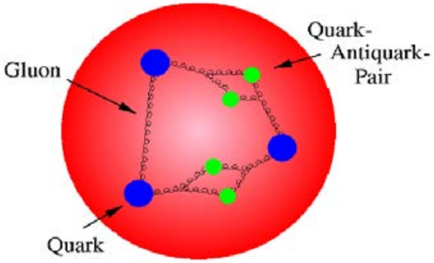
Deeply Virtual Compton Scattering (DVCS)
E12-06-114
Hall A at JLab

APS April Meeting
28 January 2017

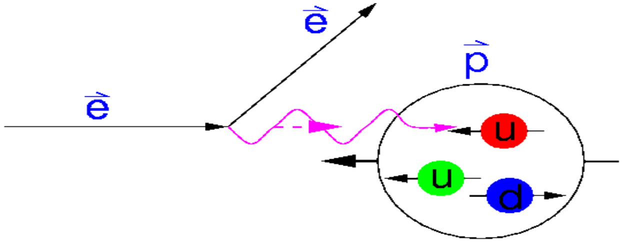
Bishnu Karki
Ohio University
Athens, OH

Introduction:

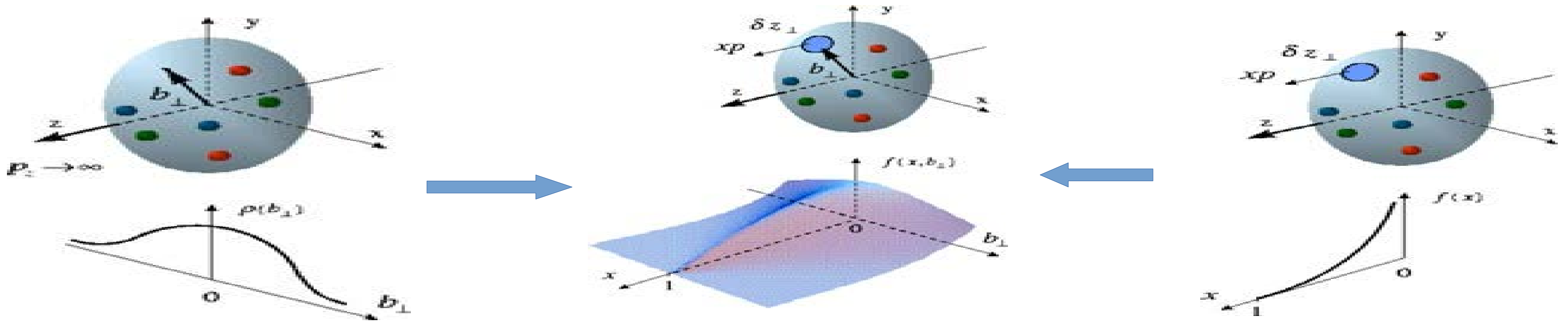
- Key objective of Nuclear Physics is to understand the structure of nucleon in terms of quarks and gluons.



- Scattering of relativistic electron off the Nucleon is one of the most powerful tool for studying the Nucleon structure.



Generalized Parton Distributions (GPDs):



Elastic Scattering:
→Proton extended object
→**Form Factors (FFs)**
✔Spatial distribution
✗Longitudinal momentum distribution

Generalized Parton distribution (GPDs):
✔ Spatial distribution
✔ Longitudinal momentum distribution

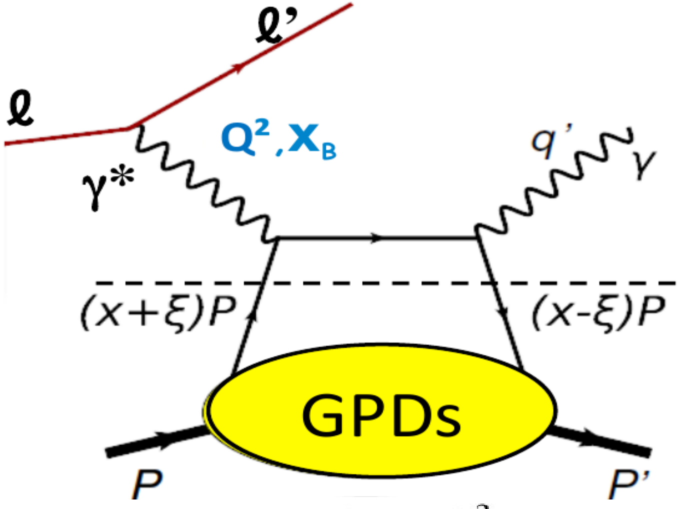
DIS:
→Discovered quarks
→**Patron distribution functions (PDFs)**
✔ Longitudinal momentum distribution
✗Spatial distribution

GPDs allows to access the 3D parton structure of Nucleon

Factorization and GPDs:

QCD Factorization allows to access GPDs in various exclusive reactions.

