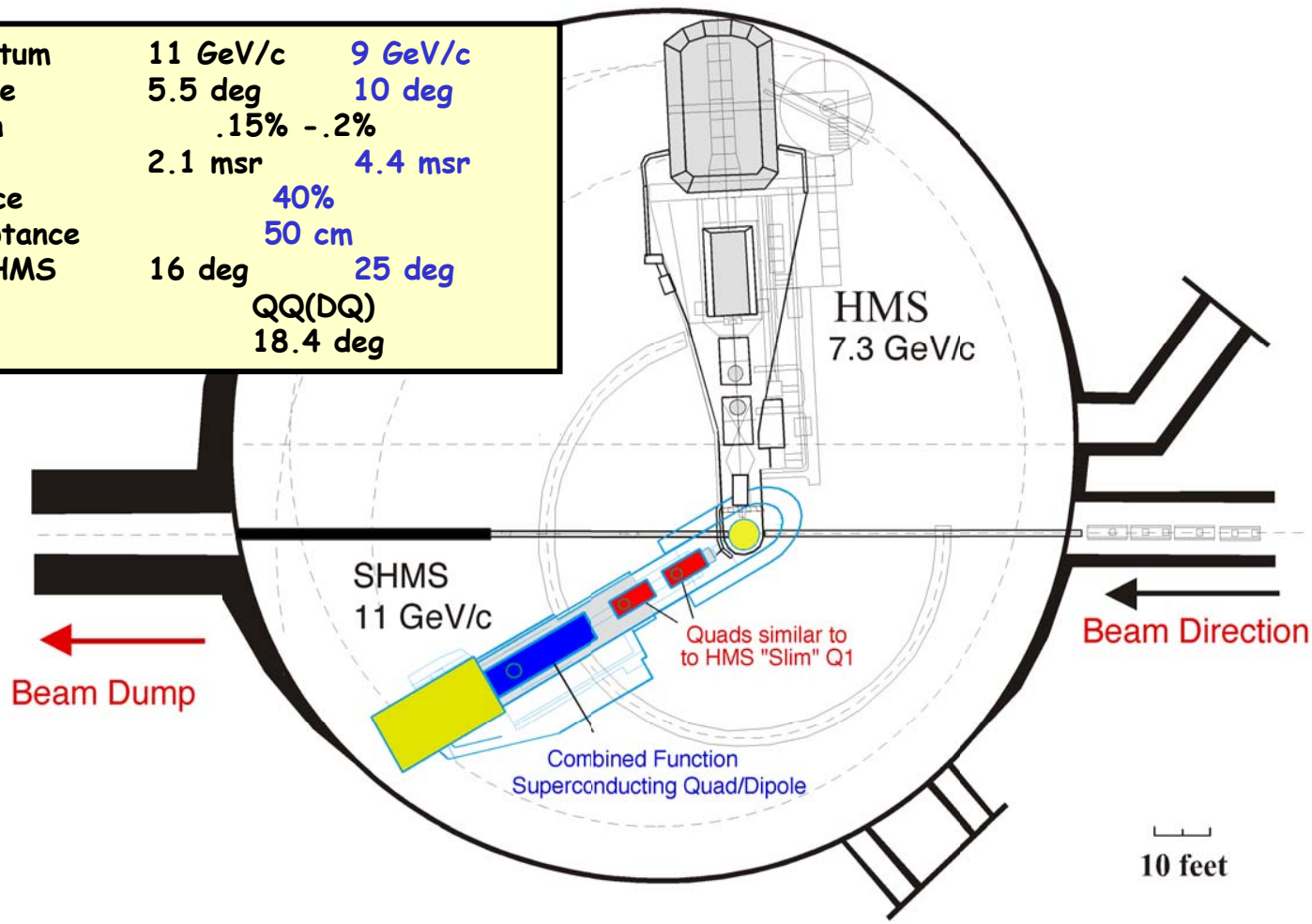
Hall C - 12 GeV pCDR

Max. Central Momentum	11 GeV/c	9 GeV/c
Min. Scattering Angle	5.5 deg	10 deg
Momentum Resolution	.15% -.2%	
Solid Angle	2.1 msr	4.4 msr
Momentum Acceptance	40%	
Target Length Acceptance	50 cm	
Opening Angle with HMS	16 deg	25 deg
Configuration	QQ(DQ)	
Bend Angle	18.4 deg	



Hall C at 12 GeV:

HMS + SHMS

- Charged particle detection with momentum up to beam energy $z = E_h/\nu = 1$
- Small angle capability essential to measure charged particle along momentum transfer θ_h // $\mathbf{q} \pm$ few ^{o}
- Precision L/T separations

$$\sigma = \Gamma\left(\sigma_T + \varepsilon\sigma_L + \varepsilon \cos(2\phi)\sigma_{TT} + [\varepsilon(\varepsilon+1)/2]^{1/2}\cos(\phi)\sigma_{LT}\right)$$

- General Infrastructure for Dedicated Experiments

→Exclusive and Semi-Exclusive Reactions ($z > 0.3$) at high Q^2
→Separation of Polarized and Unpolarized Structure Functions over large range of x and Q^2

