Le programme de Hall A au Jefferson Laboratory a 12 GeV

Alexandre Camsonne
Hall A Jefferson Laboratory
Seminaire LPC Clermont Ferrand
16 Novembre 2012

Summary

- Introduction
  - Jefferson Laboratory
  - 12 GeV Upgrade
  - Hall A presentation
  - Experimental program timeline
  - Standard equipment 12 GeV experiment
    - DVCS
  - New Large instruments
    - SuperBigBite Spectrometer
    - SoLID spectrometer
    - Moller experiment
- Conclusions

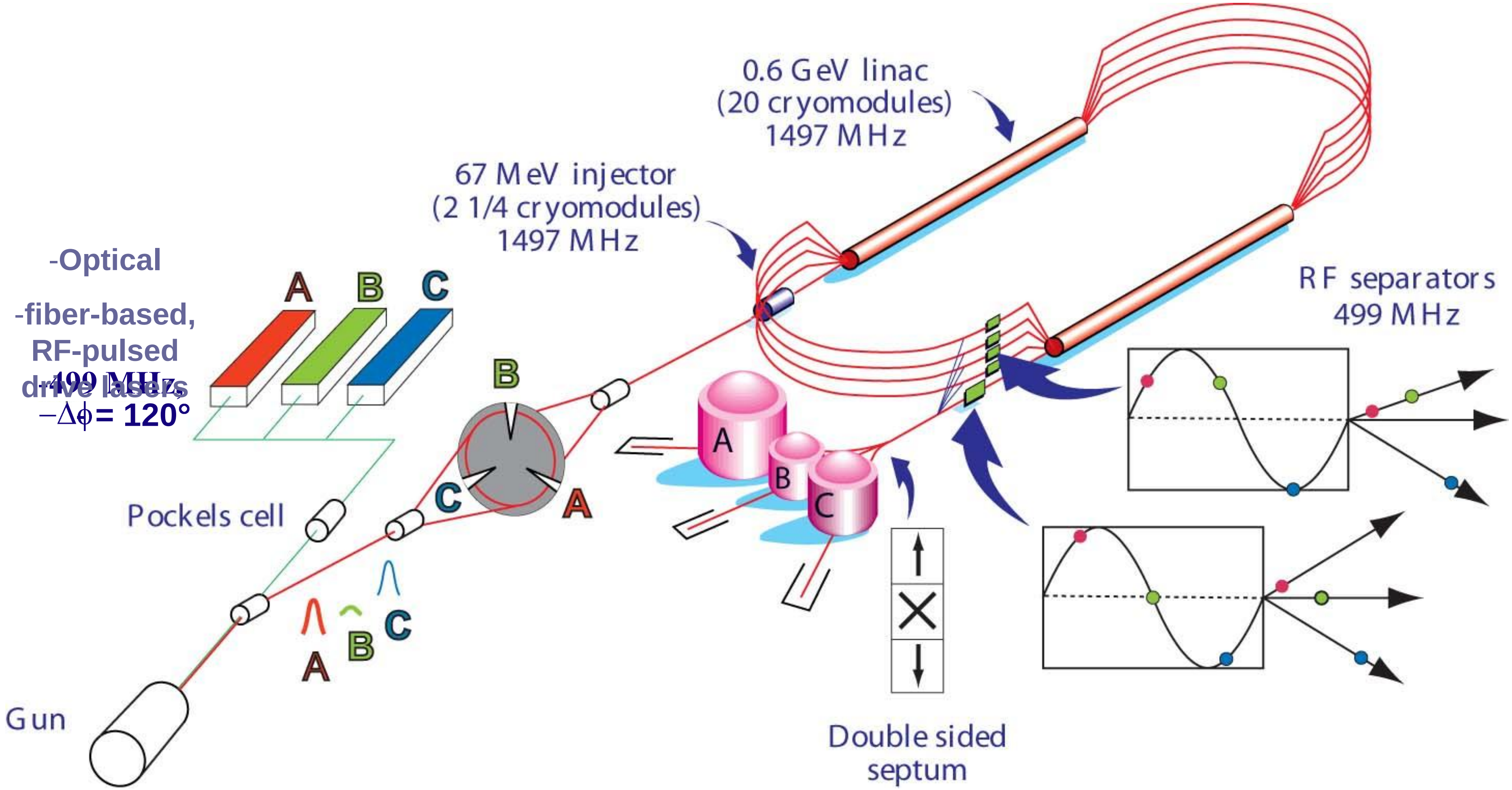
Continuous Electron Beam Accelerator Facility

-Optical

-fiber-based, RF-pulsed drive lasers

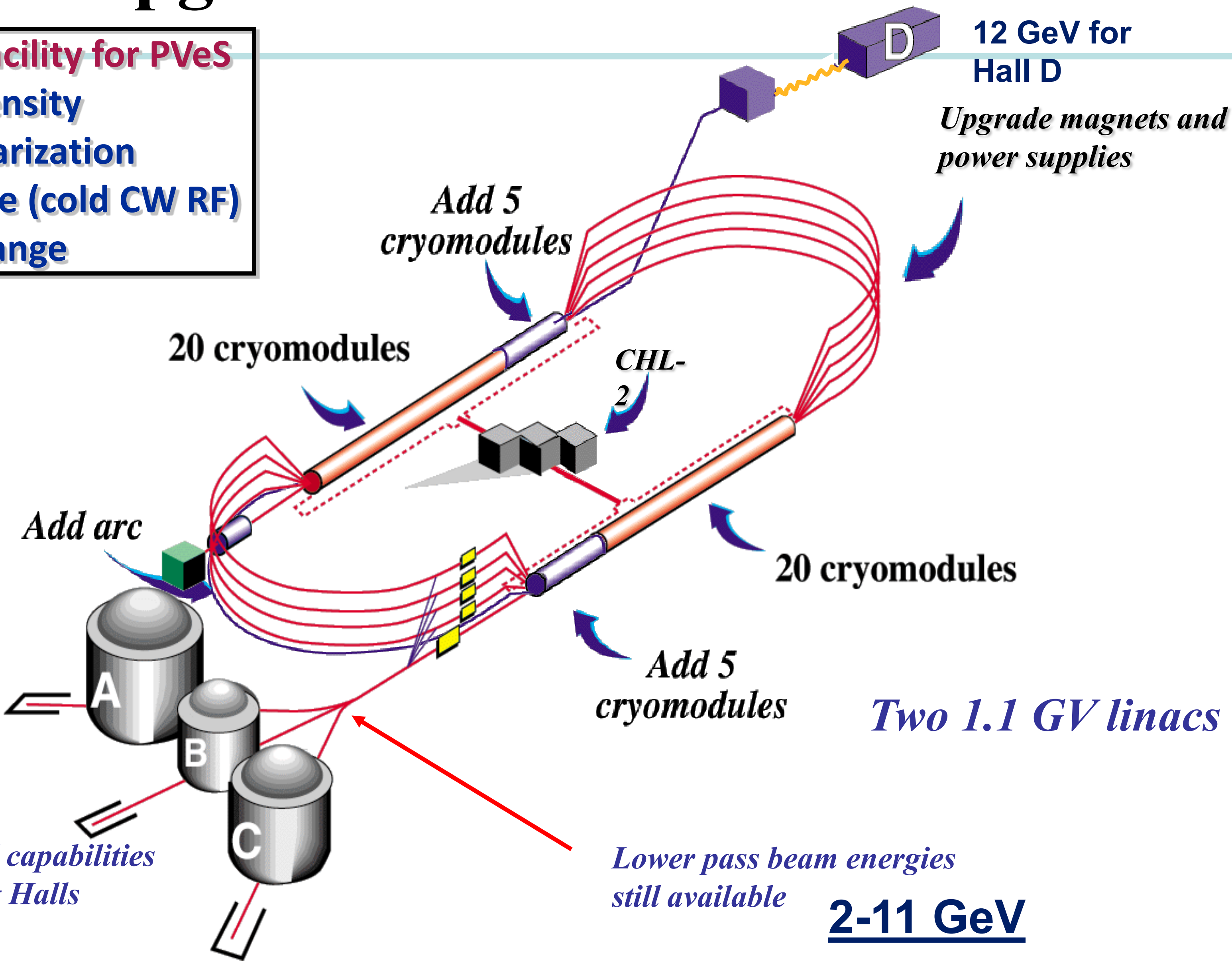
-499 MHz

$-\Delta\phi = 120°$



12 GeV Upgrade at JLab

Unique Facility for PVeS
- High intensity
- High polarization
- Low noise (cold CW RF)
- Energy range

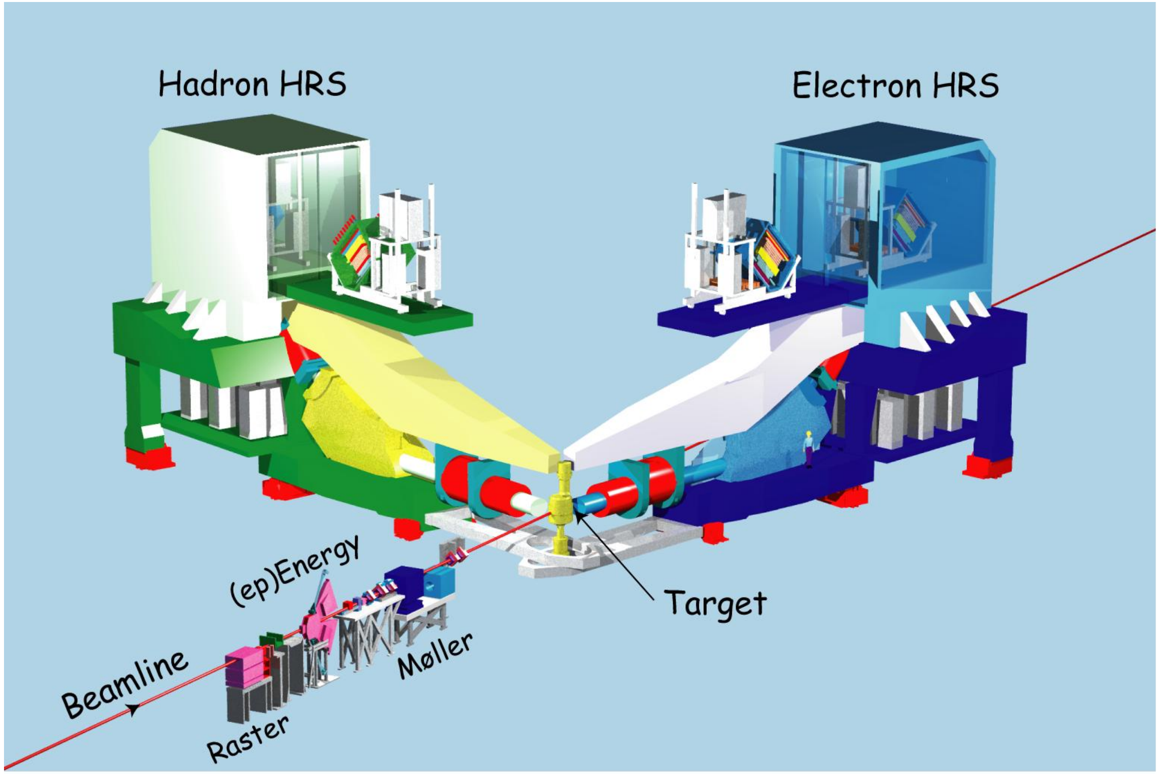


Enhanced capabilities in existing Halls

Lower pass beam energies still available

2-11 GeV

Hall A spectrometers layout



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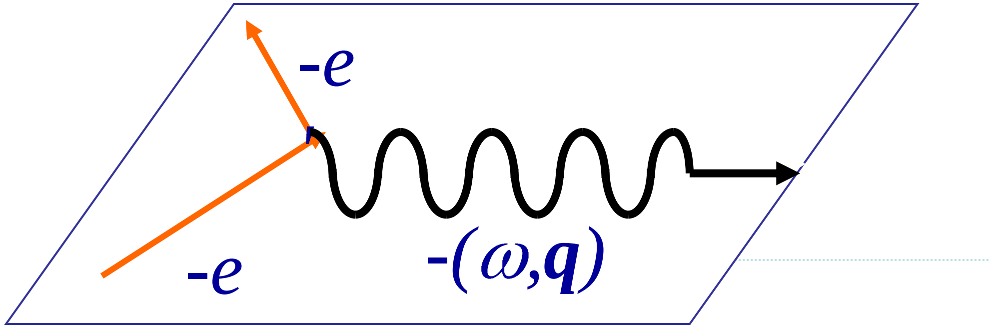
-HRS Spectrometers	FWHM
-Max. momentum	4.2 GeV/c
-Momentum acceptance	4.5%
-Momentum resolution	1.10^{-4}
-Angular acceptance	6 msr
-Angular resolution	1 mrad
-Vertex acceptance	5 cm
-Vertex reconstruction	1 mm

- Focal-Plane Detectors

- Scintillator trigger
- MWDC tracking
- Pb-glass preshower/shower
- Gas Cherenkov
- Aerogel Cherenkovs
- Ring Imaging CHerenkov

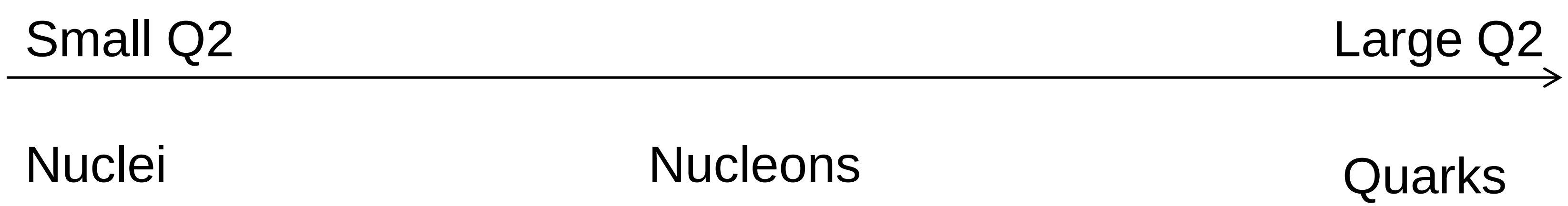
Virtual photon kinematics



-Scattered electron detected with the spectrometer

-Four-momentum transfer: $Q^2 \equiv -q_\mu q^\mu = \mathbf{q}^2 - \omega^2 = 4ee' \sin^2\theta/2$

-Allow to choose the scale of the probe



Preliminary schedule

	February - May	August – December	February - June	August - December	February - June	September - December
2014	GMp / DVCS – I (APEX)	GMp / DVCS - I				
2015			$^3H/^3He$ (A_1^n)	PREX (APEX)		
2016					A_1^n (SBS) (DVCS-II) (APEX)	SBS (A_1^n) (DVCS-II) (APEX)

Moller experiment
SoLID

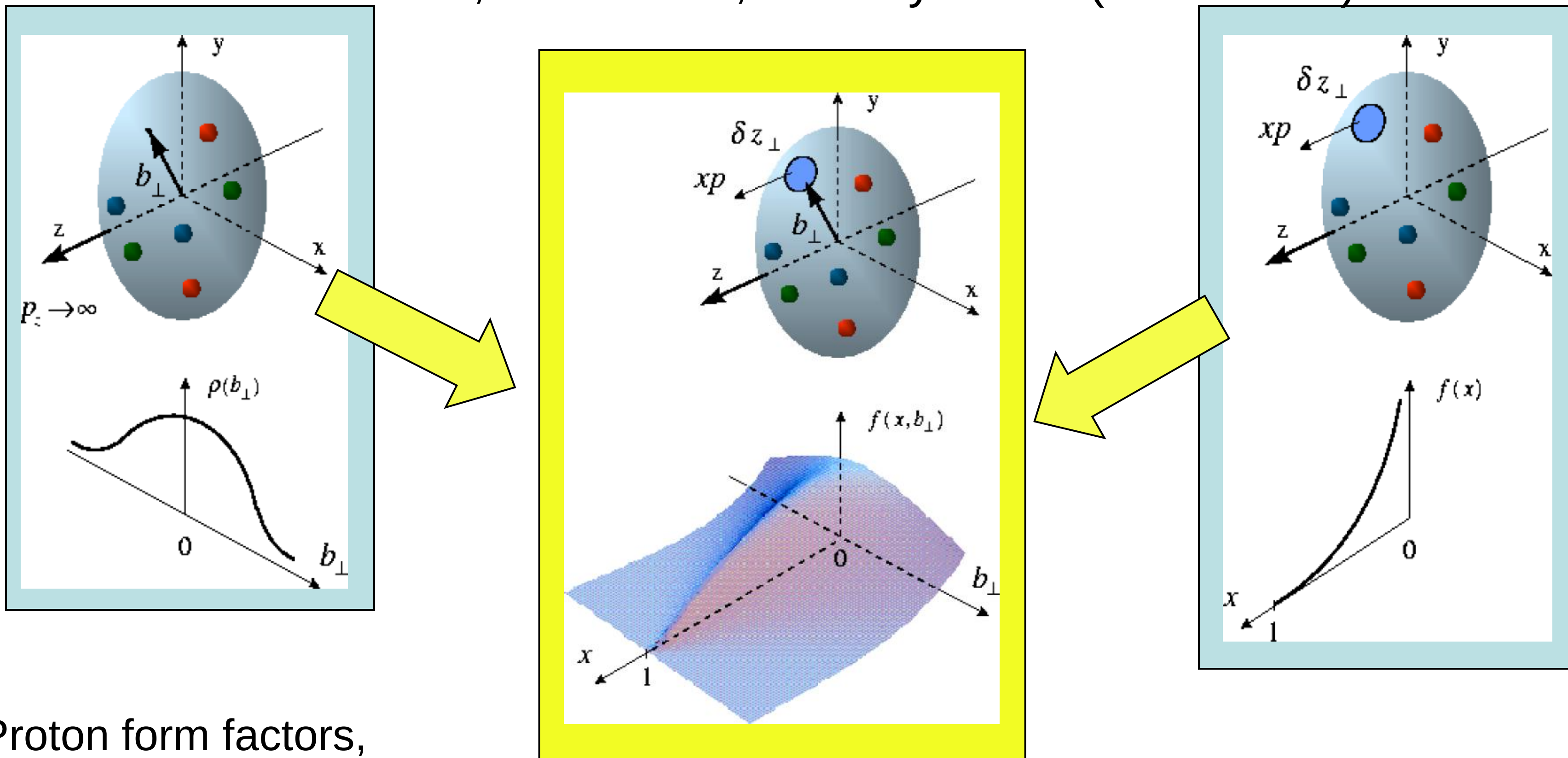
Early 12 GeV experiment

- Reuse 6 GeV Hall A equipment
  - DVCS experiment
    - HRS and calorimeter : Generalized Parton Distributions
  - Form factor experiment GMp : 2 HRS