In the Bjorken Limit $\left.\begin{array}{lcl} Q^2 = -q^2 & \rightarrow & \infty \\ \nu & \rightarrow & \infty \end{array}\right\}$ $x_B = \frac{Q^2}{2M\nu}$ fixed



$t = (p' - p)^2$

$\xi \approx \frac{x_B}{2 - xB}$

Hard Part
LO: QED
NLO: pQCD

Factorization

Soft Part
Non perturbative QCD
Parametrized by GPDs

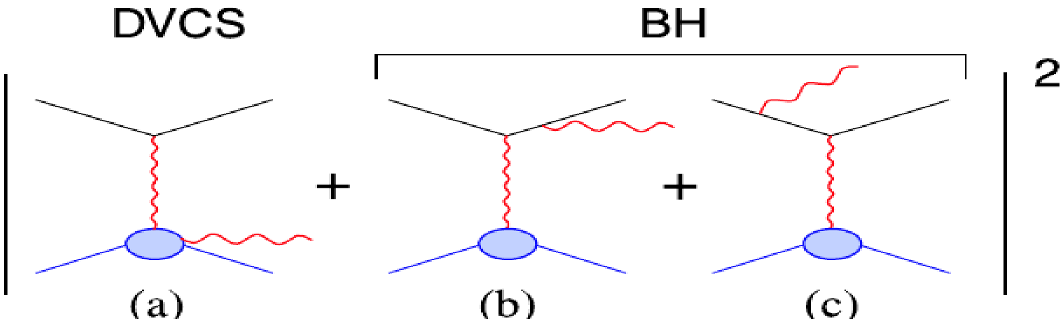
Nucleon Helicity

	Conserving	Non-conserving
Unpolarized GPDs	H	E
Polarized GPDs	$\tilde{H}$	$\tilde{E}$

Minimal Q^2 at which factorization holds must be tested

DVCS and Bethe -Heitler (BH):

ep $\longrightarrow$ epγ =



At leading twist

$$d^5\overrightarrow{\sigma} - d^5\overleftarrow{\sigma} = \Im m\,(T^{BH}\cdot T^{DVCS})$$

$$d^5\overrightarrow{\sigma} + d^5\overleftarrow{\sigma} = |BH|^2 + \Re e\,(T^{BH}\cdot T^{DVCS}) + |DVCS|^2$$

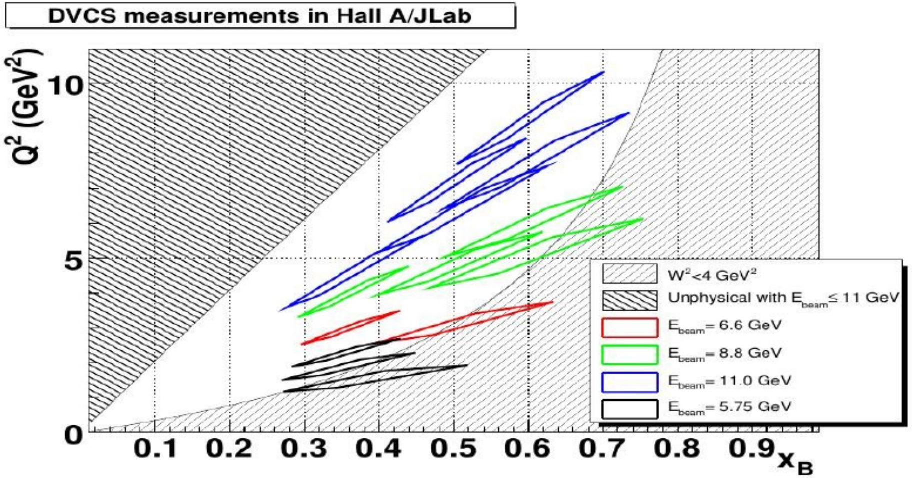
Known to 1%

Linear combinations of GPDs

Bilinear combinations of GPDS

Interference with BH gives access to Re and Im part of DVCS amplitude

DVCS in Hall A:

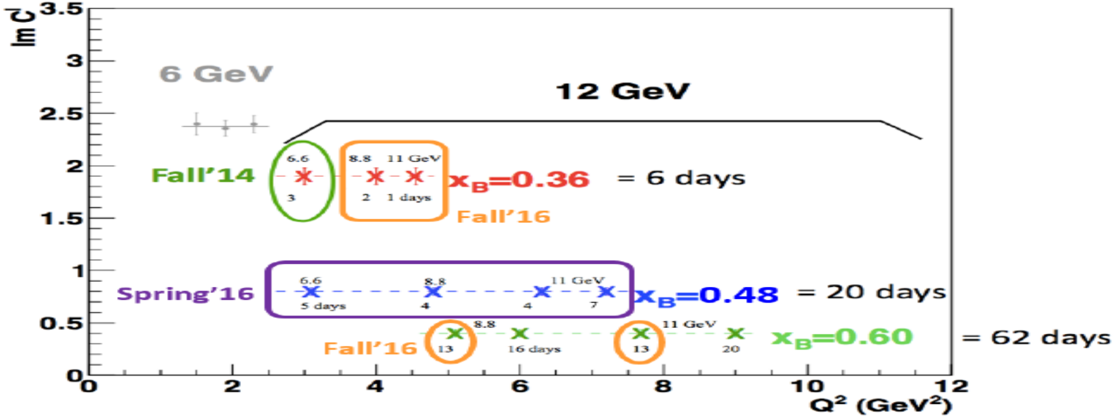


✔E00-110/E03-106 (2004) ➡ first dedicated experiment (Q^2 dependence study)

✔E07-007/E08-025 (2010) ➡ Q^2 and beam energy dependence

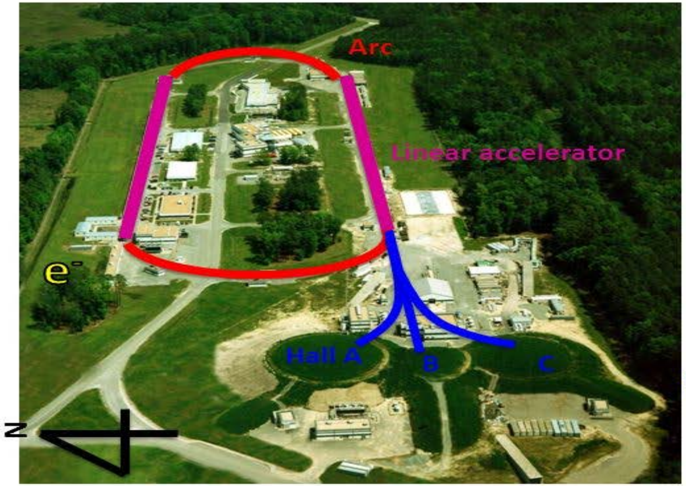
✔E12-06-114 ➡
- Wider Q^2 scans at several x_B
- Absolute cross section ~5% relative precision