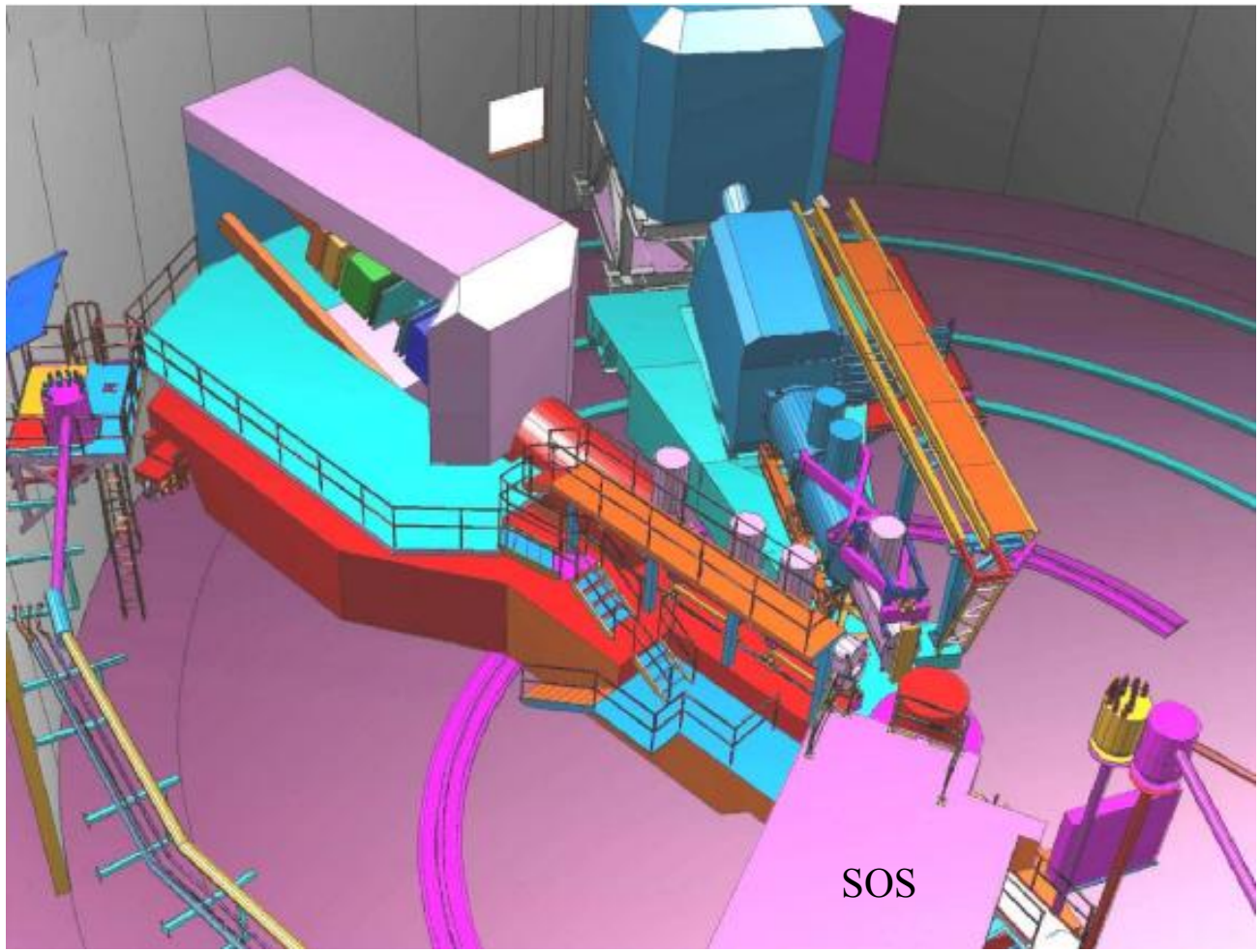
Hall C at 12 GeV:

SHMS Carriage and Shield House

16° SHMS-HMS angle.

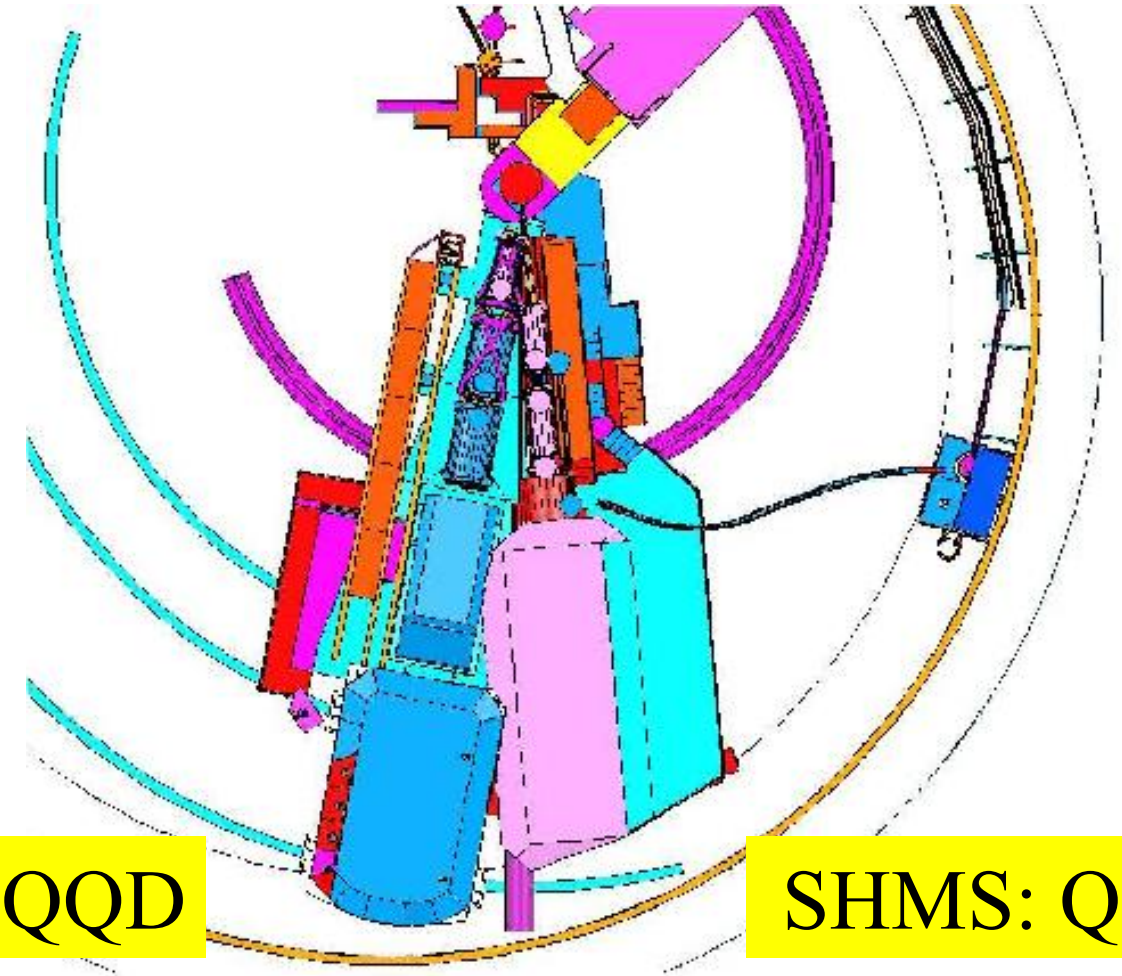
Hard connections to pivot yield 0.01° scattering angle, 0.5mm pointing reproducibility.