- PREX : Lead Radius Skin through parity violation
  - Focal plane detector in both HRS
  - Septum magnets
- A1n : Deep inelastic structure functions at large x
- APEX experiment : search for light boson

Generalized Parton Distributions (GPDs)

X. Ji, D. Mueller, A. Radyushkin (1994-1997)



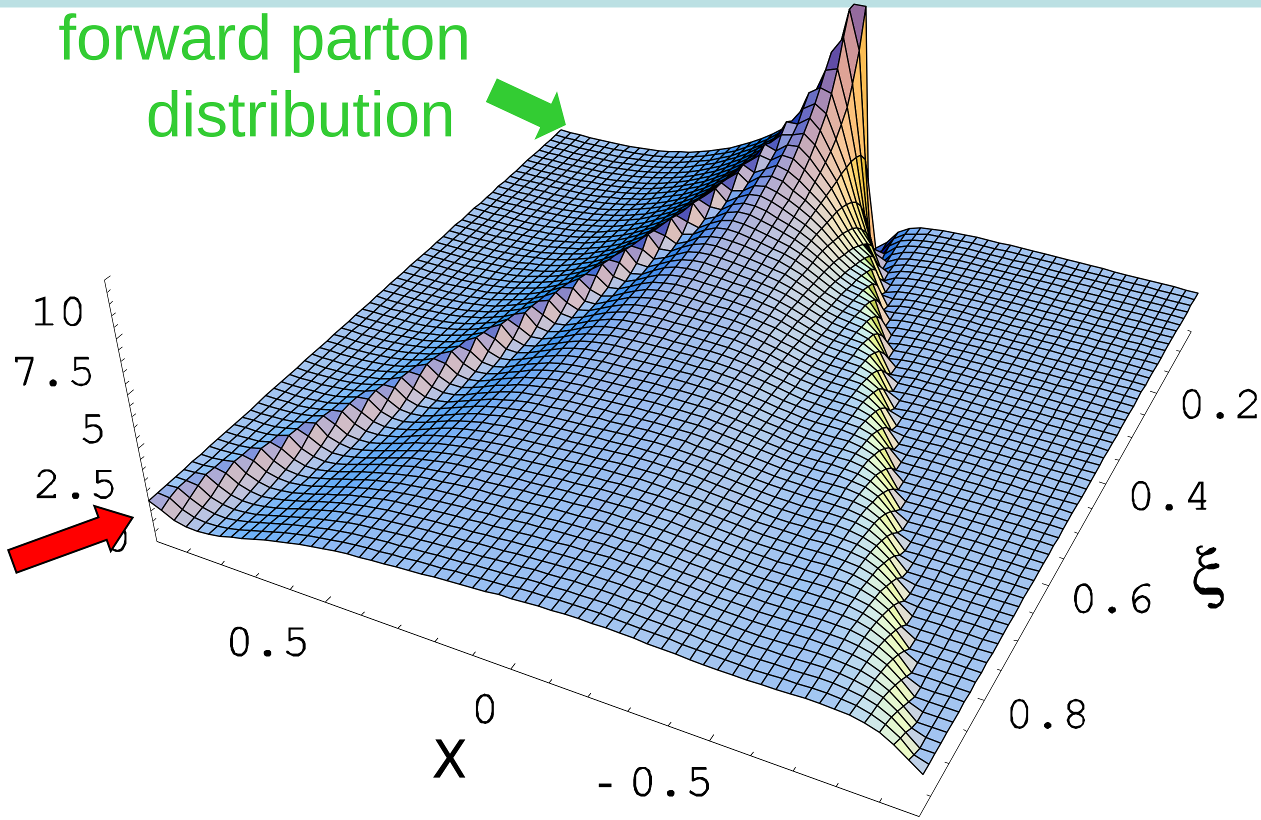
Proton form factors, transverse charge & current densities

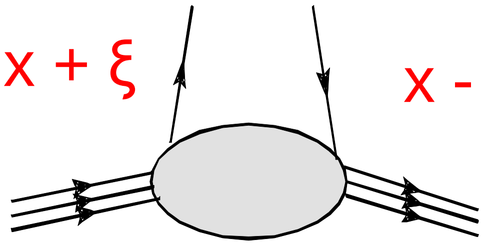
Correlated quark momentum and helicity distributions in transverse space - GPDs

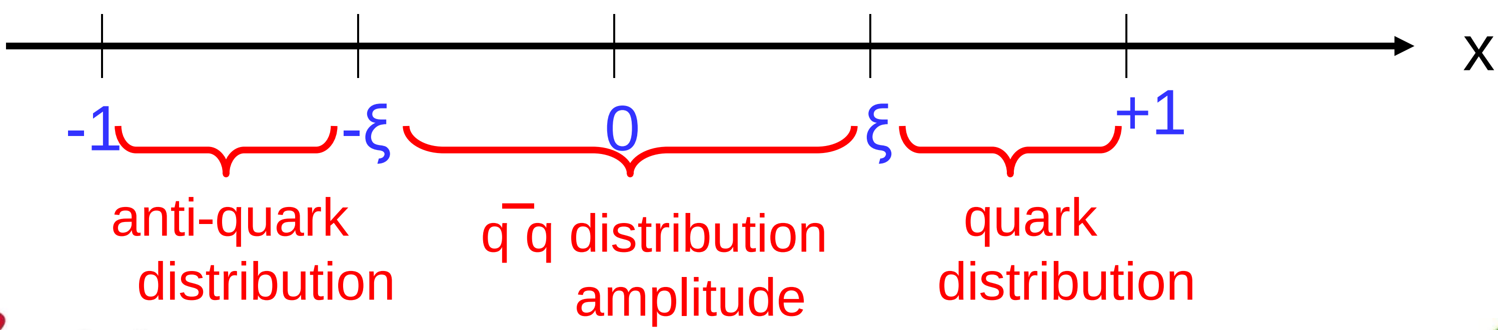
Structure functions, quark longitudinal momentum & helicity distributions

Jefferson Lab

GPDs : x and ξ dependence







known information on GPDs

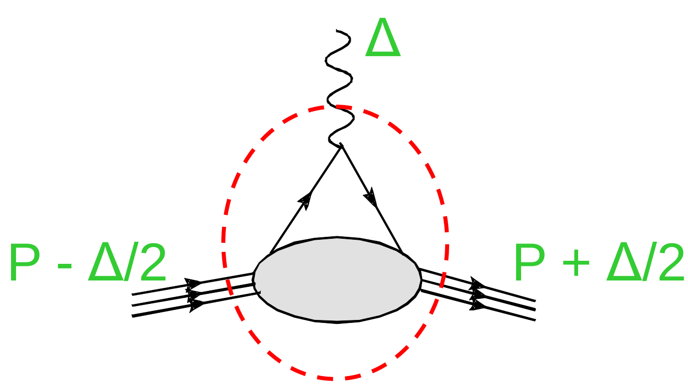
- forward limit : ordinary parton distributions

$$H^q(x, \xi = 0, t = 0) \quad = \quad q(x)$$ unpolarized quark distribution

$$\tilde{H}^q(x, \xi = 0, t = 0) \quad = \quad \Delta q(x)$$ polarized quark distribution

E^q , $\tilde{E}^q$: do NOT appear in DIS ➡ additional information

- first moments : nucleon electroweak form factors



ξ independence : Lorentz invariance

$$\int_{-1}^{1} dx \, H^q(x, \xi, t) \quad = \quad F_1^q(t)$$ Dirac

$$\int_{-1}^{1} dx \, E^q(x, \xi, t) \quad = \quad F_2^q(t)$$ Pauli

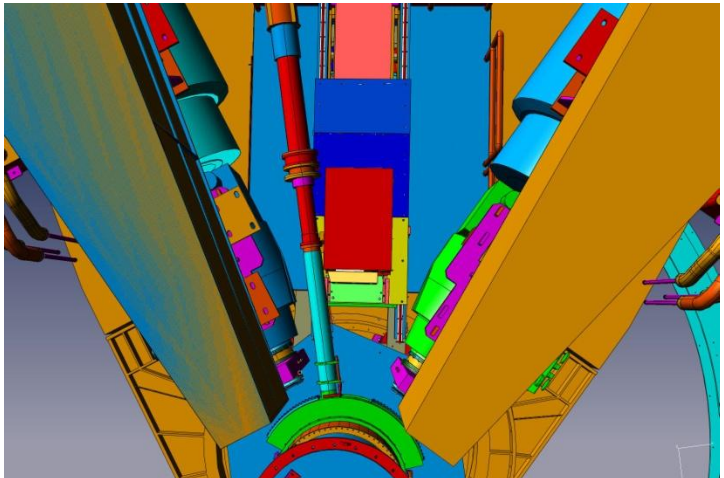
$$\int_{-1}^{1} dx \, \tilde{H}^q(x, \xi, t) \quad = \quad G_A^q(t)$$ axial

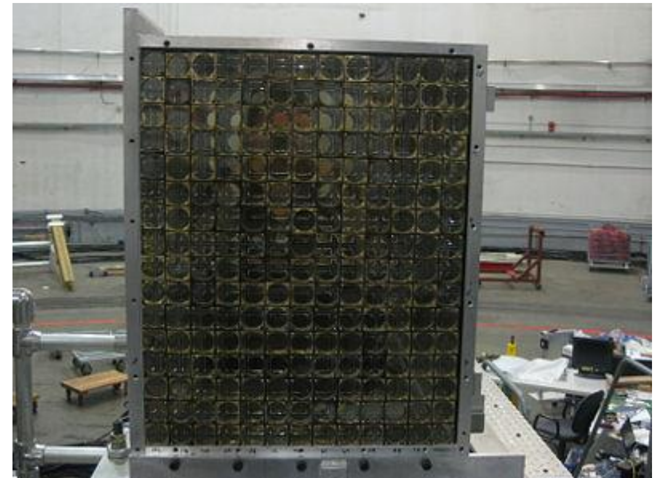
$$\int_{-1}^{1} dx \, \tilde{E}^q(x, \xi, t) \quad = \quad G_P^q(t)$$ pseudo-scalar

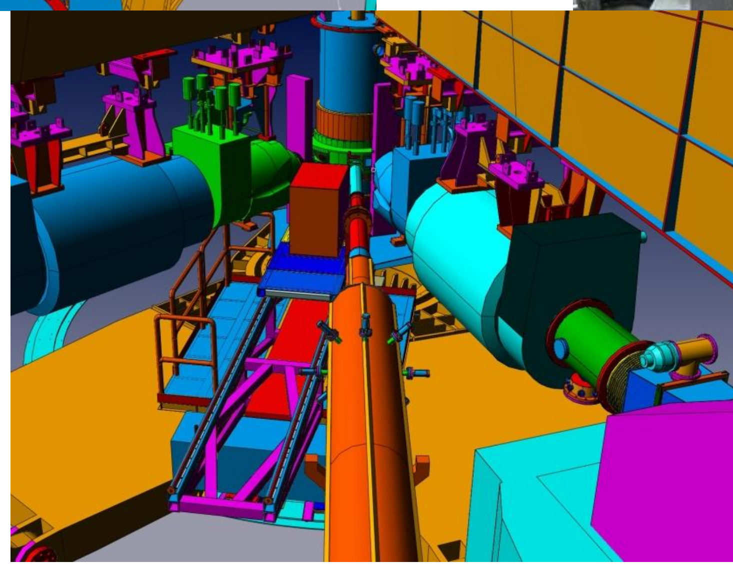
DVCS reaction

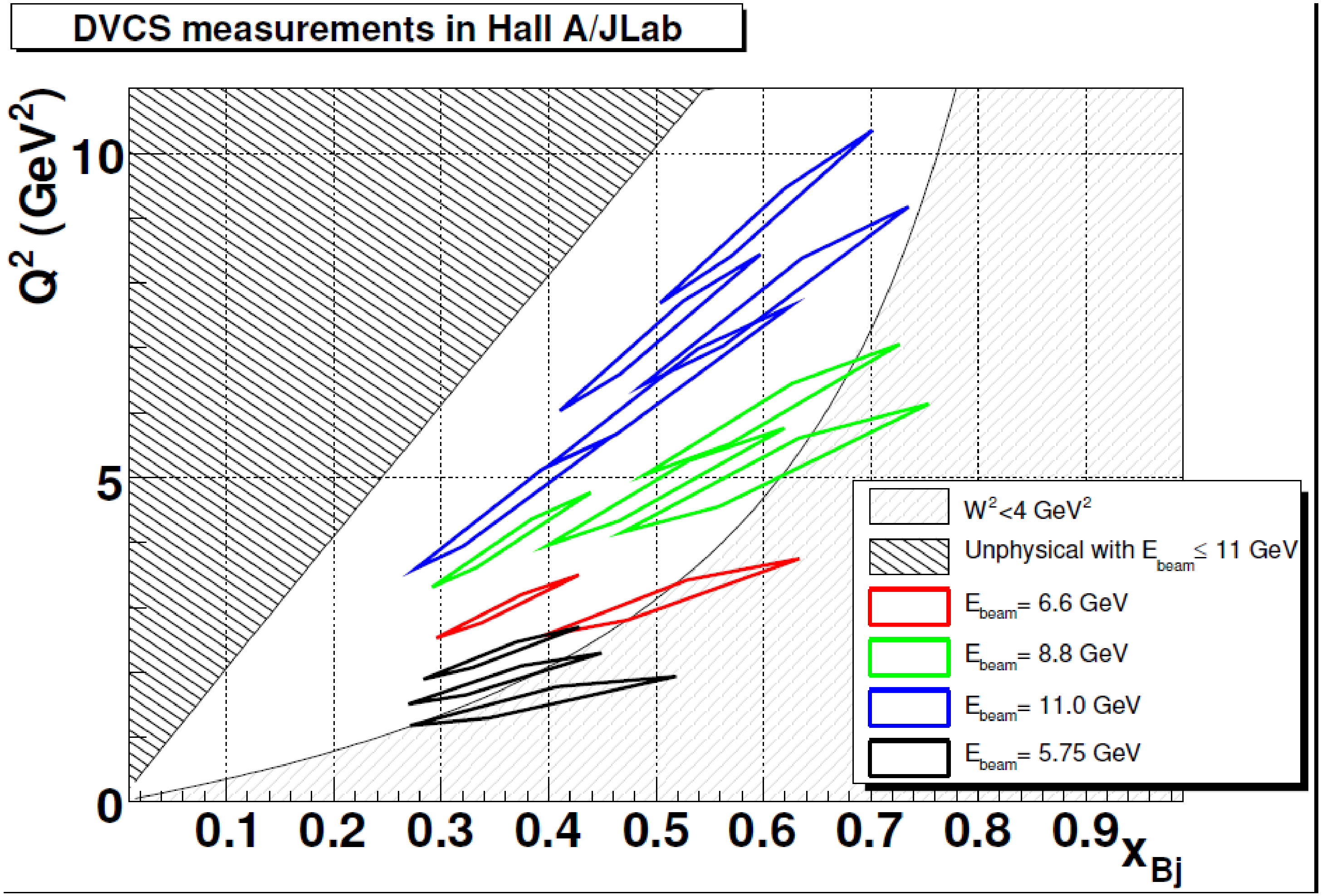
$$\vec{e}\,p \longrightarrow e'p\gamma$$

DVCS 12 GeV setup



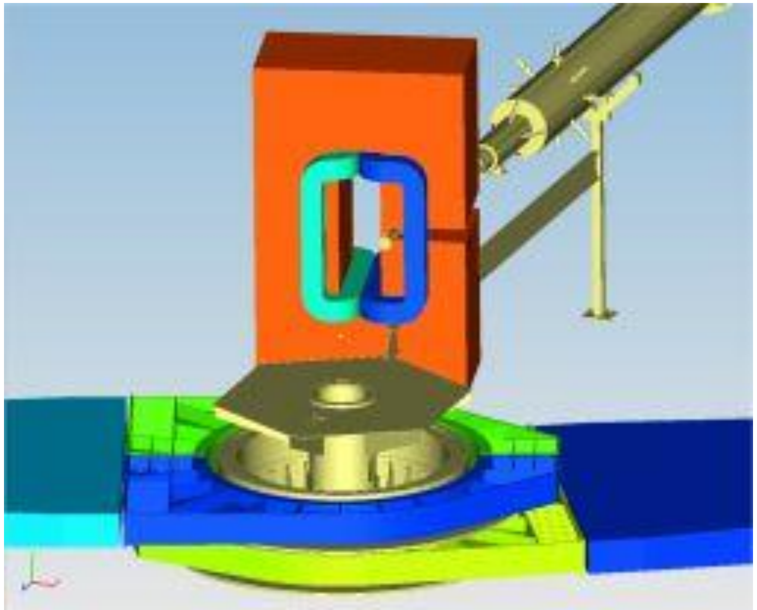






DVCS measurements in Hall A/JLab
Q^2 (GeV^2)
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
x_Bj
W^2<4 GeV^2
Unphysical with E_beam ≤ 11 GeV
E_beam= 6.6 GeV
E_beam= 8.8 GeV
E_beam= 11.0 GeV
E_beam= 5.75 GeV

SuperBigBite spectrometer



- Large dipole D48D48 from Brookhaven laboratory
- Form factor experiments
  - GE_p : Focal plane polarimeter
  - GE_n : BigBite electron + HCAL as neutron detector
  - GM_p : BigBite electron + HCAL as neutron detector
- Large trackers for momentum resolution and Focal Plane polarimeter

Parameters of SBS

Solid angle

$\theta_{central}$, degree	Ω, msr	D, meter	Hor. range, degree	Vert. range, degree
3.5	5	9.5	$\pm$ 1.3	$\pm$3.3
5.0	12	5.8	$\pm$ 1.9	$\pm$4.9
7.5	30	3.2	$\pm$ 3	$\pm$8
15	72	1.6	$\pm$ 4.8	$\pm$12.2
30	76	1.5	$\pm$ 4.9	$\pm$12.5

Resolution:

Momentum =>
$$\frac{\sigma_p}{P} = 0.0029 + 0.0003 \times p[\mathrm{GeV}]$$

Angular =>
$$\sigma_\theta = 0.14 + 1.3/p\ [\mathrm{GeV}],\ \mathrm{mrad}$$

Momentum acceptance =>
$$P \text{ range from } 2 - 10\ ,\ \mathrm{GeV/c}$$

Elastic reactions

Proton elastic form factor

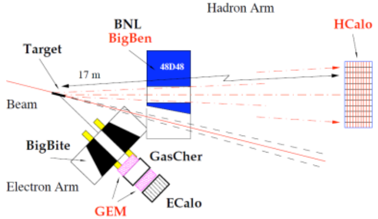
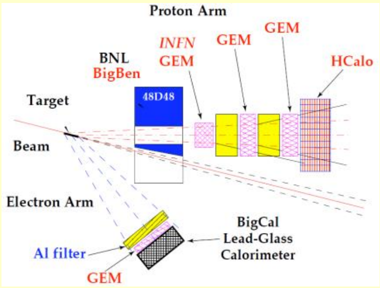
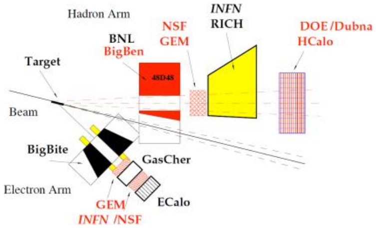
$$\vec{e}\;p \longrightarrow e'\vec{p}$$

Neutron elastic form factor

$$\vec{e}\;\vec{n} \longrightarrow e'n$$

He3
polarized
target

Some challenging experiments in Hall A

Experiments	Luminosity $(s \cdot cm^2)^{-1}$	Tracking Area (cm^2)	Resolution		
			Angular (mrad)	Vertex (mm)	Momentum (%)
GMn - GEn 	up to $7 \cdot 10^{37}$	40x150 and 50x200	< 1	<2	0.5%
GEp(5) 	**up to $8 \cdot 10^{38}$**	40x120, 50x200 and 80x300	<0.7 ~1.5	~ 1	0.5%
SIDIS 	up to $2 \cdot 10^{37}$	40x120, 40x150 and 50x200	~ 0.5	~1	<1%

Most demanding

High Rates

Large Area

Down to ~ 70 μm spatial resolution

SuperBigBite collaborators

- Trackers
  - INFN
  - UVA
- Calorimeters
  - Carnegie Mellon University
  - William and Mary

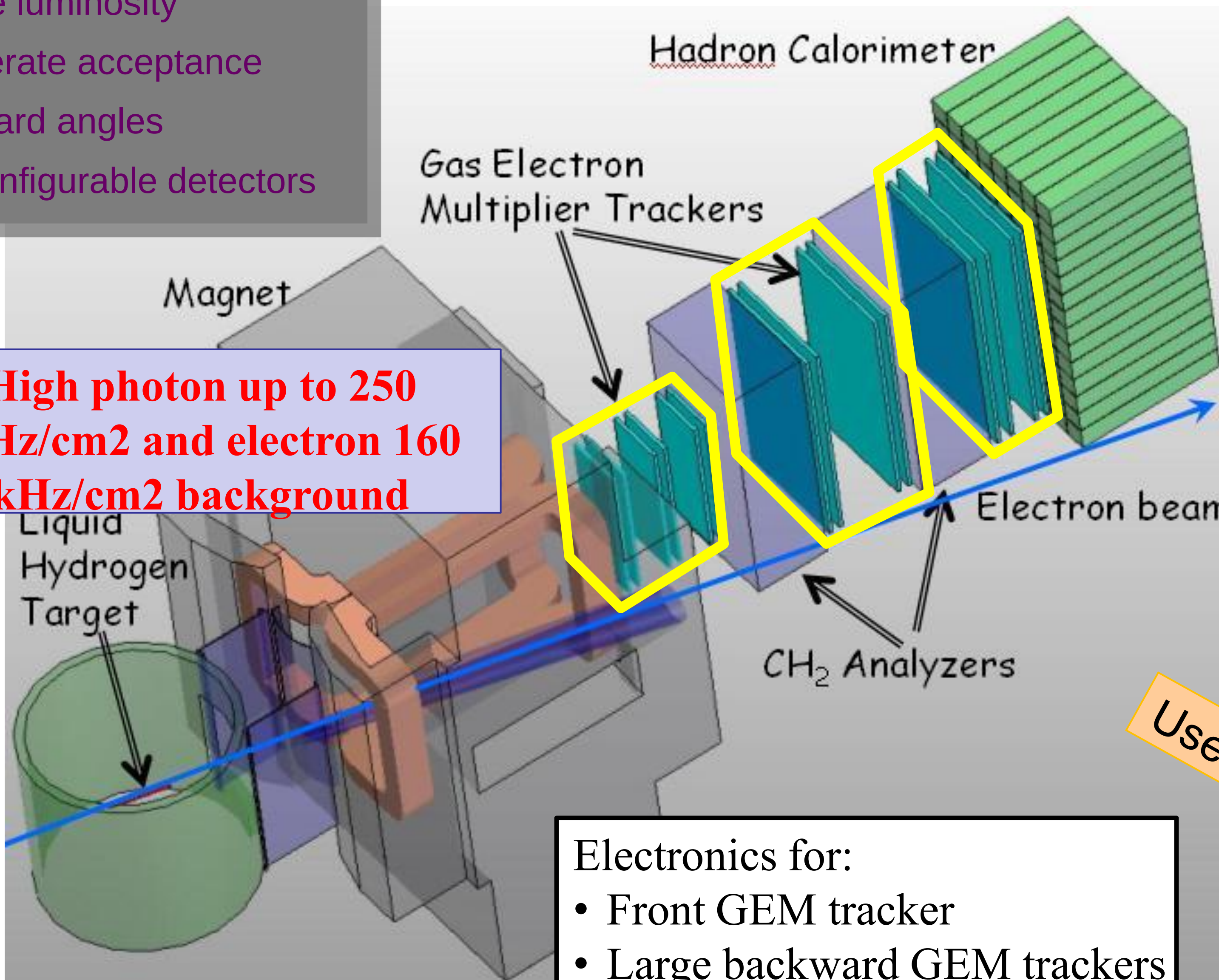
- Up to 101 700 GEM channels

- Modular design

SuperBigbite Spectrometer in Hall A

- Large luminosity
- Moderate acceptance
- Forward angles
- Reconfigurable detectors

High photon up to 250 MHz/cm2 and electron 160 kHz/cm2 background



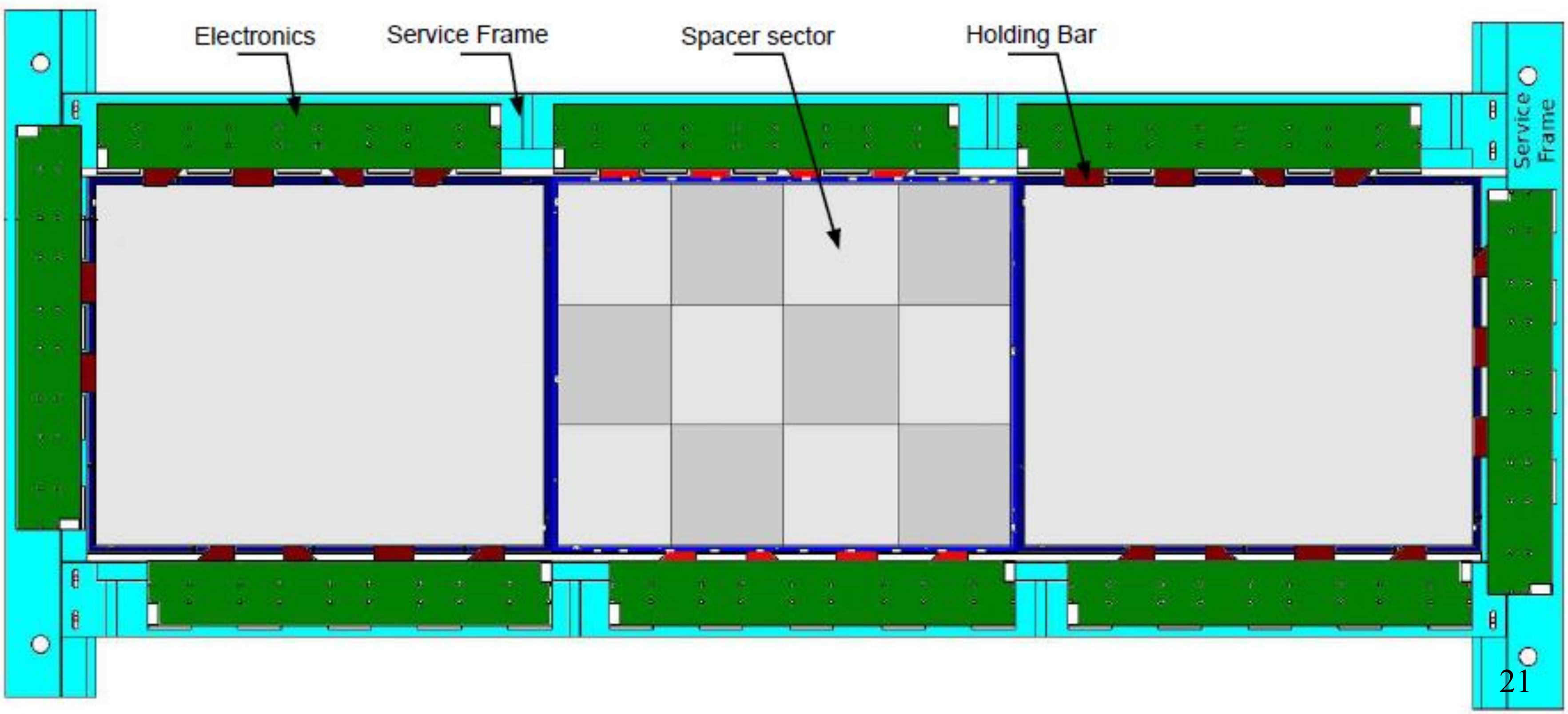
Use VME64x

Electronics for:
- Front GEM tracker
- Large backward GEM trackers

⇨ **>100k channels**

INFN Front Chamber reqs and design

- Hit spatial resolution ~ 70 μm
- Stand large background (γ ~ 250 MHz/cm^2, e/π 160 kHz/cm^2)
- Transverse area at least 40x120 cm^2
- Event rate at the level of 20 kevents/s
- Reuse in different configurations

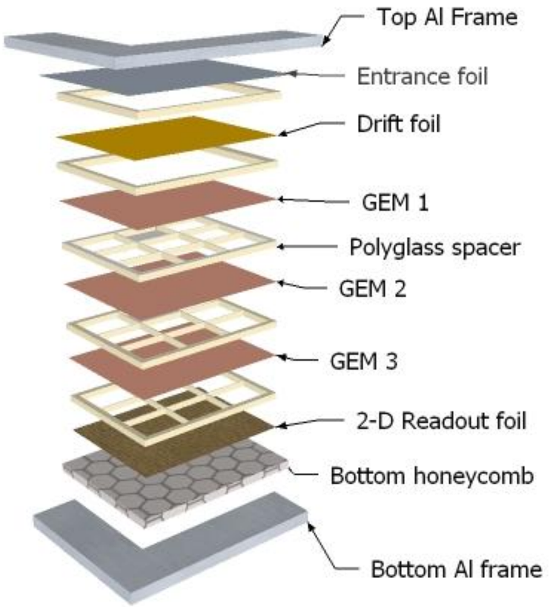


Tracker approach: 40x50 cm^2 Module

- **Use the same "basic" module for all trackers types**
  - Size: 40x50 cm^2 active area + 8 mm frame width
    - FEM study:

Frame width	(mm)	5	6	7	8	9	10
Maximum Sag	(μm)	180	24	21	19	16	12

  - 3 x GEM foils (moving to single mask tech.)
  - 2D strip readout (a la COMPASS) - 0.4 mm pitch
  - x/y coordinates

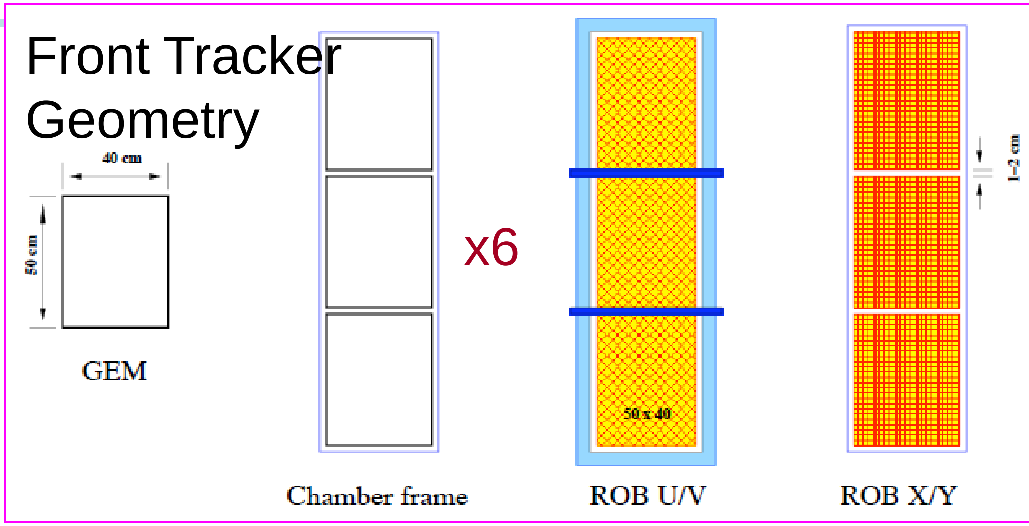


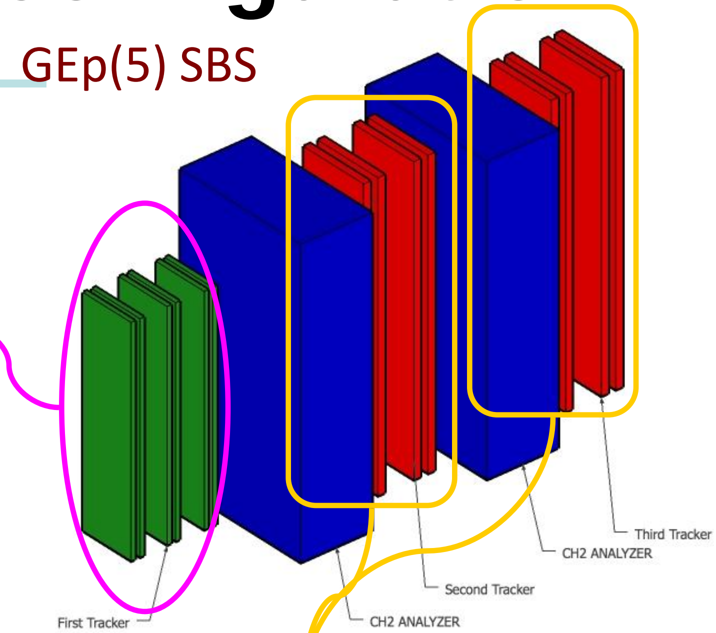
Two exceptions in readout foil:

1. Front Tracker last 2 chambers:
   - Double segmented readout to reduce occupancy
2. Coordinate Detector: 1D strip readout

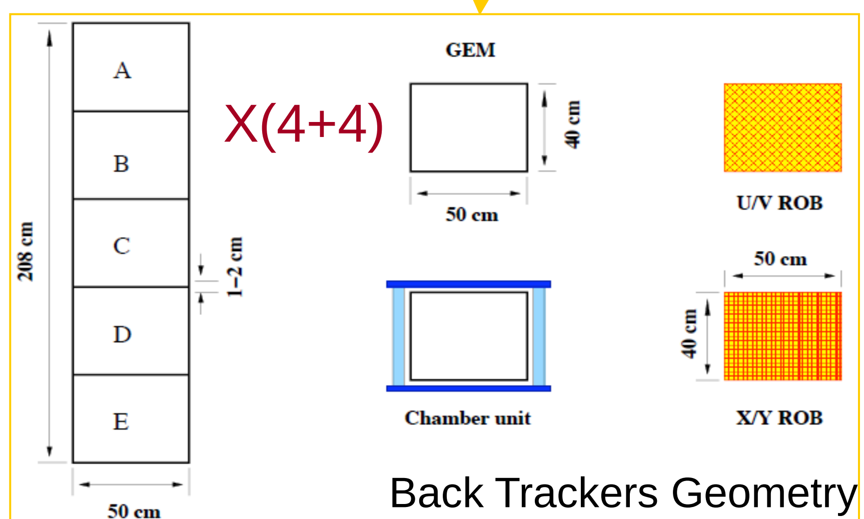
   1 mm pitch

Tracker Chambers configuration



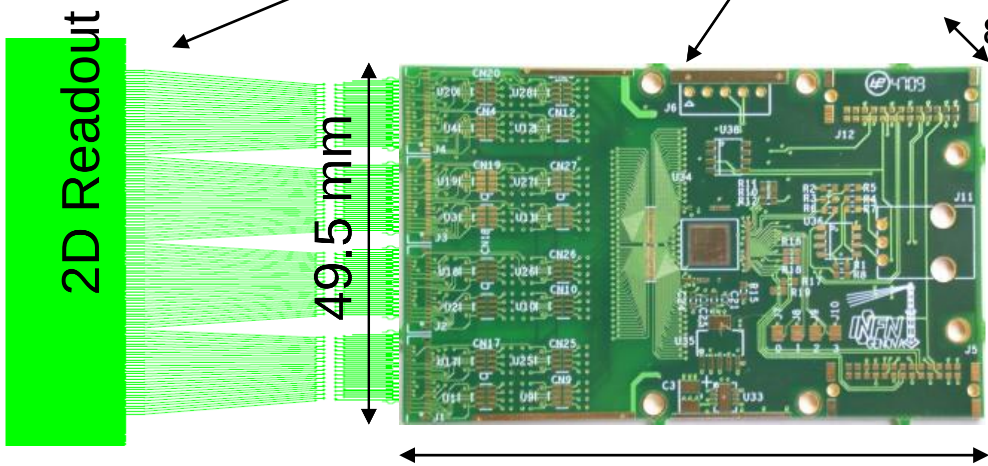


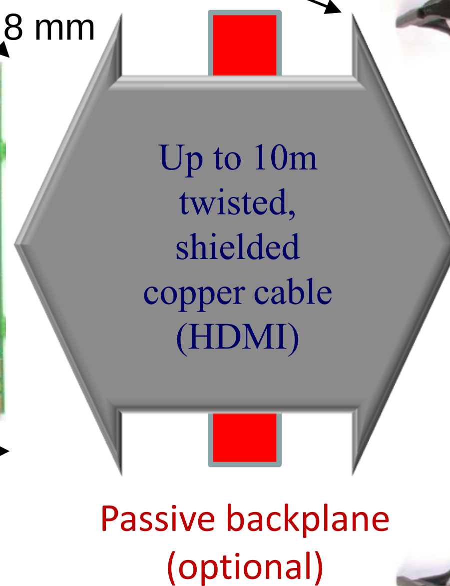
- ✓ Modules are composed to form larger chambers with different sizes
- ✓ **Electronics along the borders and behind the frame (at 90) – cyan and blue in drawing**
- ✓ **Carbon fiber support frame around the chamber (cyan in drawing); dedicated to each chamber configuration**