Scaling tests of the DVCS cross section



~50% of PAC allocation completed between 2014 and 2016

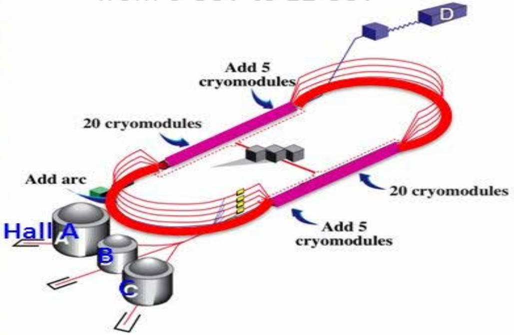
Jefferson Lab and 12 GeV Upgrade



Aerial view of Jefferson Lab

Recirculating linear accelerator

Beam energy upgrade
from 6 GeV to 12 GeV



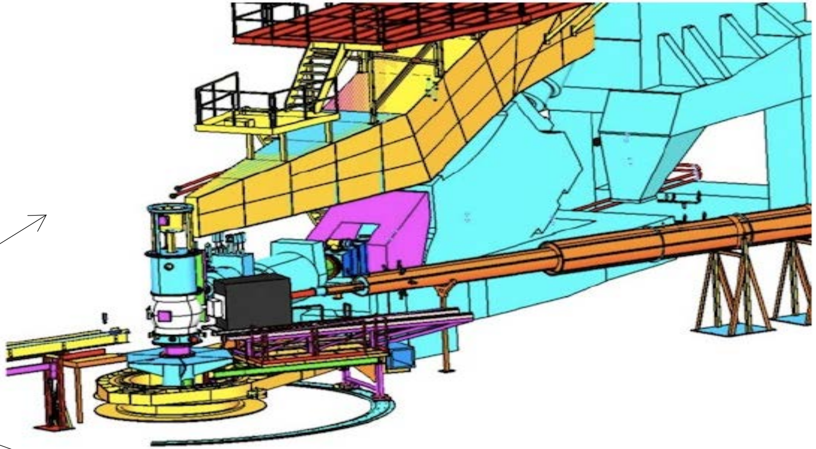
12 GeV Upgrade project

- Beam dump commissioning
- 5 pass, 2.1 GeV/pass
- High beam polarization (85%)
- Up to 80 μA (single Hall)
- Hall A, B and D running at same time

- Routine beam energy measurement (10^{-3} level)
- Upgraded raster system
- Upgraded Moller and Compton polarimetry

DVCS is one first experiment to take data after 12 GeV Upgrade.

- High Resolution Spectrometer
  (P0 = 4.3 GeV, resolution 1x 10^{-4})
- Dedicated calorimeter.
  (Resolution 3.6 % at 4.2 GeV)