1m shielding typ.



Hall C at 12 GeV:

Co-Existence of SHMS with HMS

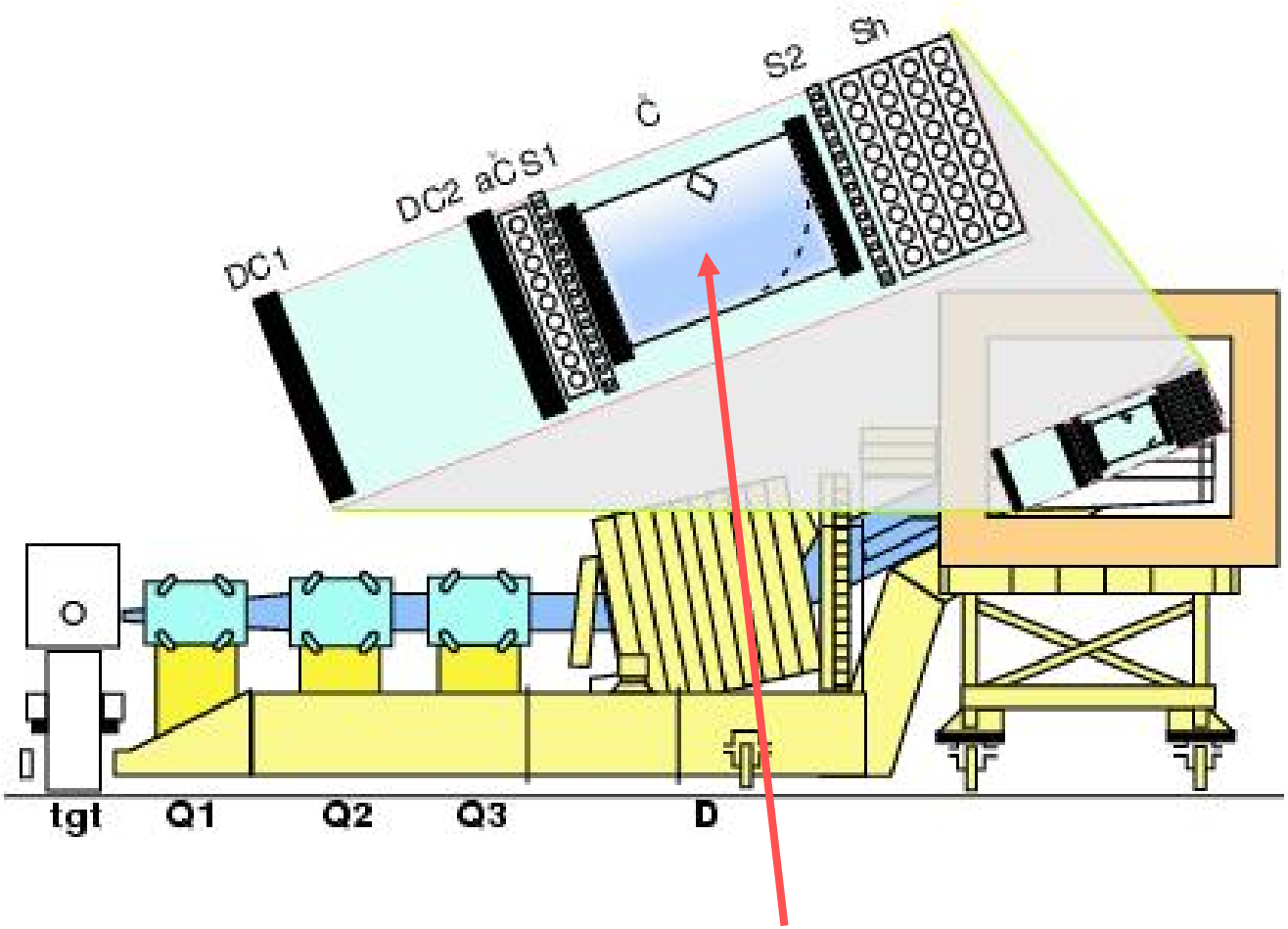


HMS: QQQD

SHMS: QQ(QD)

Hall C at 12 GeV:

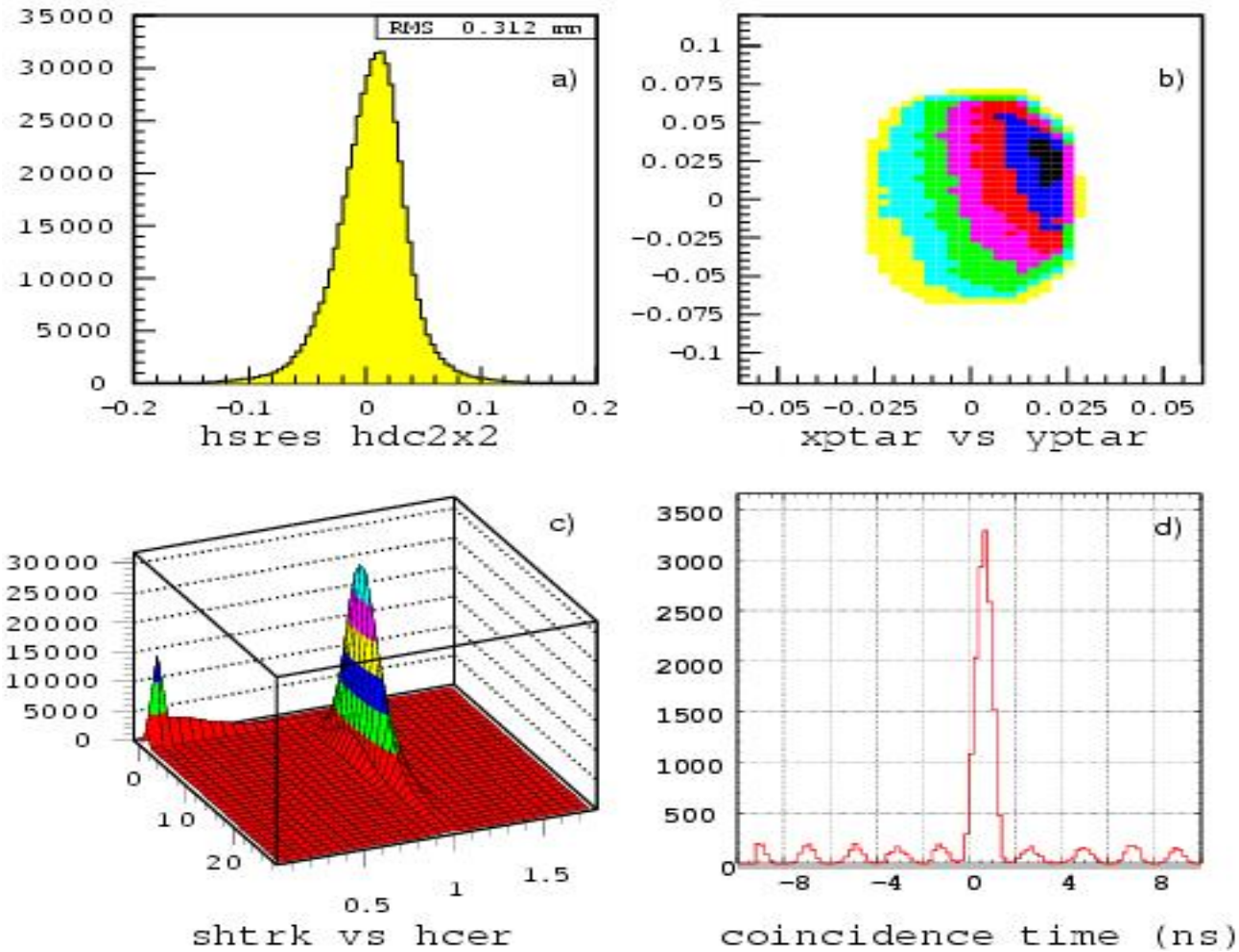
HMS



Option: replace Cherenkov with FPP

Hall C at 12 GeV:

HMS Performance



Hall C at 12 GeV:

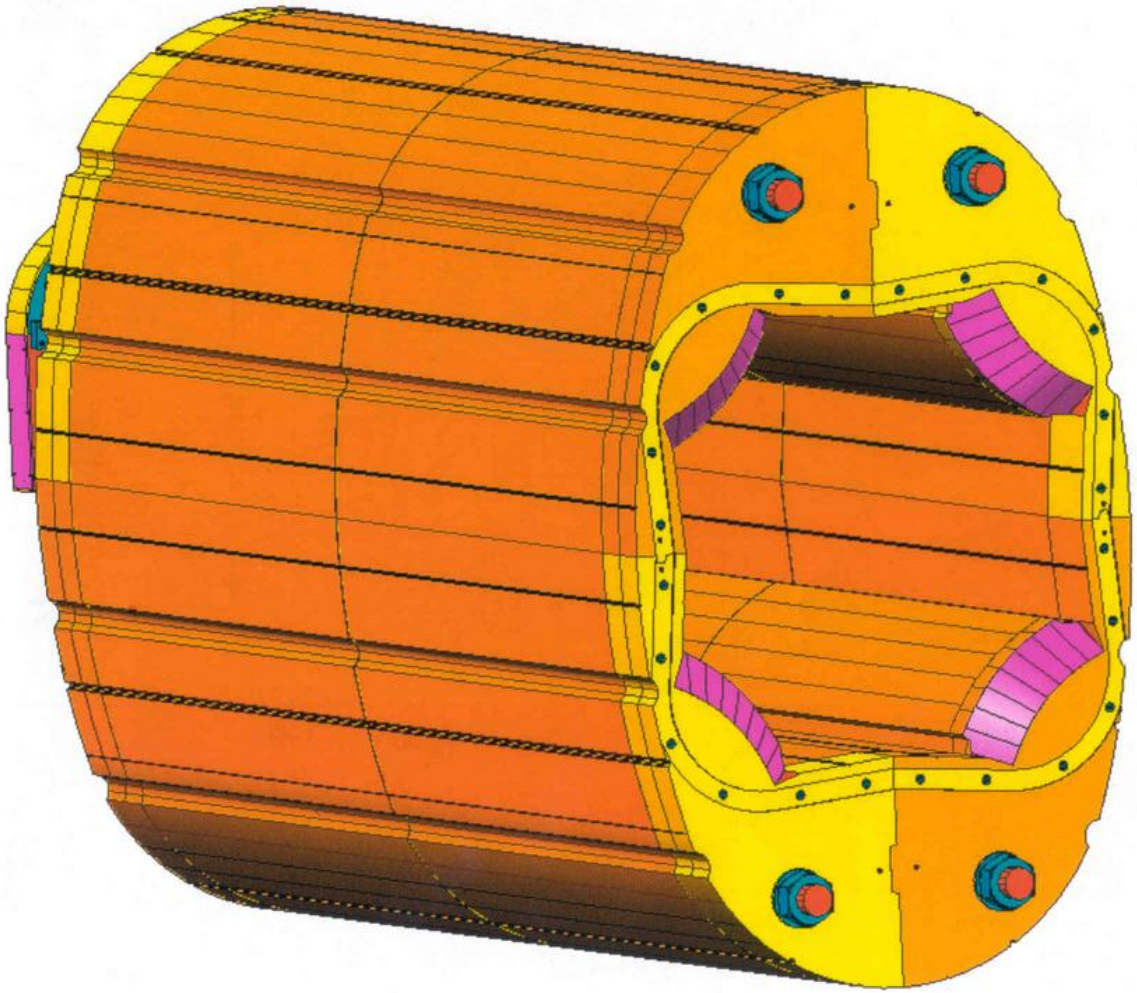
HMS Performance

Parameter	HMS Performance
Range of Central Momentum	0.4 to 7.3 GeV/c
Momentum Acceptance	±10%
Momentum Resolution	0.1% - 0.15%
Scattering Angle Range	10.5 to 90 degrees
Maximum Target Length at 90 degrees	10 cm
Horizontal Angle Acceptance	±32 mrad
Vertical Angle Acceptance	±85 mrad
Solid Angle Acceptance	8.1 msr
Horizontal Angle Resolution	0.8 mrad
Vertical Angle Resolution	1.0 mrad
Vertex Reconstruction Resolution	0.3 cm
Maximum Flux within Acceptance	~5 MHz
Electron-hadron discrimination	1000:1 at 98% efficiency
Pion-kaon discrimination	100:1 at 95% efficiency