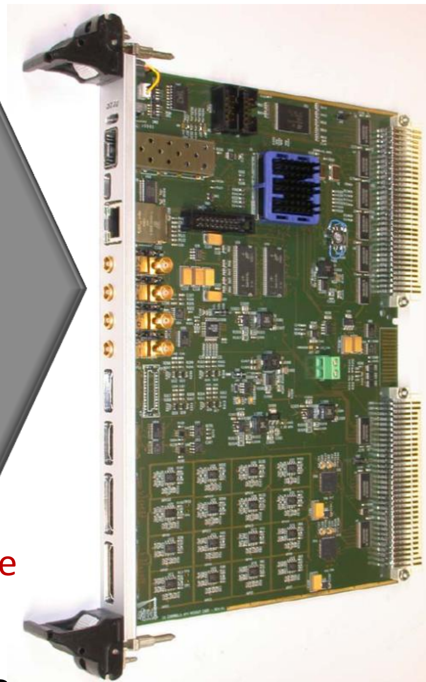


Electronics Components

- GEM ⇒ FEC ⇒ MPD ⇒ DAQ





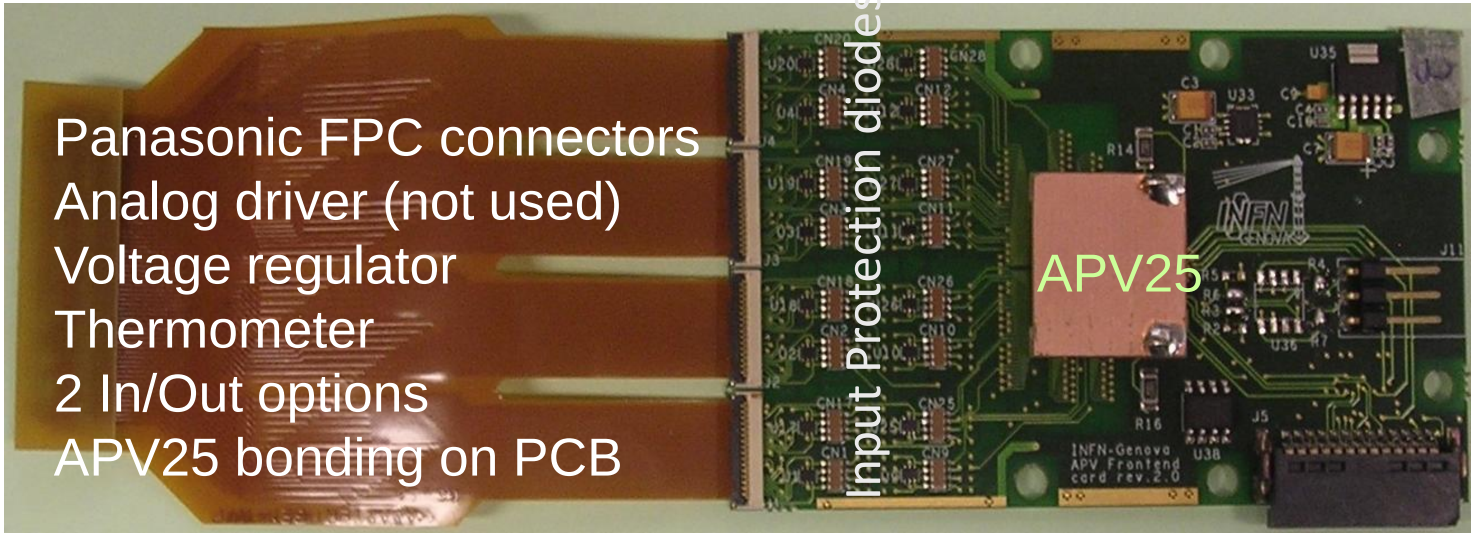


Main features:

- Use analog readout APV25 chips
- 2 “active” components: Front-End card and VME64x custom module
- Copper cables between front-end and VME
- Optional backplane (user designed) acting as signal bus, electrical shielding, GND distributor and mechanical support

Front End Card (Proto 1 – basically final)

- GEM ⇒ **FEC** ⇒ MPD ⇒ DAQ

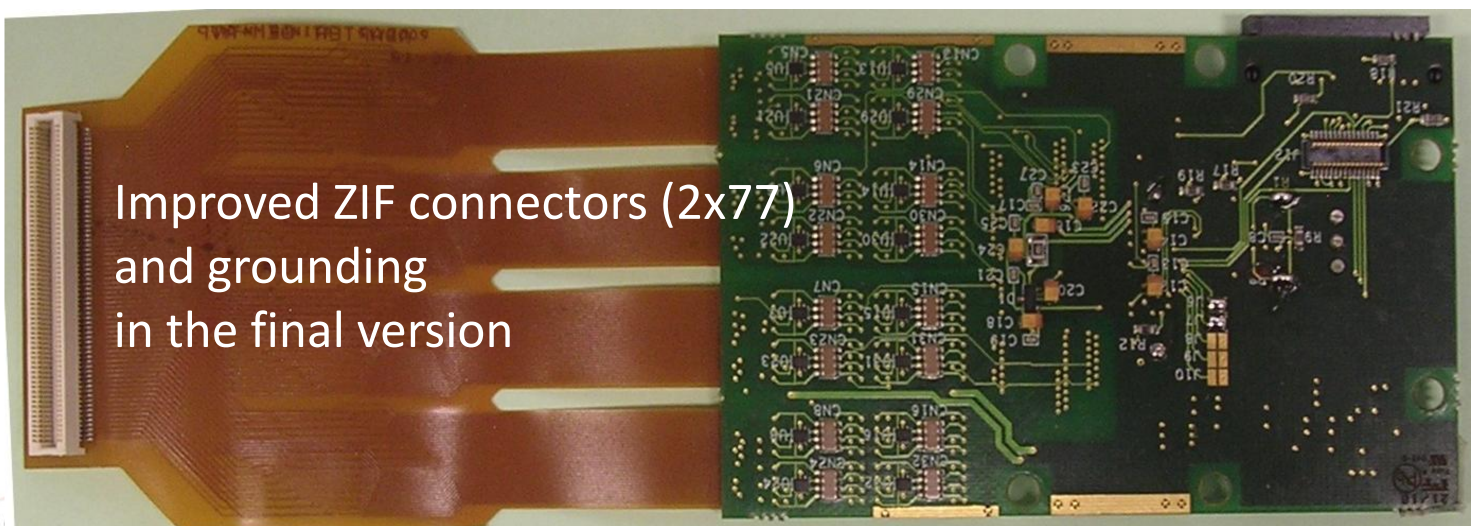


Analog Output

Digital Input + Power supply

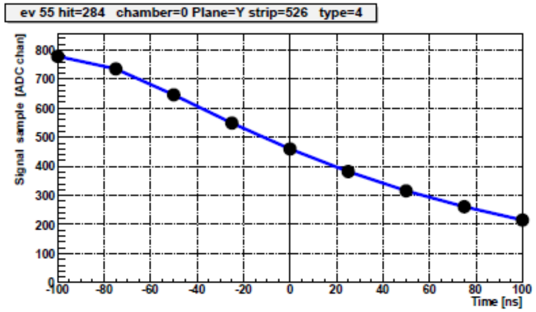
mainl
for
test

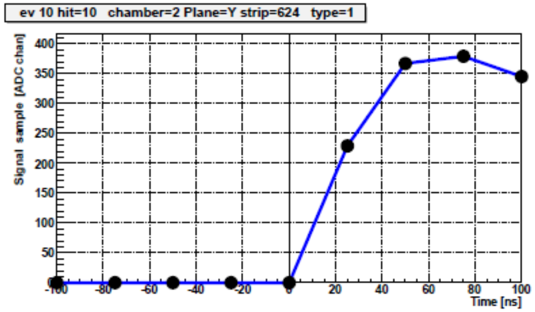
ERNI marketing changed: female connector available only wired

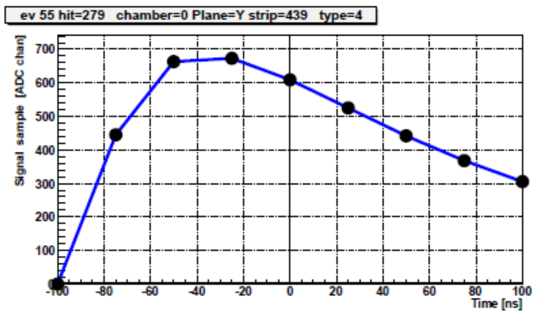


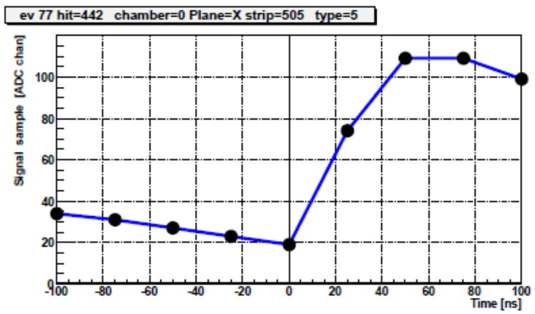
Analog out +
Digital Input +
Power supply

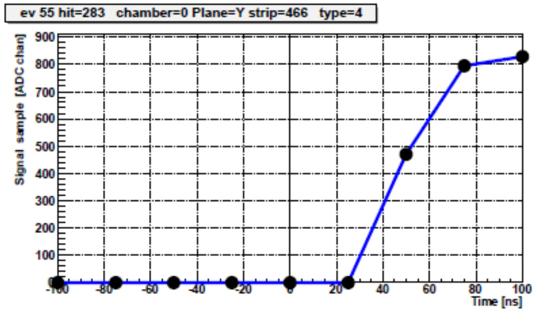
Simulated APV25 GEM signal

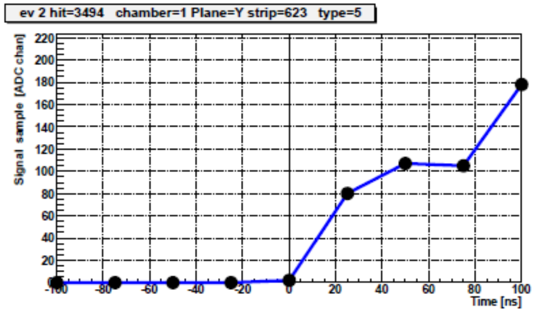




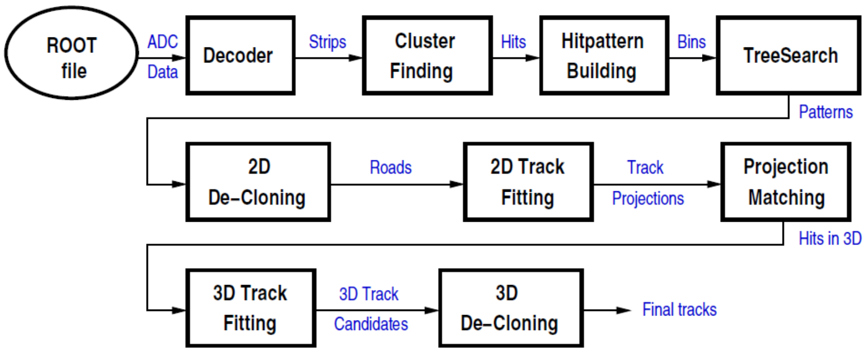


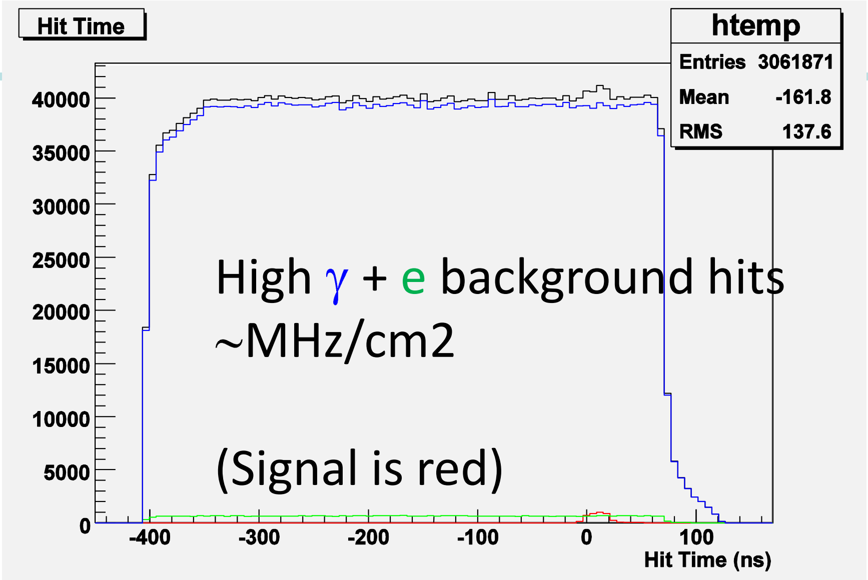






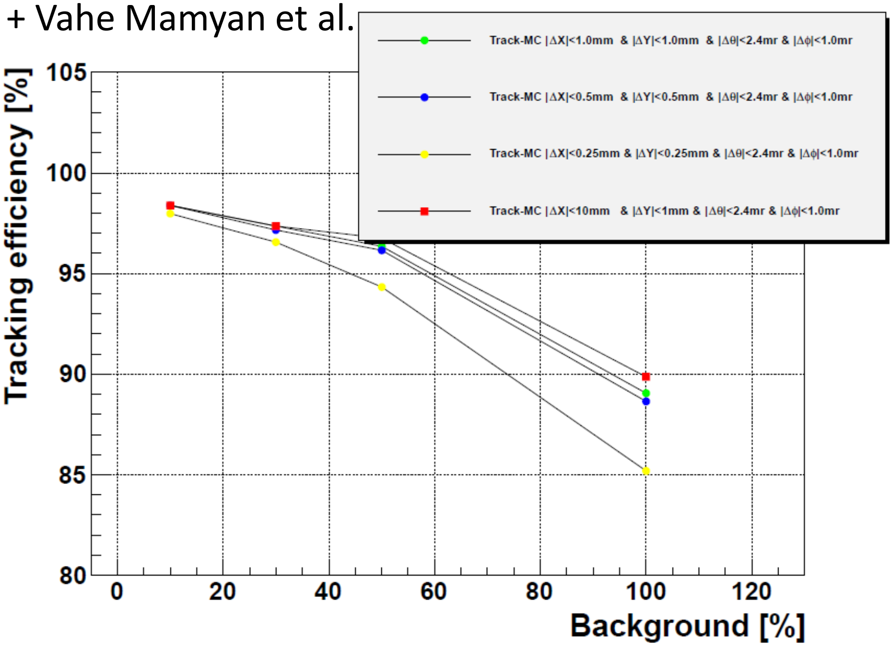
MonteCarlo + Digitazation + Tracking

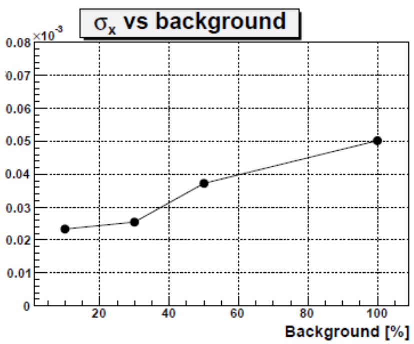


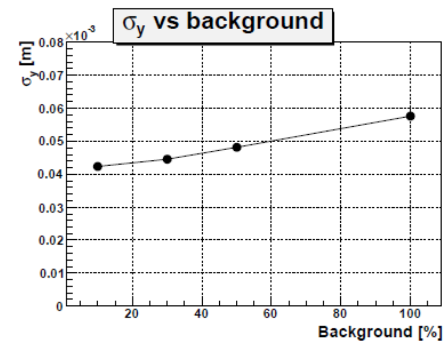


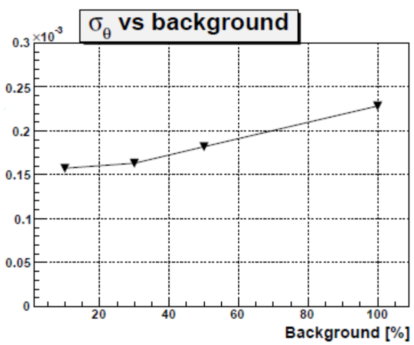
6 GEM chambers with x/y readout
Use multisamples (signal shape)
for background filtering

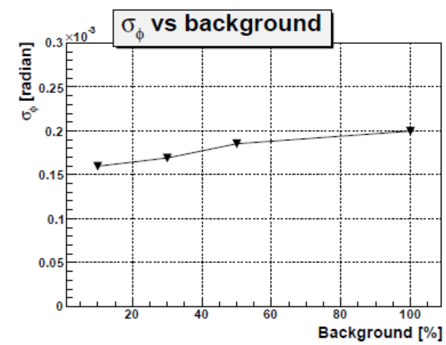
Bogdan Wojtsekhowski + Ole Hansen
+ Vahe Mamyan et al.