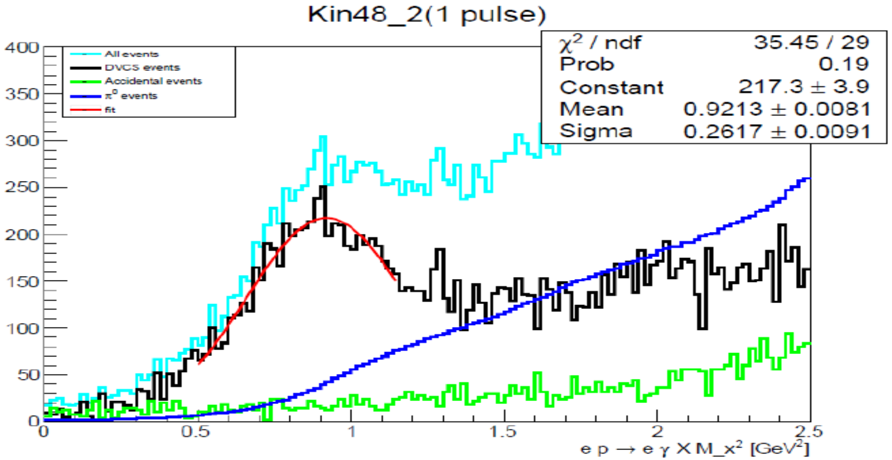
Polarized e^- beam

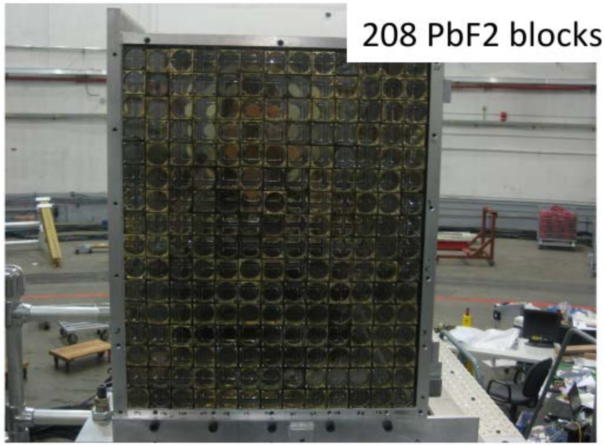
LH_2

e^- to HRS

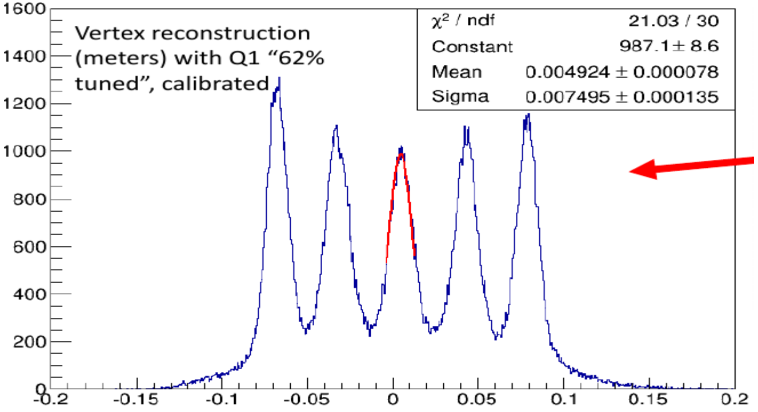
γ

Recoil proton reconstructed by MM^2

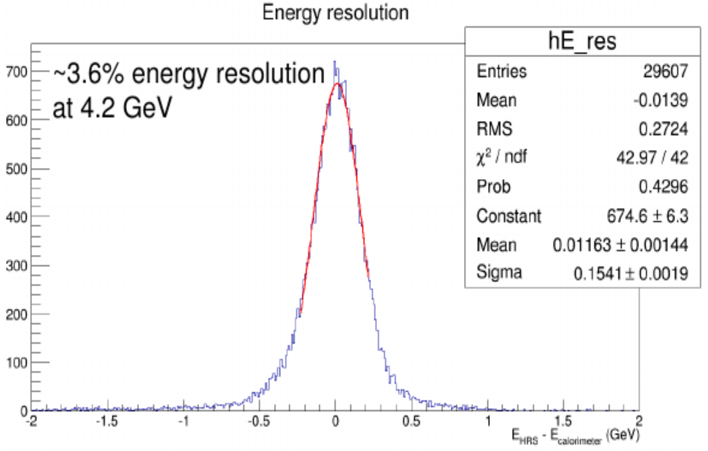




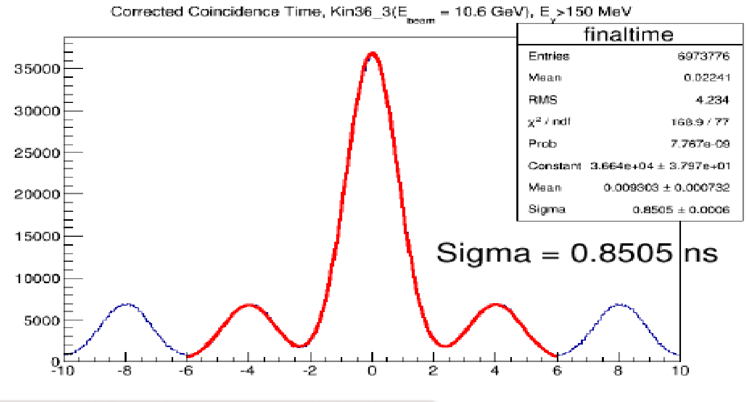
So far...



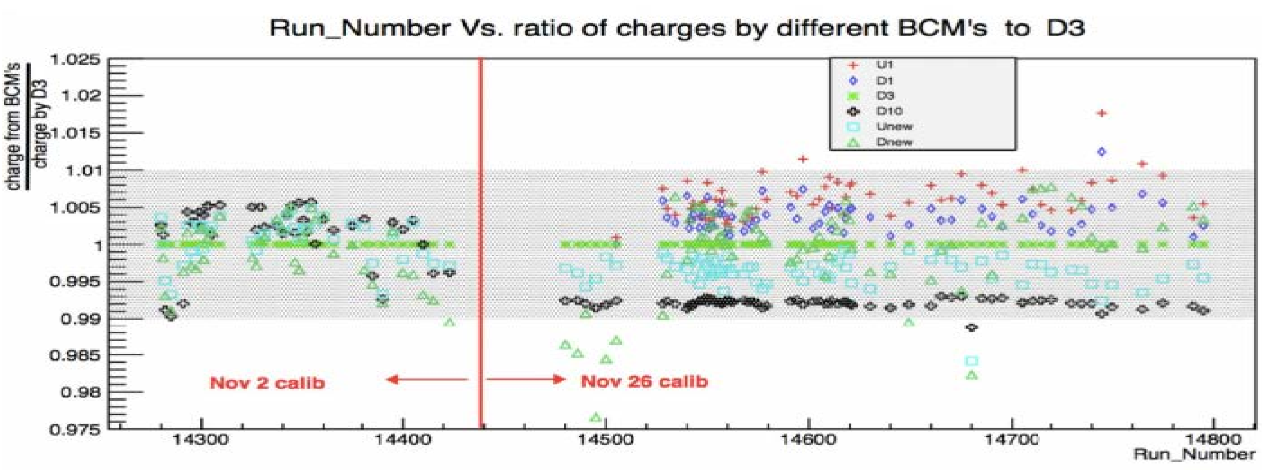
Optics calibration
Vertex reconstruction