Hall C at 12 GeV:

SHMS Quads - Based on Existing HMS-Q1

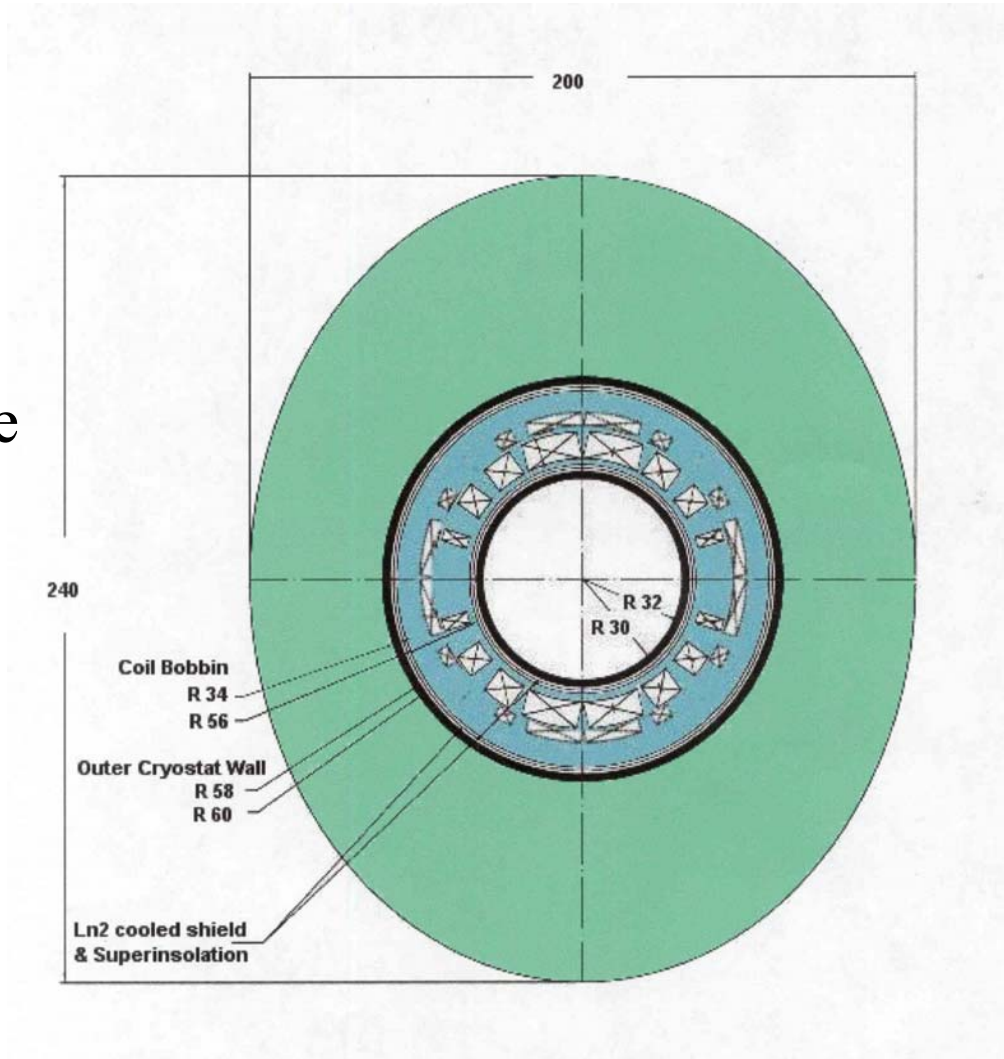
- Slightly increased gradient (8.6 T/m) compared to HMS-Q1
- TOSCA (JLab) and external feasibility study show there are no issues
- Design and Tooling still available at company → affordable



Hall C at 12 GeV:

SHMS Combined Function Magnet

- Quadrupole "inside" Dipole to reduce current density
- TOSCA (JLab) and external feasibility study
  - cryostability
  - coil, conductor conservative
  - force containment will require careful engineering, but no excessive forces
  - energy quench within allowable margins
- "Can be built without prototyping or R&D"