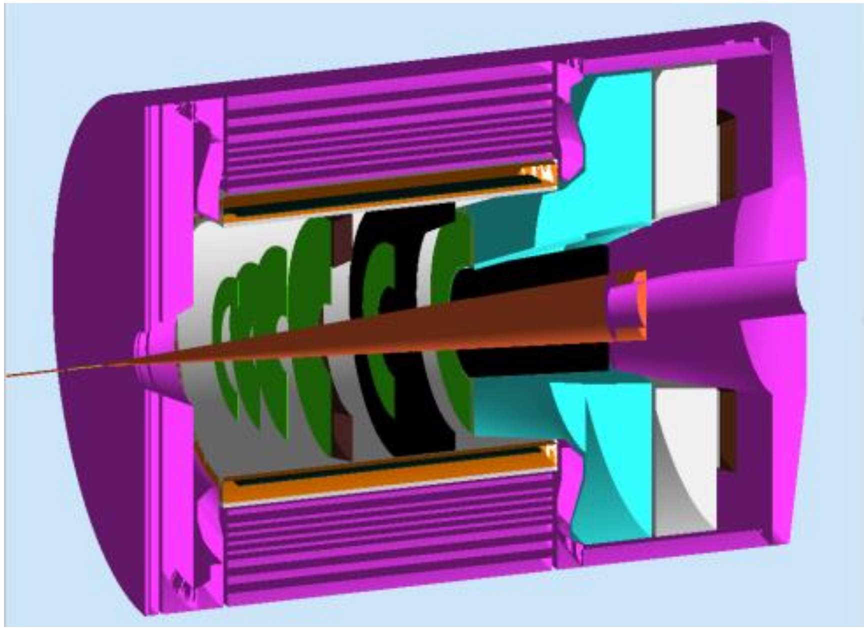


SuperBigBite

- Funded approved by DOE
- Detector will be available in Hall A
- High luminosity, large acceptance design
- 4 experiments approved
- Several possible detector layout

SoLID project

- Solenoidal Large Intensity Device
- Large solenoidal superconducting magnet (CLEO or BABAR magnet)



- Parity violation experiment
- Semi Inclusive Transversity

- Up to 200 KHz trigger rate
- 141 000 channels

- Chinese collaboration
- US institutions

QCD and Hadronic Structure in PV-DIS

Charge Symmetry Violation

- Direct sensitivity of parton-level CSV
- Important implications for PDF's
- *Could be* partial explanation of the NuTeV anomaly

Higher Twist

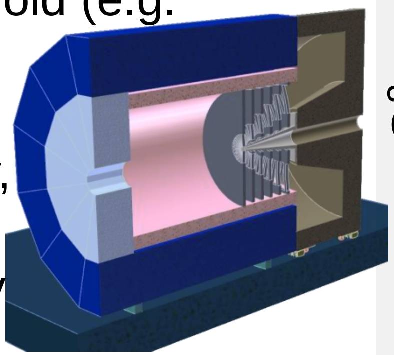
- cancellations isolate effects to coherent operator: Diquarks!
- HT thumbprint (increase with x, Q^2) should be clear if it is significant

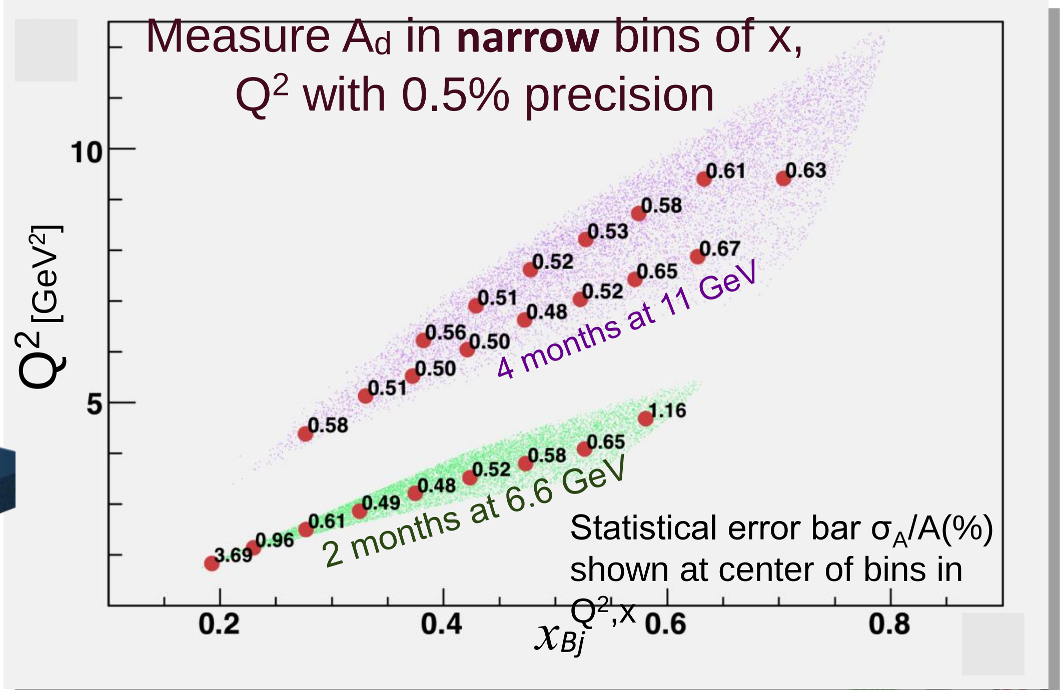
Strategy: requires precise kinematics and broad range

Variations over x, Q^2 can discriminate QCD effects and new physics

SOLID

- Large acceptance spectrometer based on large solenoid (e.g. CLEO)
- High luminosity
- Tracking, calorimetry, Cerenkov detectors
- Precision polarimetry



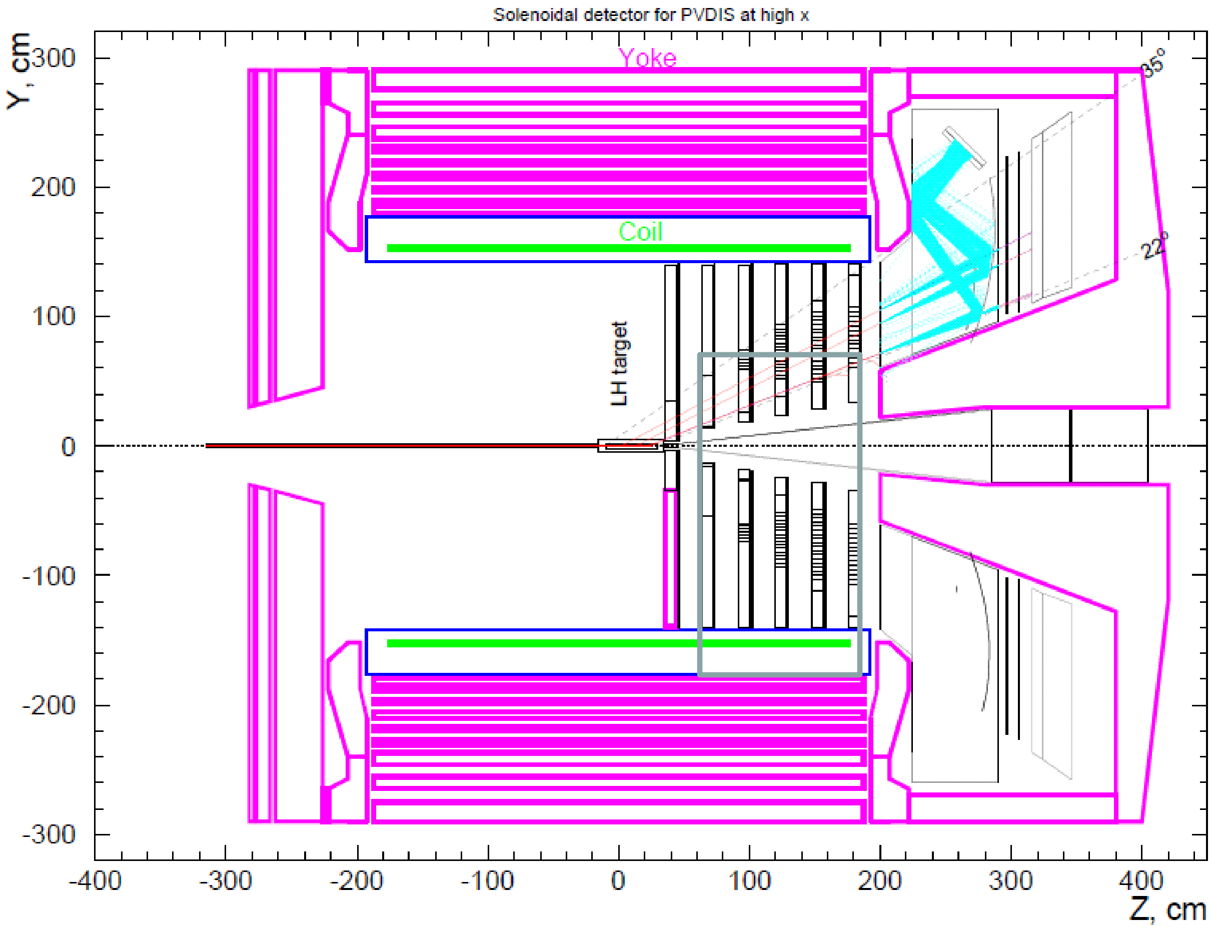


Inclusive reactions

Deuterium target

$$\vec{e}\,d \longrightarrow e'X$$

Detector layout for PVDIS



200 to 500 KHz of electrons

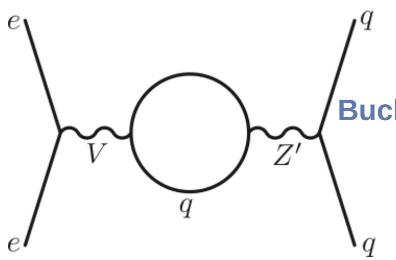
30 individual sectors

Max 17 KHz/sector

SoLID would fill a unique corner of parameter space

No other technique can provide comparable precision on axial hadronic weak neutral currents

Leptophobic Z'



arXiv:1203.1102v1
Buckley and Ramsey-Musolf

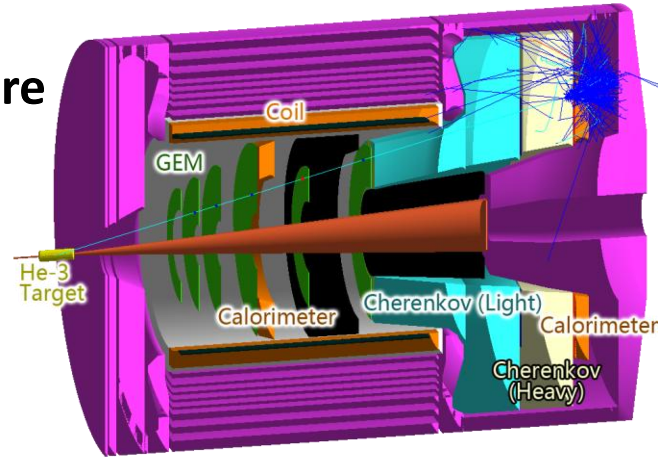
Since electron vertex must be vector, the Z' cannot couple to the C_{1q}'s if there is no electron coupling: can only affect ***C_{2q}'s***

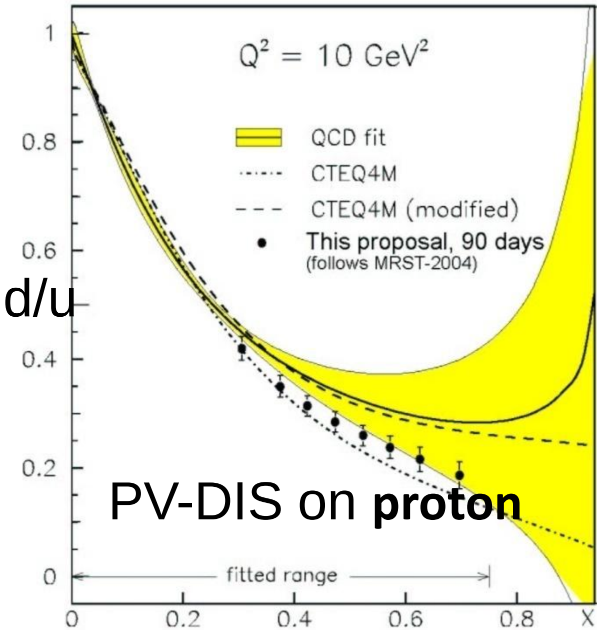
- *Leptophobic Z' as light as 120 GeV could have escaped detection*

Deuterium PV-DIS drives the need for SoLID, but it also supports a <u>broad program of hadronic studies</u>

Transverse Spin Structure semi-inclusive DIS from polarized targets

J/Ψ Production





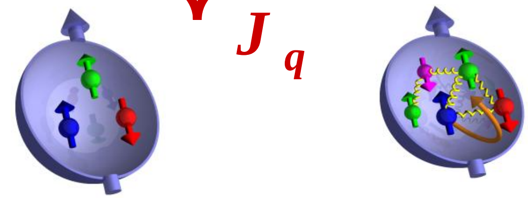
PV-DIS on **proton**

Nucleon Spin Structure

- Understand Nucleon Spin in terms of quarks and gluons (QCD).
  - **Nucleon spin is ½ at all energies, how to divide non trivial (recent development by Chen *et al*., Wakamatsu)**

Nucleon's spin
Ji's Sum Rule
(example)

$$\frac{1}{2} = \underbrace{\frac{1}{2}\sum_f (q_f^+ - q_f^-) + L_q}_{J_q} + J_g$$

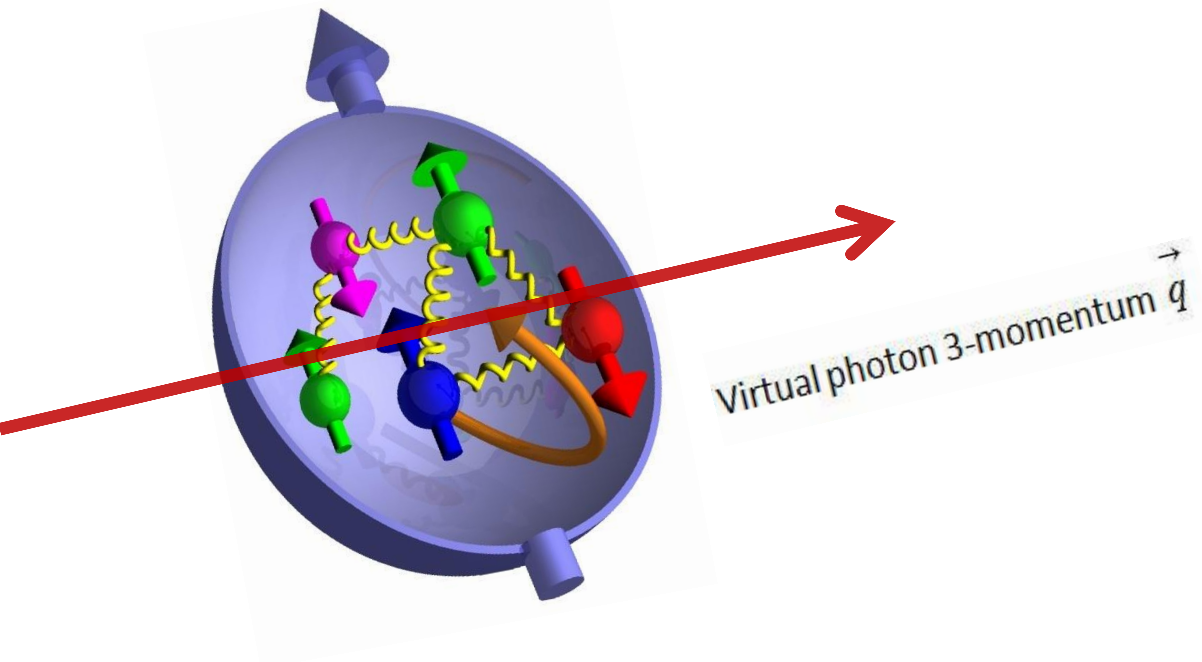


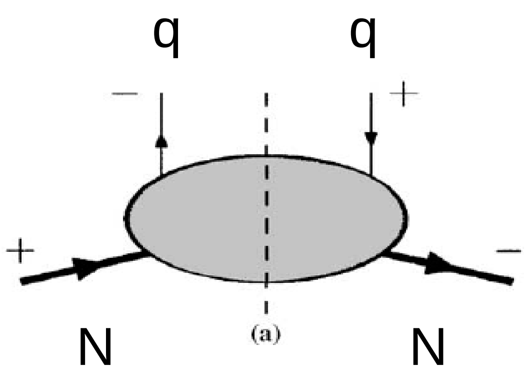
~30% from quark spin by EMC
1/3 confirmed by more precise data
Gluon intrinsic spin contribution not large

  - Small contribution from quarks and gluons' intrinsic spin
  - Orbital angular momentum of quarks and gluons is important
    - **Understanding of spin-orbit correlations.**

Transverse Spin Structure

Longitudinal Spin structure function: g_{1L}
Its transverse spin counter part (**Transversity**): h





$$\text{Nucleon tensor charge} = \int_{-1}^{1} h_{1T}\, dx$$

All Leading Twist TMDs

→ Nucleon Spin
→ Quark Spin

Nucleon Polarization		Quark polarization: Un-Polarized	Quark polarization: Longitudinally Polarized	Quark polarization: Transversely Polarized
	U	f_1 =		$h_1^{\perp}$ = − **Boer-Mulder**
	L		g_1 = − **Helicity**	$h_{1L}^{\perp}$ = −
	T	$f_{1T}^{\perp}$ = − **Sivers**	$g_{1T}^{\perp}$ = −	h_{1T} = − **Transversity** $h_{1T}^{\perp}$ = − **Pretzelosity**

Semi Inclusive reactions

Polarized He3 target

Detect one pion in the final state

$$\vec{e}\,\vec{n} \longrightarrow e'\pi^{+/-}X$$

Access Parton Distributions through Semi-Inclusive DIS

$$\frac{d\sigma}{dxdyd\phi_S dzd\phi_h dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\cdot$$

$$\{F_{UU,T} + \ldots$$
$$+\varepsilon\cos(2\phi_h)\cdot F_{UU}^{\cos(2\phi_h)} + \ldots$$

Unpolarized

$$+S_L[\varepsilon\sin(2\phi_h)\cdot F_{UL}^{\sin(2\phi_h)} + \ldots]$$
$$+S_T[\varepsilon\sin(\phi_h+\phi_S)\cdot F_{UT}^{\sin(\phi_h+\phi_S)}$$
$$+\sin(\phi_h-\phi_S)\cdot(F_{UL}^{\sin(\phi_h-\phi_S)} + \ldots)$$
$$+\varepsilon\sin(3\phi_h-\phi_S)\cdot F_{UT}^{\sin(3\phi_h-\phi_S)} + \ldots]$$

Polarized Target

$$+S_L\lambda_e[\sqrt{1-\varepsilon^2}\cdot F_{LL} + \ldots]$$
$$+S_T\lambda_e[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\cdot F_{LT}^{\cos(\phi_h-\phi_S)} + \ldots]\}$$

