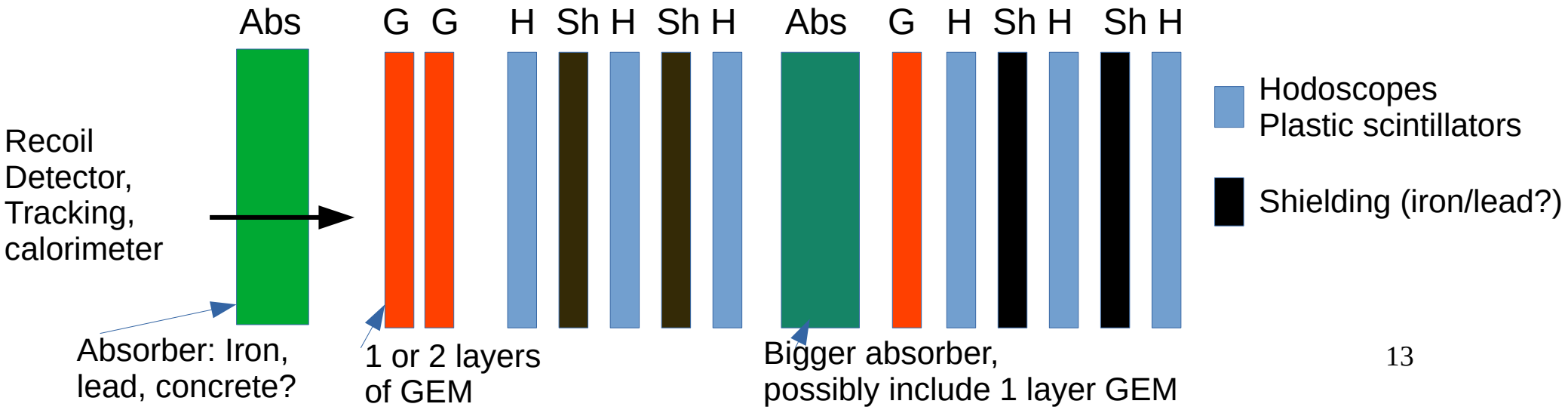
Muon detectors

- R&D in parallel with SoLID DDVCS project (we have a bit more experts there), but likely can't use the same technology, and not the same dimensions. Both experiment benefit from each others and initial in-beam tests likely / can be done simultenaously

- Too early to discuss much: we are taking ANY advice from you here

- specific plan for VT group is to work (much harder now) on GEANT4 and study background (pion…) in parallel to test simple apparatus for now in our lab

- Here is idea we are starting with (used as both trigger/veto + muon with simple tracking): - starting from TCS setup, we have GEM in front of calorimeter for muon track



SUMMARY

1) There is a lot of work to do

2) It is very challenging but the physics outcome have huge potential

3) We are working hard on it

4) We are happy to receive any positive and negative comments

5) It is complementary to other GPD related projects