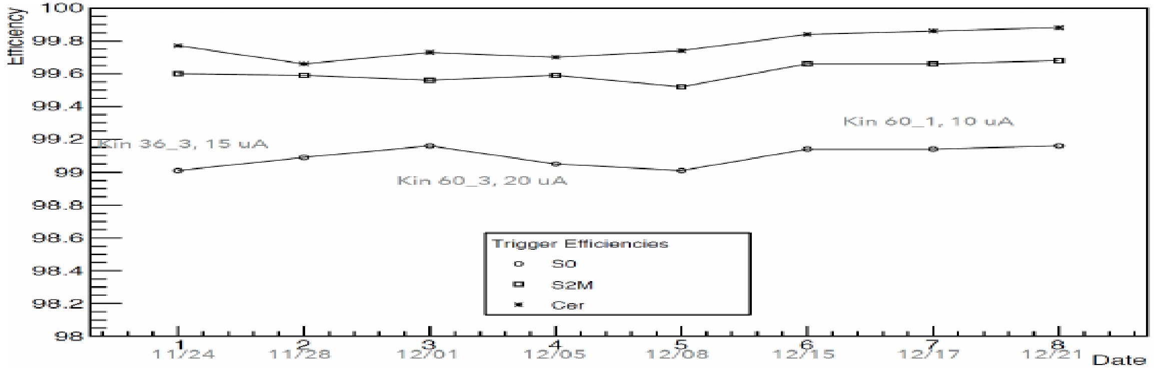


Calorimeter Calibration



Coincidence time correction





So far ...

Charge Measurement:
BCMs calibrated
measured charge agrees within 1% from different BCMs

Efficiency of triggers:
S0, S2 and Cherenkov > 99%

Conclusion and Outlook:

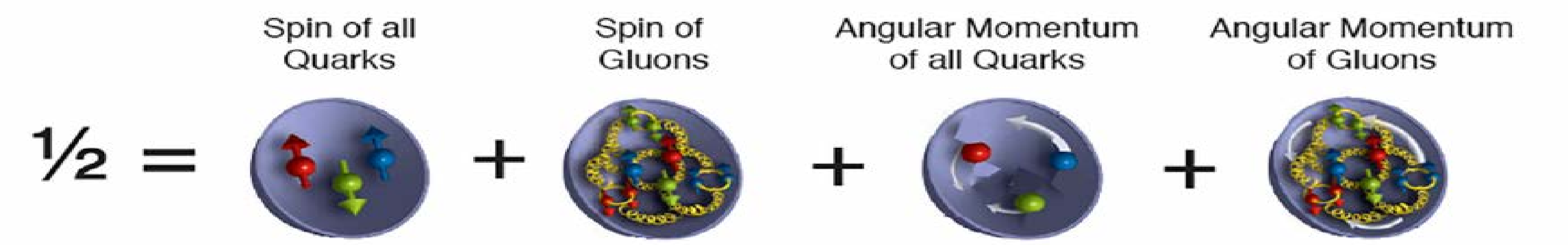
- Data taking completed at end of 2016.
  - ✔ In each X_B several Q^2 Scans.
- Data analysis already started.
- Exciting results to come.

Acknowledgments:

Hall A DVCS Collaboration
Hall A Collaboration
Hall A technical staff
Accelerator staff

Thank you !!!

Proton Spin Puzzle:



Contribution of the **angular momentum of quarks** to proton spin:

$$\frac{1}{2} = \underbrace{\frac{1}{2}\Delta\Sigma + L_q}_{J_q} + J_g \quad \Rightarrow \quad J_q = \frac{1}{2}\int_{-1}^{1} dx\, x[H^q(x,\xi,0) + E^q(x,\xi,0)]$$

Ji's sum rule

Only 30% of proton spins comes from spin of quarks and antiquarks.

Contribution from Orbital angular momentum (OAM) of quarks can be determined.

Energy and Polarization

- October 31: E_{beam} = 8.495 GeV ; polarization = 86.75(±0.10 ±1.0)%
- November 28: E_{beam} = 10.590 GeV ; polarization = 85.39(±0.11 ±1.0)%
- December 07: E_{beam} = 10.591 GeV ; polarization = 84.18(±0.10 ±1.0)%
- December 19: E_{beam} = 8.498 GeV ; polarization = 86.20(±0.10 ±1.0)%