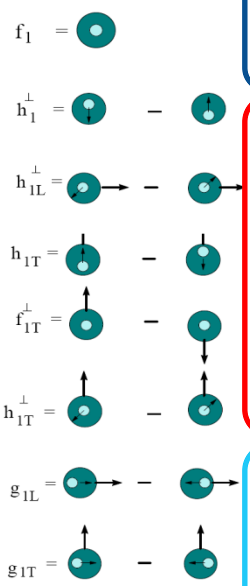
Polarized Beam and Target

Boer-Mulder

Transversity

Sivers

Pretzelosity



S_L, S_T: Target Polarization; λ_e: Beam Polarization

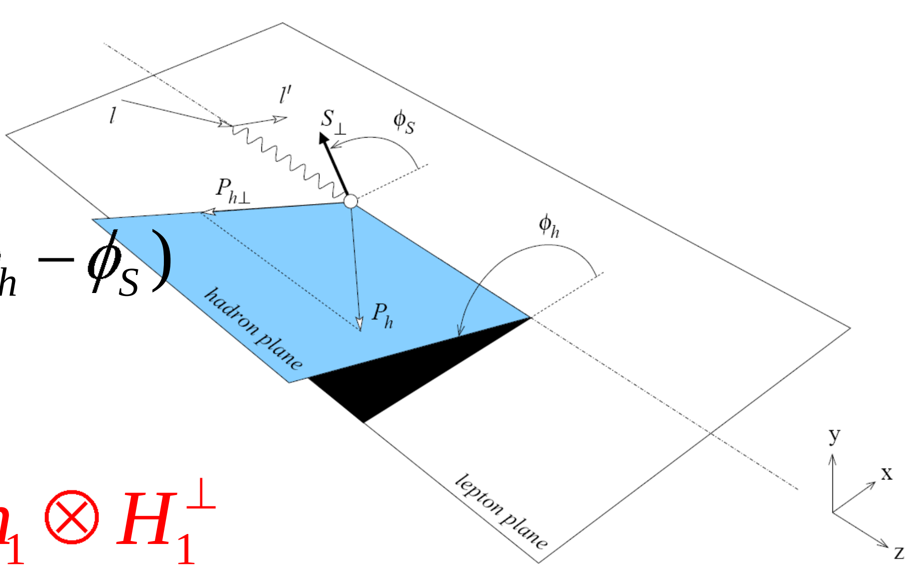
Jefferson Lab

Separation of Collins, Sivers and pretzelocity effects through angular dependence

$$A_{UT}(\varphi_h^l, \varphi_S^l) = \frac{1}{P}\frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

$$= A_{UT}^{Collins}\sin(\phi_h + \phi_S) + A_{UT}^{Sivers}\sin(\phi_h - \phi_S)$$

$$+ A_{UT}^{Pretzelosity}\sin(3\phi_h - \phi_S)$$



$$A_{UT}^{Collins} \propto \langle \sin(\phi_h + \phi_S) \rangle_{UT} \propto h_1 \otimes H_1^{\perp}$$

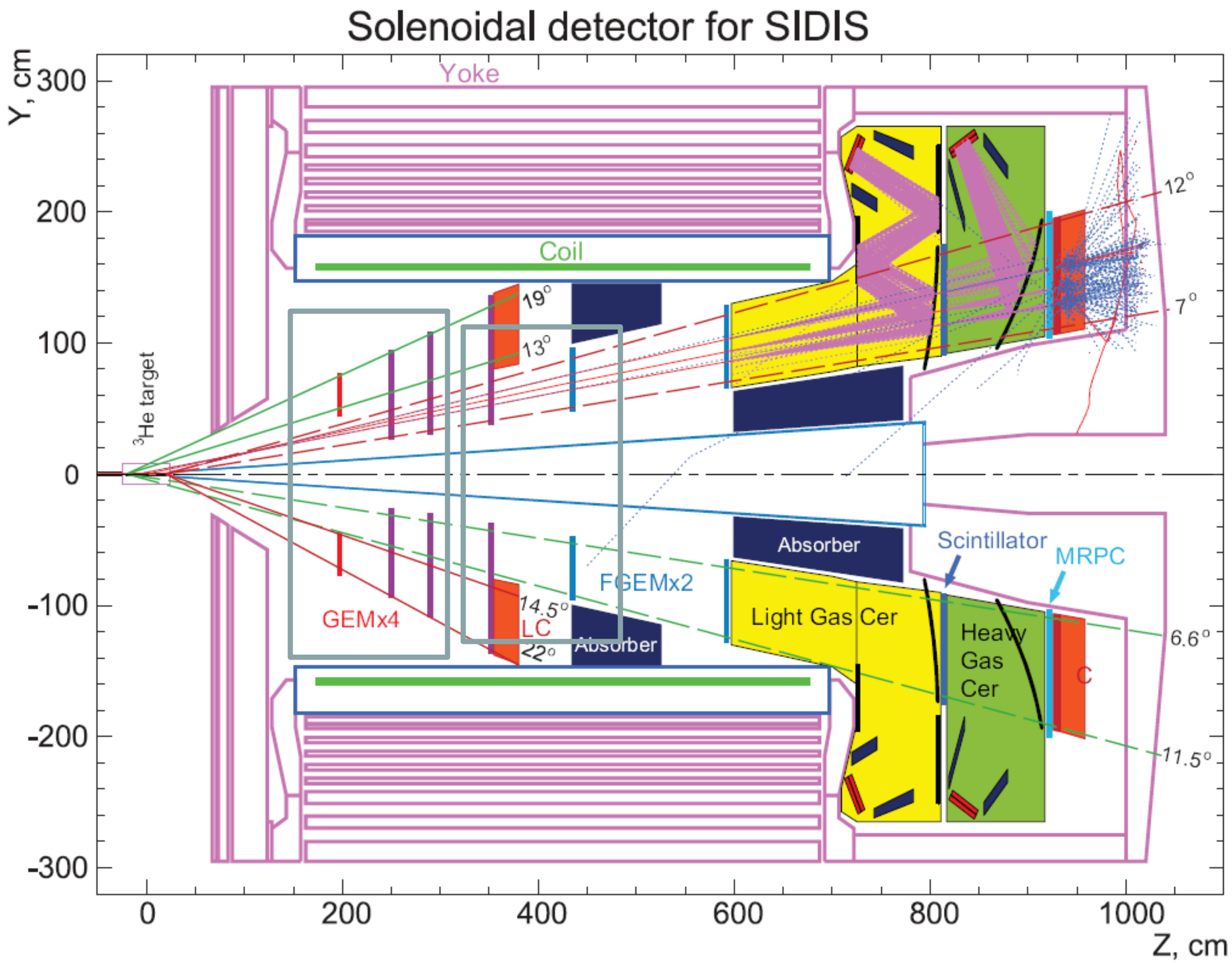
$$A_{UT}^{Sivers} \propto \langle \sin(\phi_h - \phi_S) \rangle_{UT} \propto f_{1T}^{\perp} \otimes D_1$$

$$A_{UT}^{Pretzelosity} \propto \langle \sin(3\phi_h - \phi_S) \rangle_{UT} \propto h_{1T}^{\perp} \otimes H_1^{\perp}$$

SIDIS SSAs depend on 4-D variables (x, Q^2, z and P_T)

Large angular coverage and precision measurement of asymmetries in 4-D phase space is essential.

Detector layout for SIDIS



Max rate 300 KHz

UVA SoLID

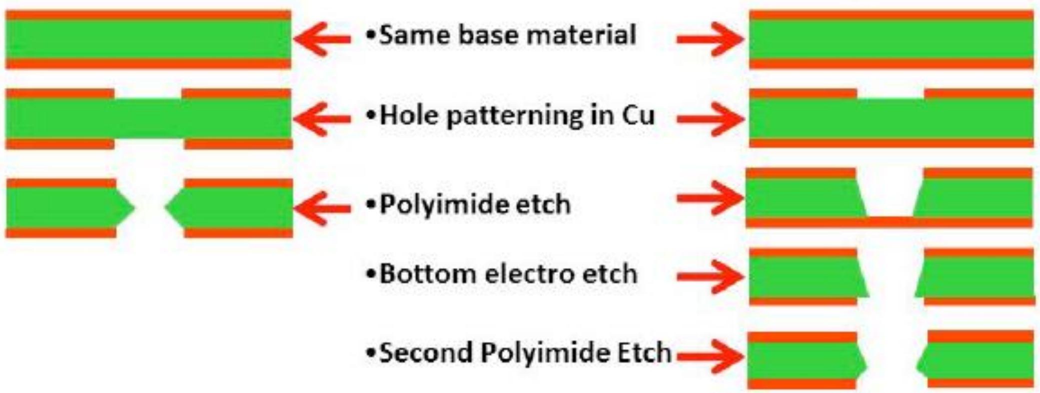
Single Mask Technology

GEM double mask Vs GEM single Mask

- Base material : Polyimide 50um + 5um on both sides
- Polyimide : Apical NP from company Kaneka (Japan)
- Supplier of the copper clad material : Nippon Mining (Japan)

Original method
- Double mask

Last few years
- Single mask



CMS Upgrade Prototype (42cm x 990 cm)

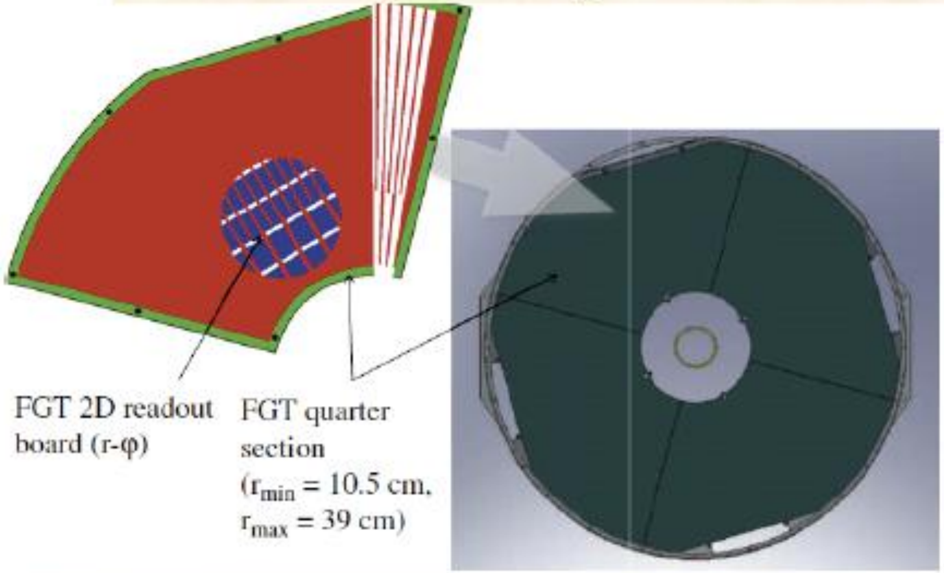
- Limited to 40cm x 40cm due to
  - Mask precision and alignment

- Limited to 2m x 60cm due to
  - Base material
  - Equipment

08/29/2011 Rui De Oliveira 5

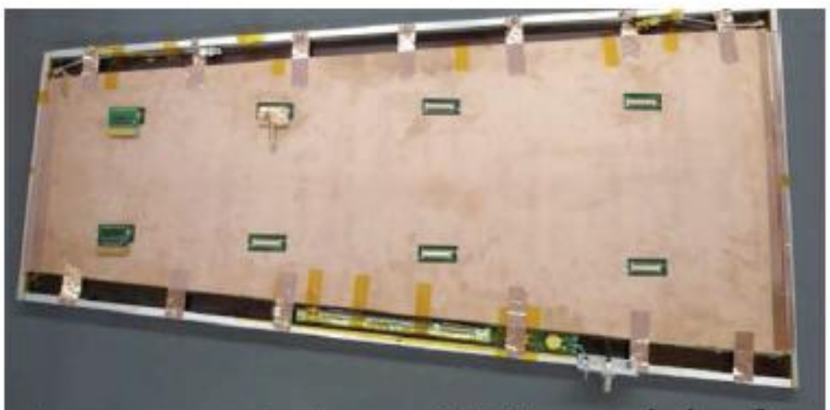
Large size available in recent years!

Large GEM chamber projects

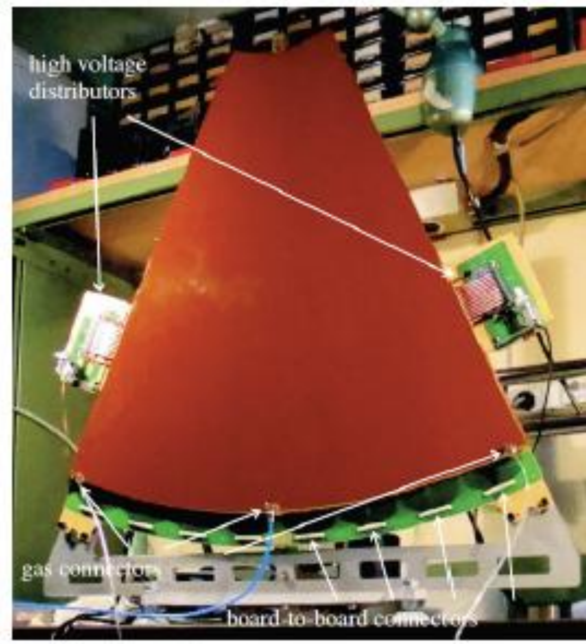


STAR Front GEM Tracker

- 6 triple-GEM disks around beam
- IR~10.5 cm, OR~39 cm
- APV25 electronics



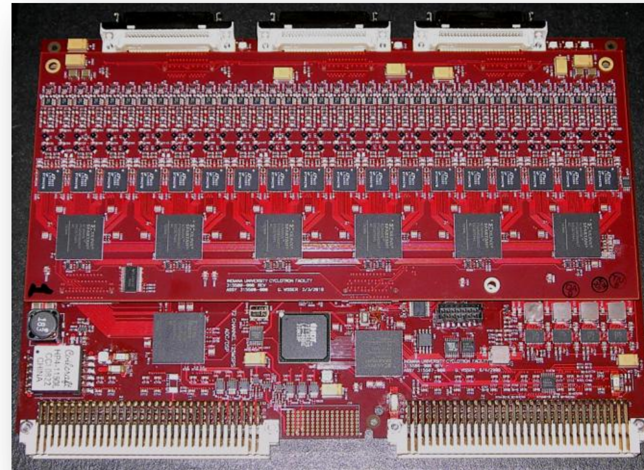
Large prototype GEM module for CMS: 99 cm x (22 – 45.5) cm



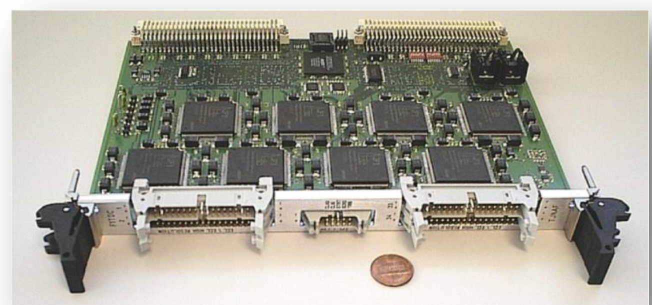
TOTEM T1 prototype made with single mask GEM foils (33 cm x 66 cm)

Custom Electronics for JLab

- VME Switched Serial (VXS) backplate
  - 10 Gbps to switch module (J_0)
  - 320 MB/s VME-2eSST (J_1/J_2)
- All payload modules are fully pipelined
  - **FADC125** (12 bit, 72 ch)
  - **FADC250** (12 bit, 16 ch)
  - **F1-TDC** (60 ps, 32 ch or 115 ps, 48 ch)
- Trigger Related Modules
  - **C**rate **T**rigger **P**rocessor (**CTP**)
  - **S**ub-**S**ystem **P**rocessor (**SSP**)
  - **G**lobal **T**rigger **P**rocessor (**GTP**)
  - **T**rigger **S**upervisor (**TS**)
  - **T**rigger **I**nterface/Distribution(**TI/D**)
  - **S**ignal **D**istribution (**SD**)

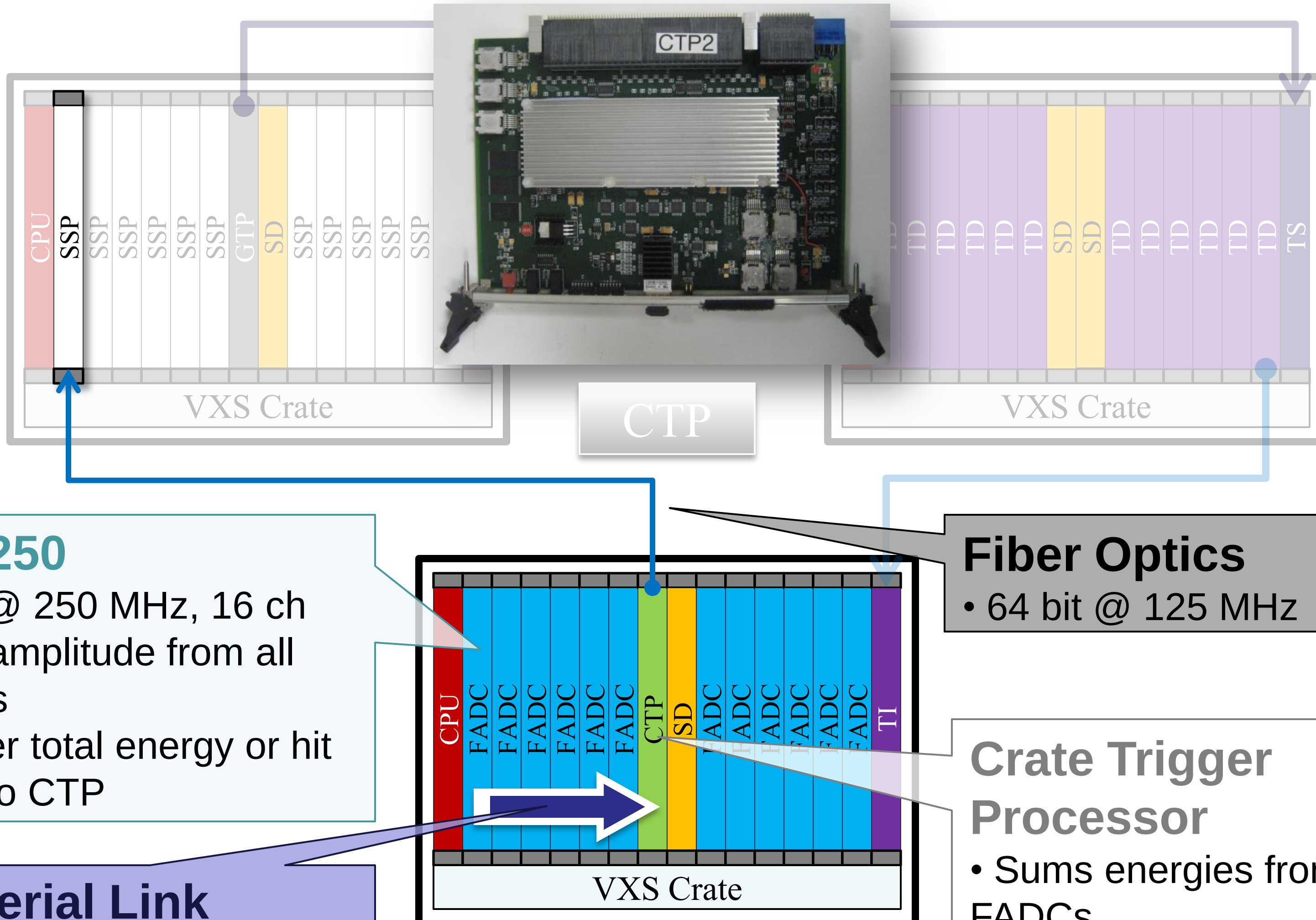


FADC125



F1-TDC

L1 Trigger Diagram



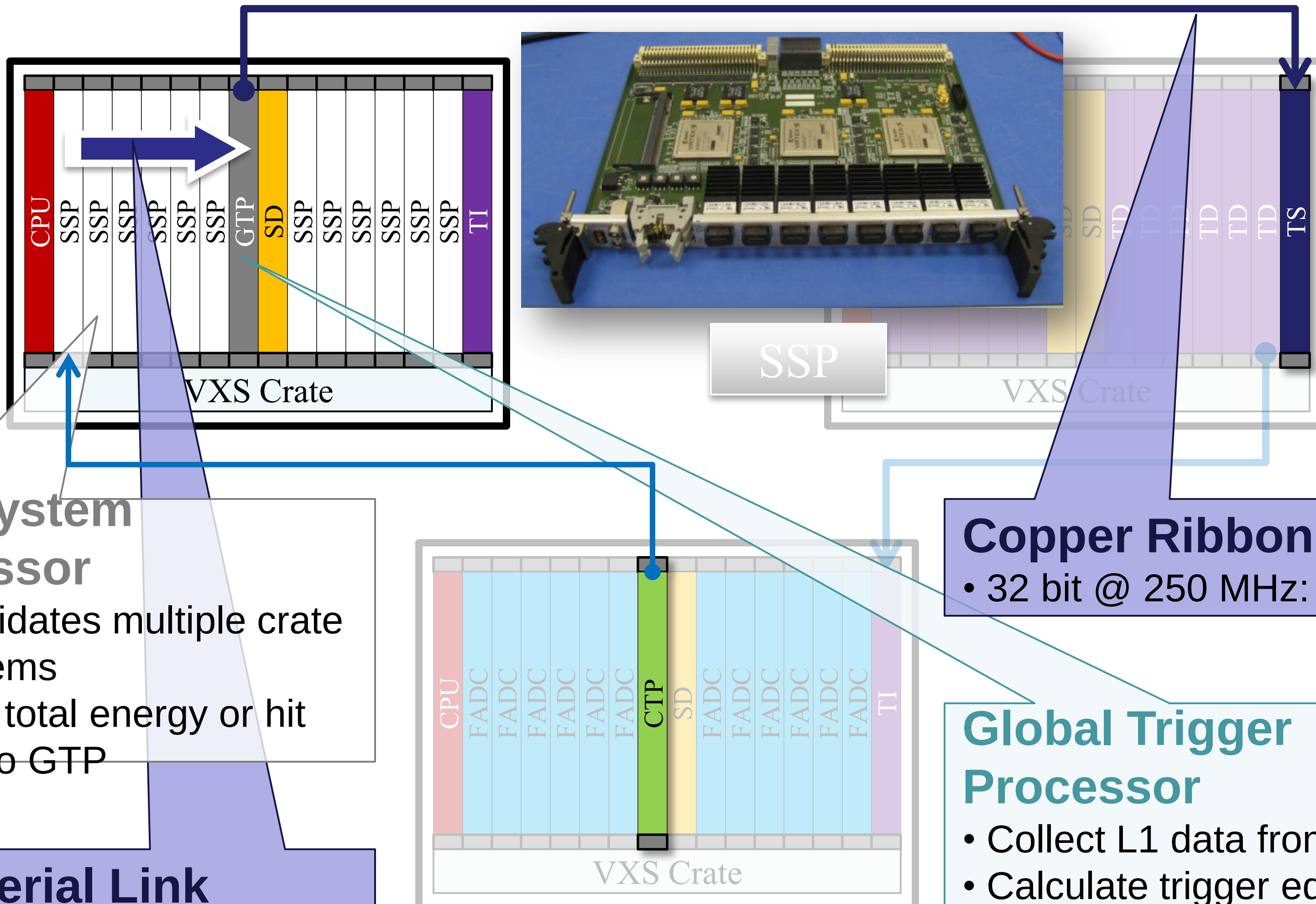
FADC250
- 12 bit @ 250 MHz, 16 ch
- Sums amplitude from all channels
- Transfer total energy or hit pattern to CTP

Fiber Optics
- 64 bit @ 125 MHz

VXS Serial Link
- 16 bit @ 250 MHz: 4 Gbps

Crate Trigger Processor
- Sums energies from FADCs
- Transfer total energy or hit pattern to SSP

L1 Trigger Diagram



Sub-System Processor

- Consolidates multiple crate subsystems
- Report total energy or hit pattern to GTP

VXS Serial Link

- 32 bit @ 250 MHz: 8 Gbps

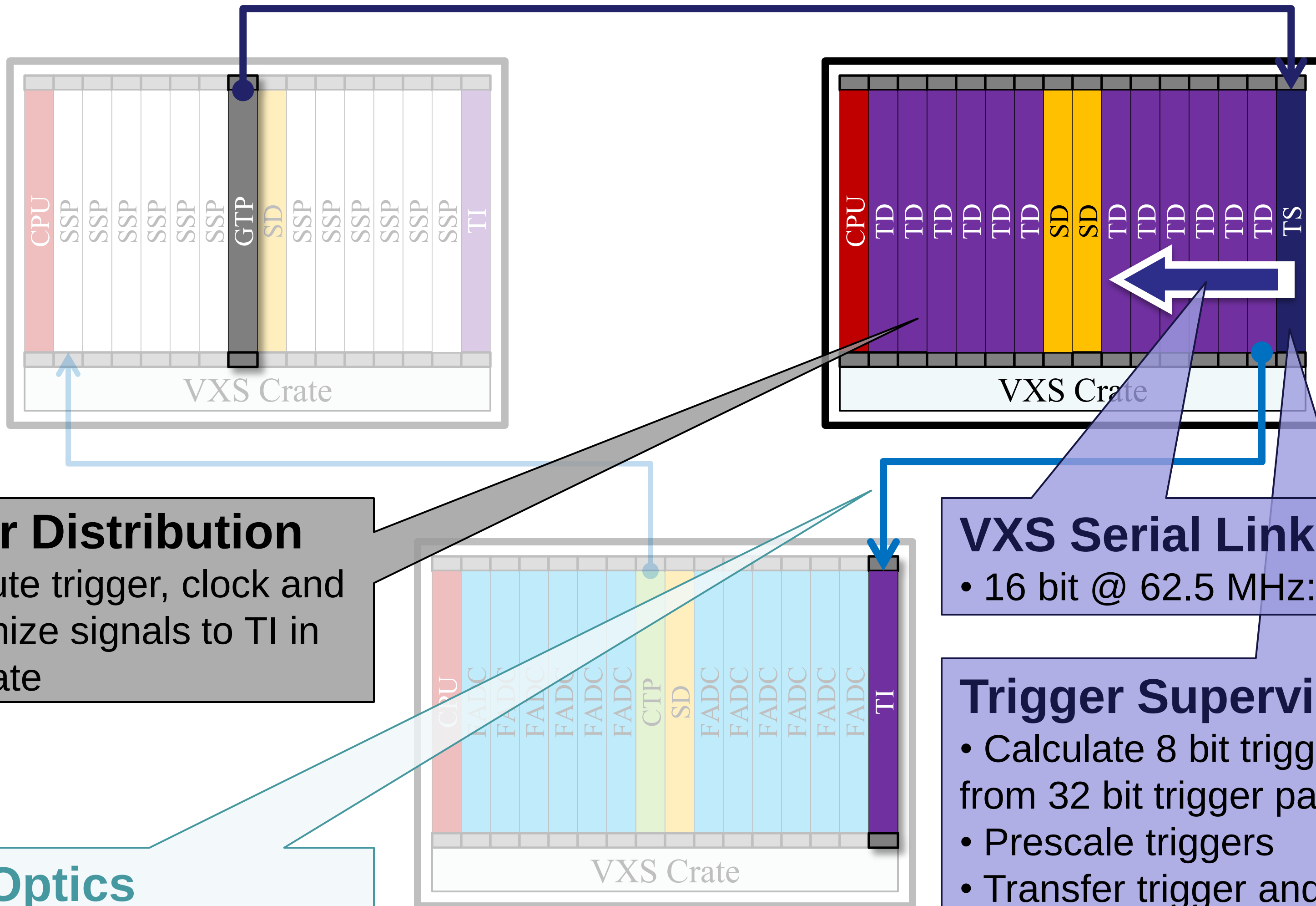
Copper Ribbon Cable

- 32 bit @ 250 MHz: 8 Gbps

Global Trigger Processor

- Collect L1 data from SSPs
- Calculate trigger equations
- Transfer 32 bit trigger pattern to TS

L1 Trigger Diagram



Trigger Distribution

- Distribute trigger, clock and synchronize signals to TI in each Crate

VXS Serial Link

- 16 bit @ 62.5 MHz: 1 Gbps

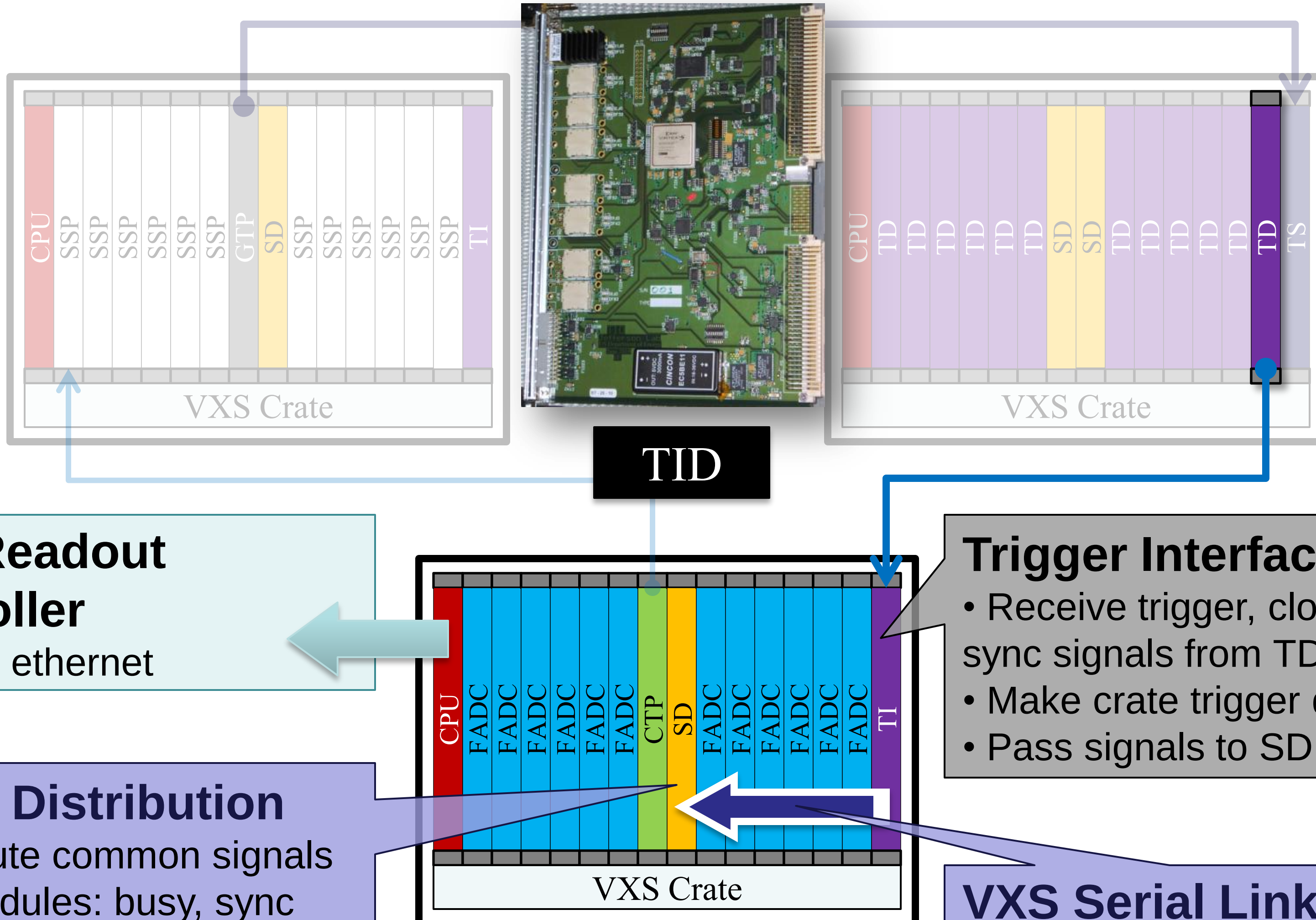
Trigger Supervisor

- Calculate 8 bit trigger types from 32 bit trigger pattern
- Prescale triggers
- Transfer trigger and sync signal to TD (16 bit total)

Fiber Optics

- 16 bit @ 62.5 MHz: 1 Gbps

L1 Trigger Diagram



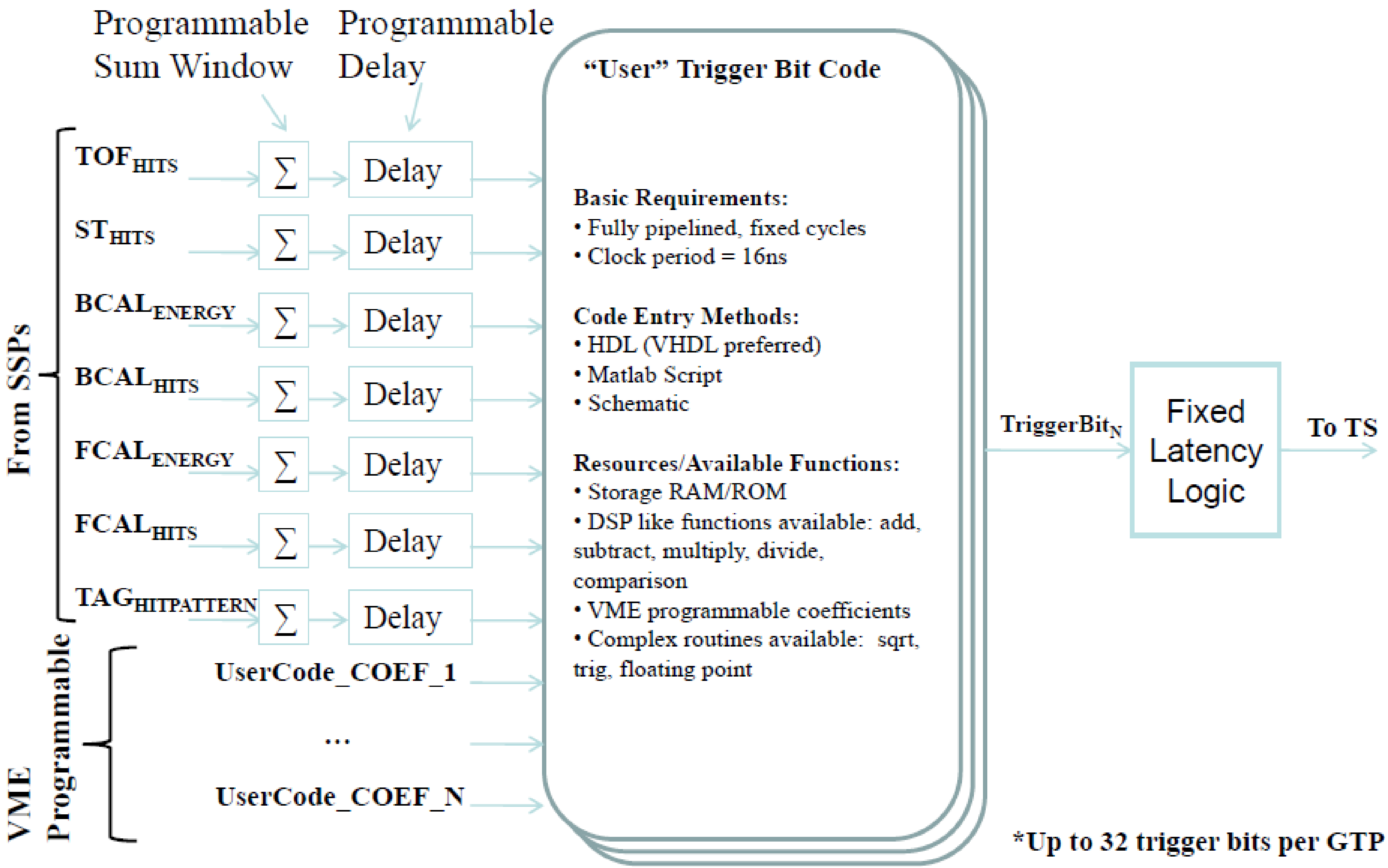
VME Readout Controller
- Gigabit ethernet

Trigger Interface
- Receive trigger, clock and sync signals from TD
- Make crate trigger decision
- Pass signals to SD

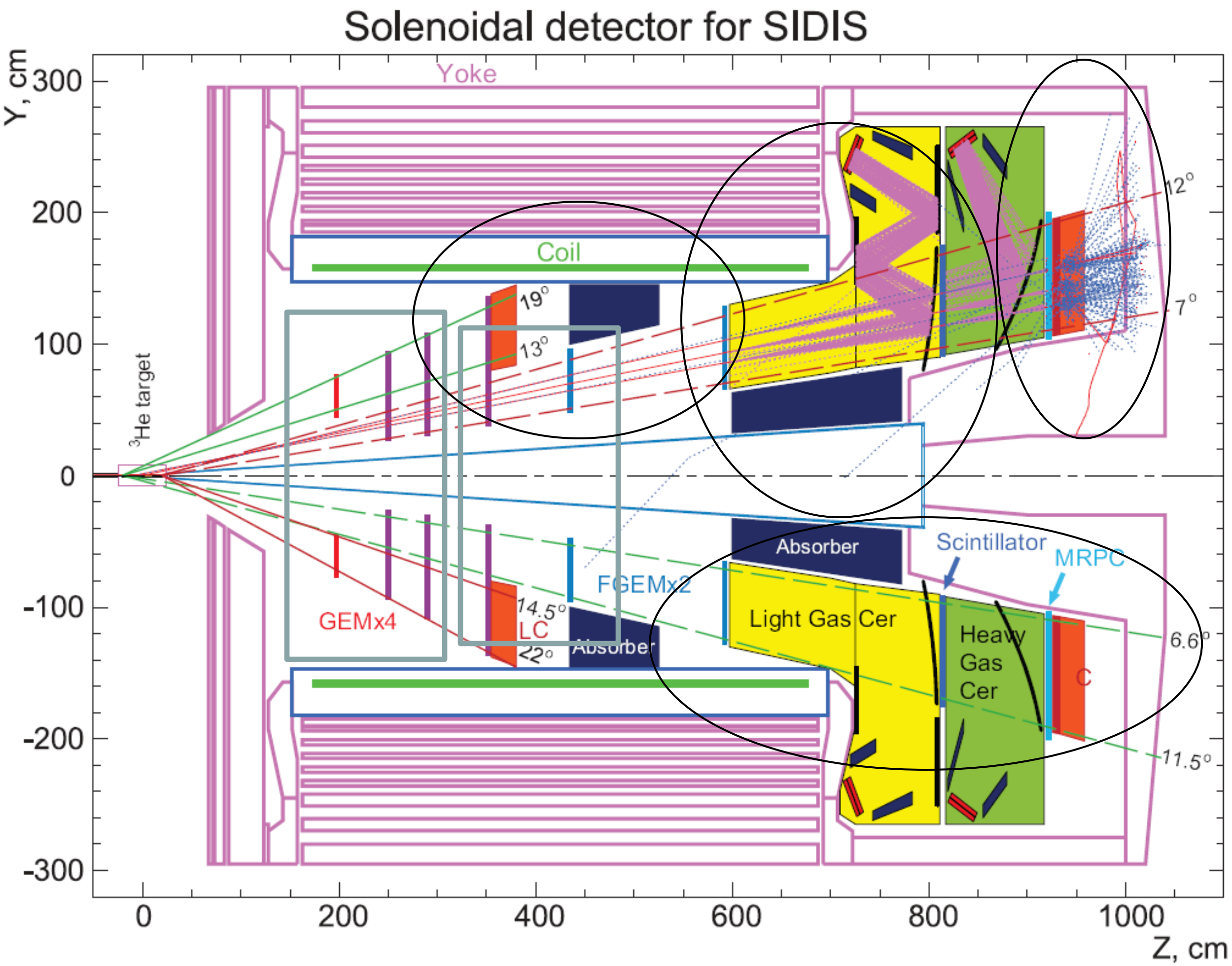
Signal Distribution
- Distribute common signals to all modules: busy, sync and trigger 1/2

VXS Serial Link
- 4 bit @ 250 MHz: 1 Gbps

GTP Trigger Bit Example



Trigger for SIDIS



Electron

Max rate 300 KHz

Pion

SoLID

- Large azimutal coverage
- Designed for high luminosity
- PVDIS and SIDIS proposal accepted
- Looking for international cooperation and DOE funding : Director review in 2013

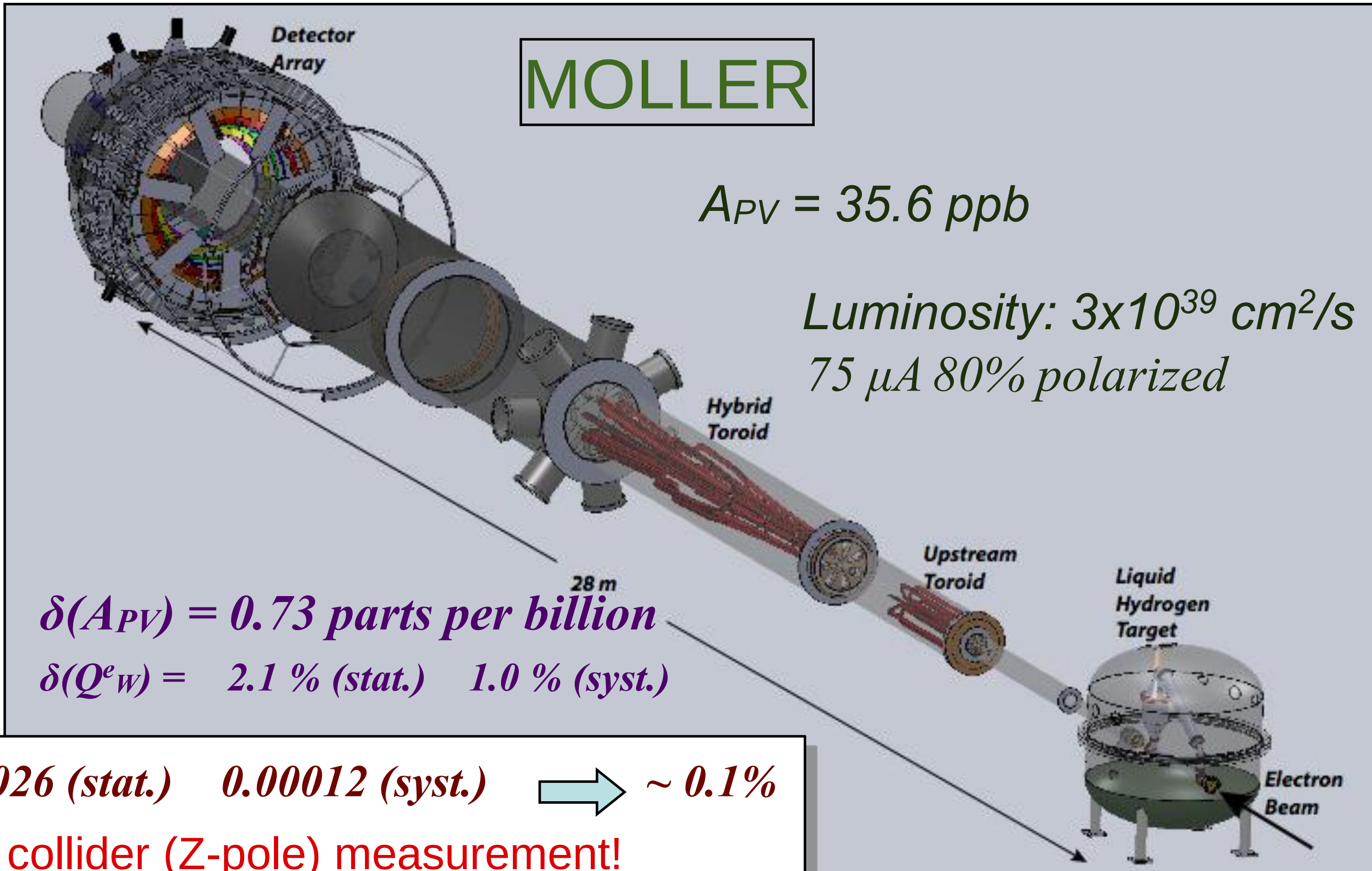
MOLLER at 11GeV JLab

An ultra-precise measurement of the weak mixing angle using Møller scattering

$$A_{PV} \propto E_{\rm lab}\, Q_W^e, \quad \sigma \propto \frac{1}{E_{\rm lab}}$$

Figure of Merit proportional to beam power

At 11 GeV, JLab luminosity and stability makes large improvement possible



MOLLER

A_{PV} = 35.6 ppb

Luminosity: 3×10^{39} cm^2/s

75 μA 80% polarized

δ(A_{PV}) = 0.73 parts per billion

δ(Q^e_W) = 2.1 % (stat.) 1.0 % (syst.)

δ($\sin^2\theta_W$) = 0.00026 (stat.) 0.00012 (syst.) ⇨ ~ 0.1%

Matches best collider (Z-pole) measurement!

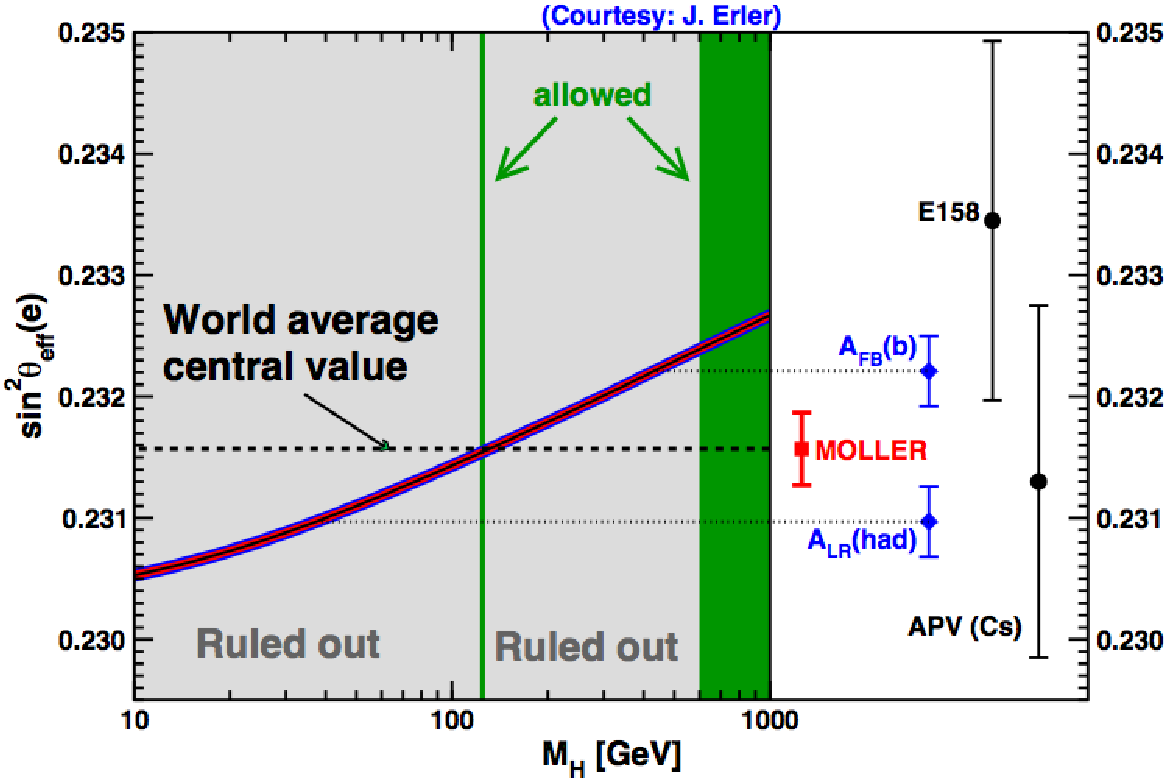
Precision Measurement of $\sin^2\theta_W$

Direct measurement of SM weak mixing angle is average of two measurements that disagree by 3σ...

...yet the naive statistical average agrees to a very high level with the LHC Higgs candidate

We failed to nail $\sin^2\theta_W$ when we had the colliders! -B.Marciano

The consistency of the SM prediction, between directly measured m_H, m_W, m_t, $\sin^2\theta_W$ bears testing



- **$\sin^2\theta_W$ improvements at hadron colliders very challenging**
- **“Giga-Z” option of ILC or neutrino factory: powerful but far future**

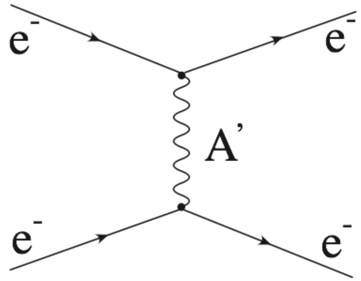
MOLLER Sensitivity to BSM Physics

$$\mathcal{L}_{e_1 e_2} = \sum_{i,j=L,R} \frac{g_{ij}^2}{2\Lambda^2} \bar{e}_i \gamma_\mu e_i \bar{e}_j \gamma^\mu e_j \quad \Rightarrow \quad \frac{\Lambda}{\sqrt{|g_{RR}^2 - g_{LL}^2|}} = 7.5 \text{ TeV}$$

best contact interaction reach for leptons at low OR high energy

To do better for a 4-lepton contact interaction would require:
Giga-Z factory, linear collider, neutrino factory or muon collider

Light interaction boson A'



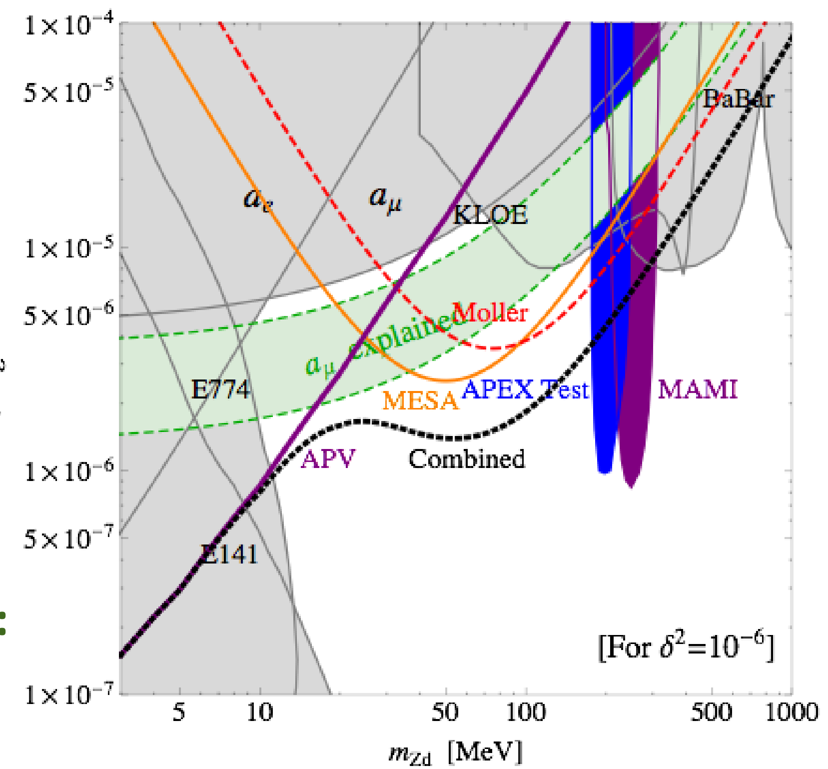
Hypothesis could explain $(g-2)_\mu$ discrepancy as well as several intriguing astrophysical anomalies related to dark matter

Beyond kinetic mixing: introduce mass mixing with Z

$$\epsilon_Z = \frac{m_{Z_d}}{M_Z} \delta$$

Davoudiasl, Lee, Marciano **arXiv:1203.2947v2**

MOLLER reach: red dashed lines



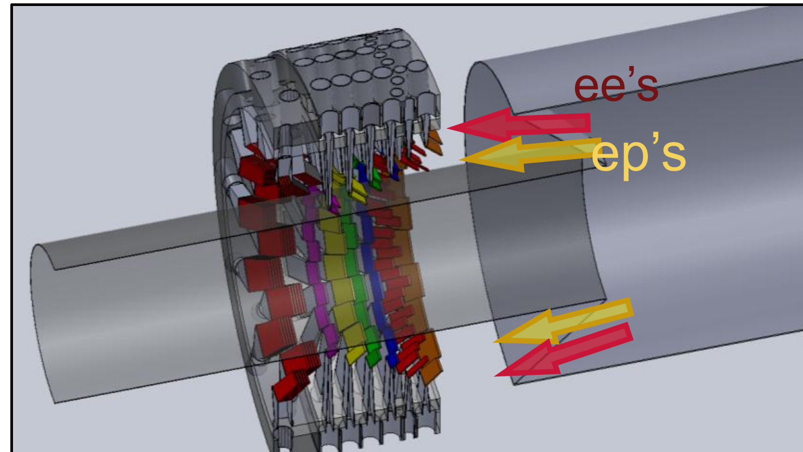
Complementary to direct heavy photon searches: Lifetime/branching ratio model dependence vs mass mixing assumption

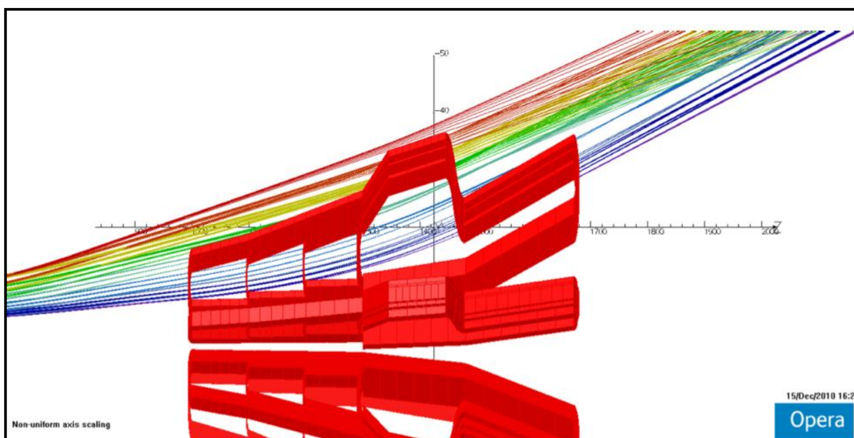
Jefferson Lab

Meeting the Challenges of MOLLER

Unprecedented Precision

- ~ 150 GHz scattered electron rate (80ppm at 2kHz)
- 100% Azimuthal acceptance, with θ_{lab} ~ 5-15 mrad
- Robust and redundant 0.4% beam polarimetry
- 1 nm control of beam centroid on target
- > 10 gm/cm^2 target needed





Preparations on Track

- Strong Collaboration being formed with international participation
- JLab Director's Review (chair: C. Prescott) gave strong endorsement
- Conceptual design and cost range being developed (~ 20M$)
- Funding proposal has been submitted to DoE
- ~3 years construction, aim to complete data collection in 2020

Conclusion

- Modest baseline upgrade in Hall A
- First Hall to use 12 GeV beam : experiments using 6 GeV equipment
- General purpose hall with several large installation projects
- Parity program
  - SoLID
  - Moller
- Nucleon structure program
  - Deeply Inelastic Structure Functions
  - Nucleon Form Factors (SuperBigBite)
  - Generalized Parton Distributions
  - Transversity

Rich physics program for the next 15 years