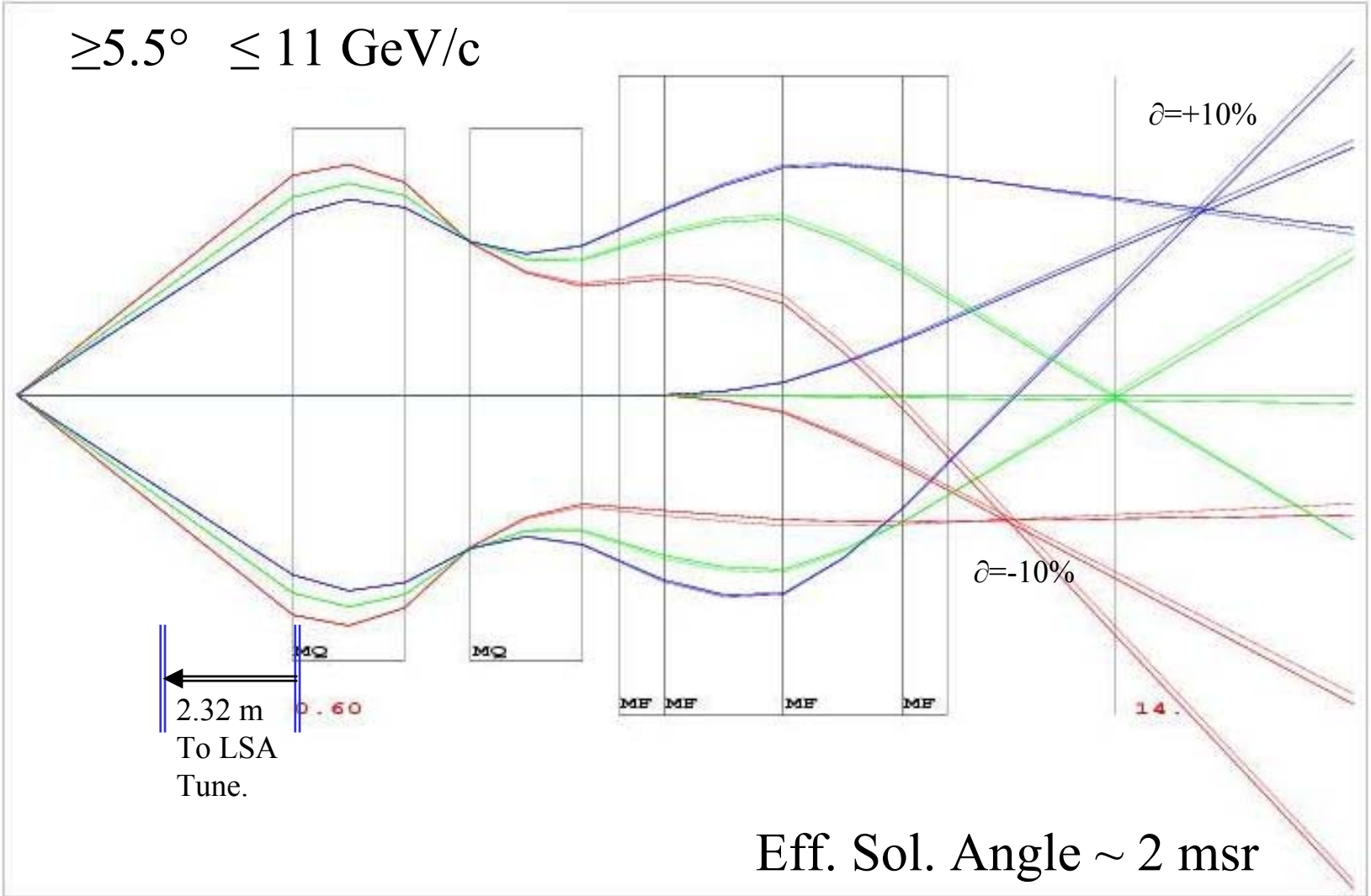
Hall C at 12 GeV:

SHMS Specifications

Parameter	SHMS Specifications
Range of Central Momentum	2 to 11 GeV/c
Momentum Acceptance	-15% to +25%
Momentum Resolution	< 0.2%
Scattering Angle Range	5.5 to 25 degrees
Maximum Target Length at 90 degrees	50 cm
Horizontal Angle Acceptance	±18 mrad
Vertical Angle Acceptance	±50 mrad
Solid Angle Acceptance	4 msr (LSA tune) 2 msr (SSA tune)
Horizontal Angle Resolution (yptar)	2-4 mrad
Vertical Angle Resolution (xptar)	1-2 mrad
Target Resolution (ytar)	0.2 - 0.6 cm
Maximum Flux within Acceptance	~5 MHz
Minimum Acceptable e/h discrimination	1000:1 at 98% efficiency
Minimum Acceptable π/K discrimination	100:1 at 95% efficiency

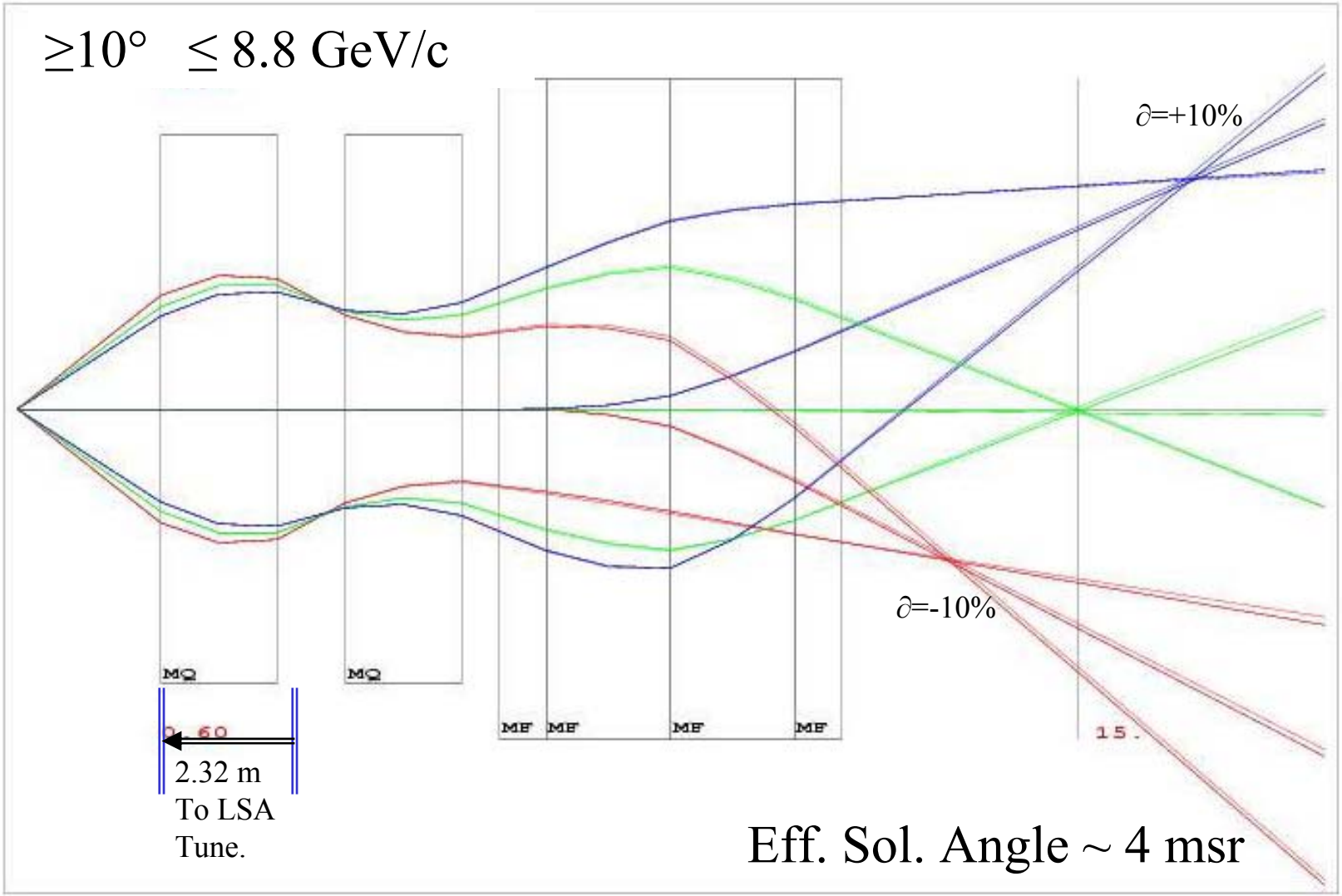
Hall C at 12 GeV:

SHMS Small-Solid-Angle Tune Model



Hall C at 12 GeV:

SHMS Large-Solid-Angle Tune Model

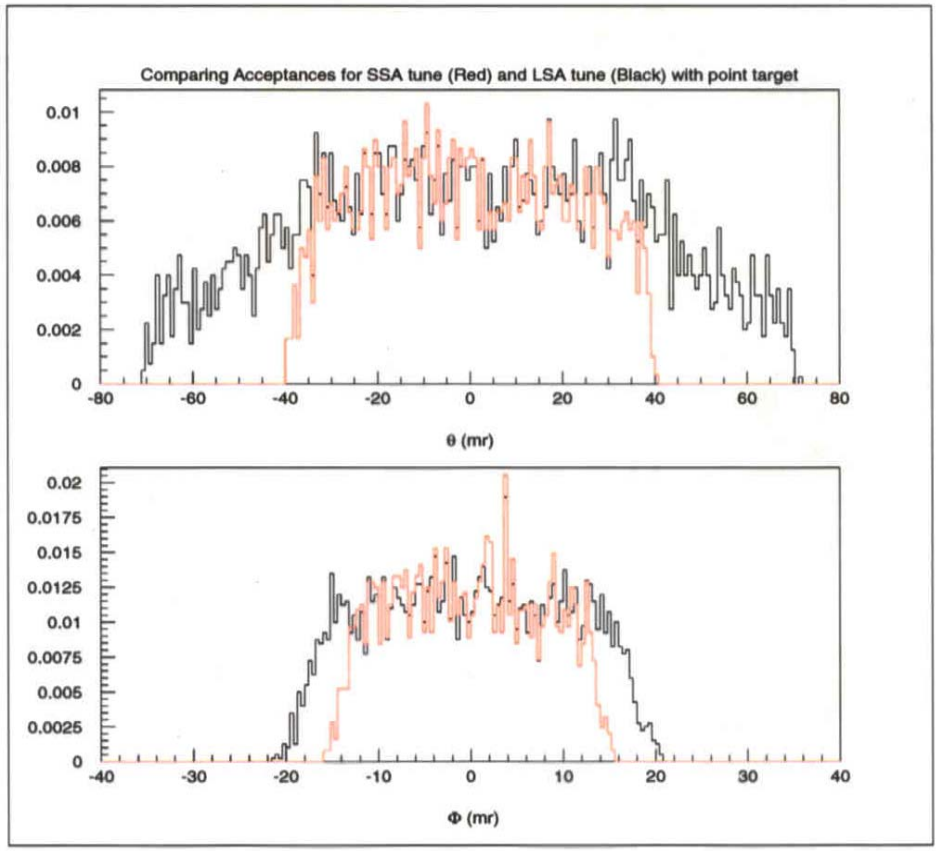


Hall C at 12 GeV:

SHMS Acceptance

Point Target

LSA Tune
SSA Tune

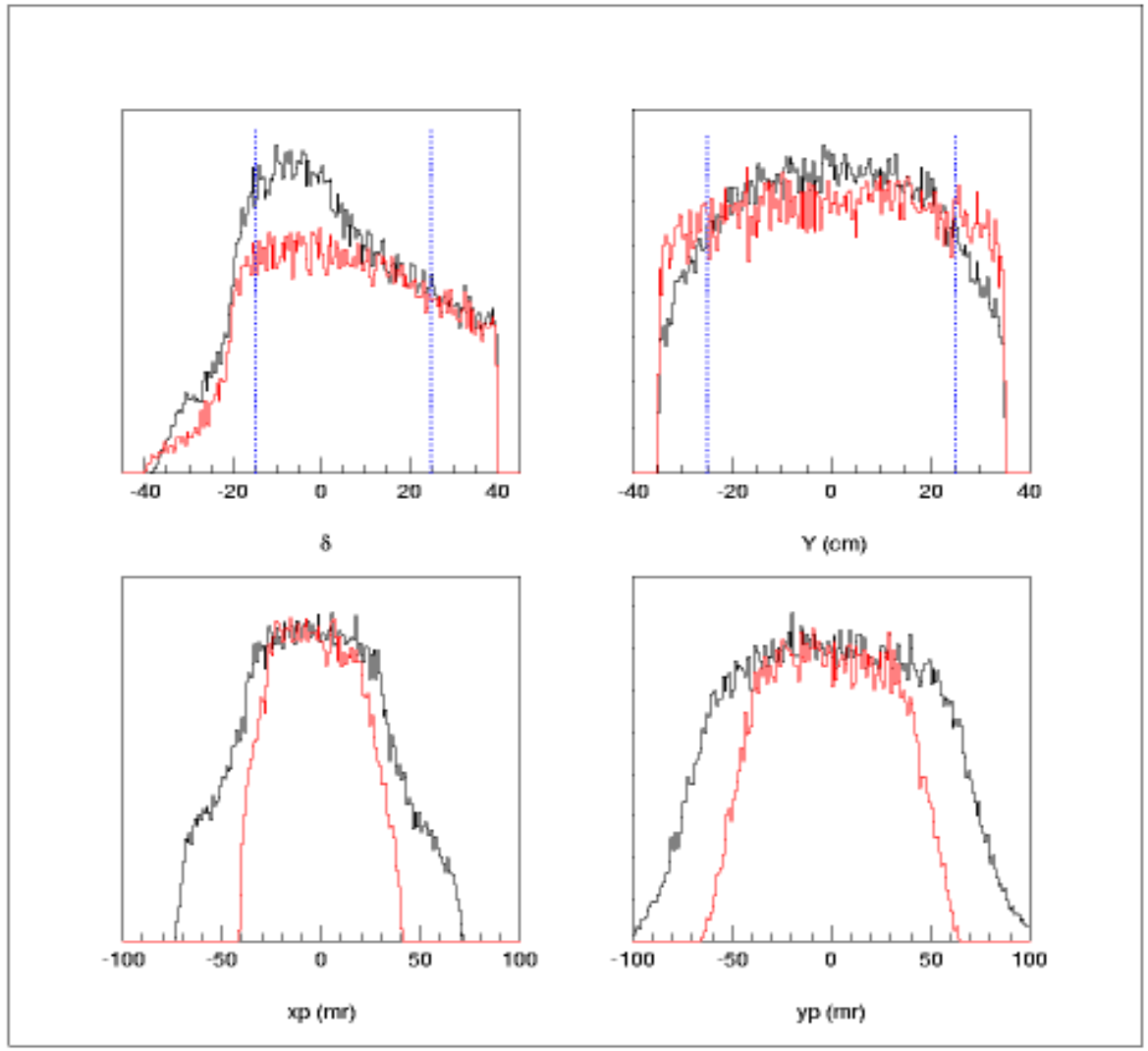


Hall C at 12 GeV:

SHMS Acceptance

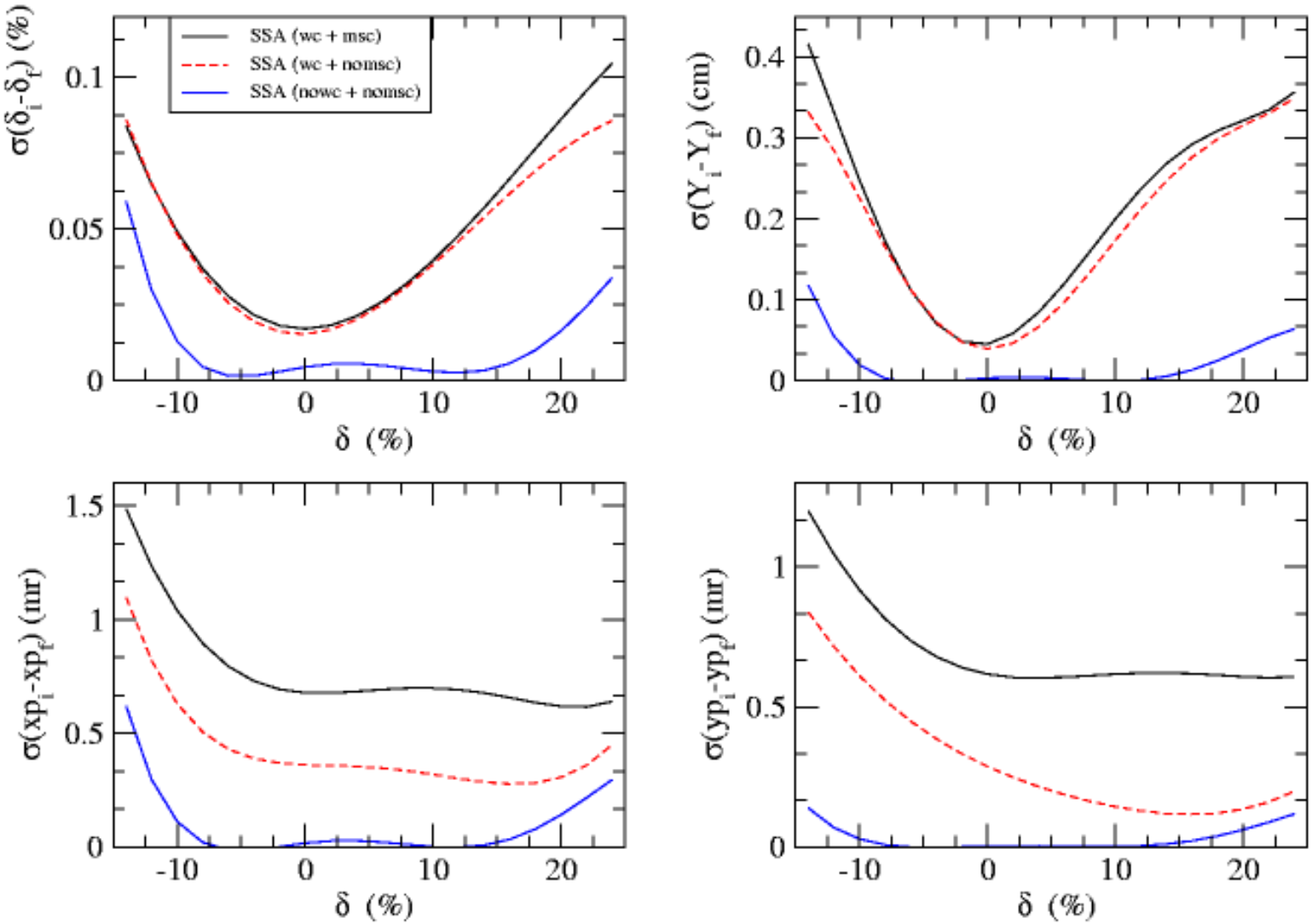
50cm Target
(viewed at 90°)

LSA Tune
SSA Tune



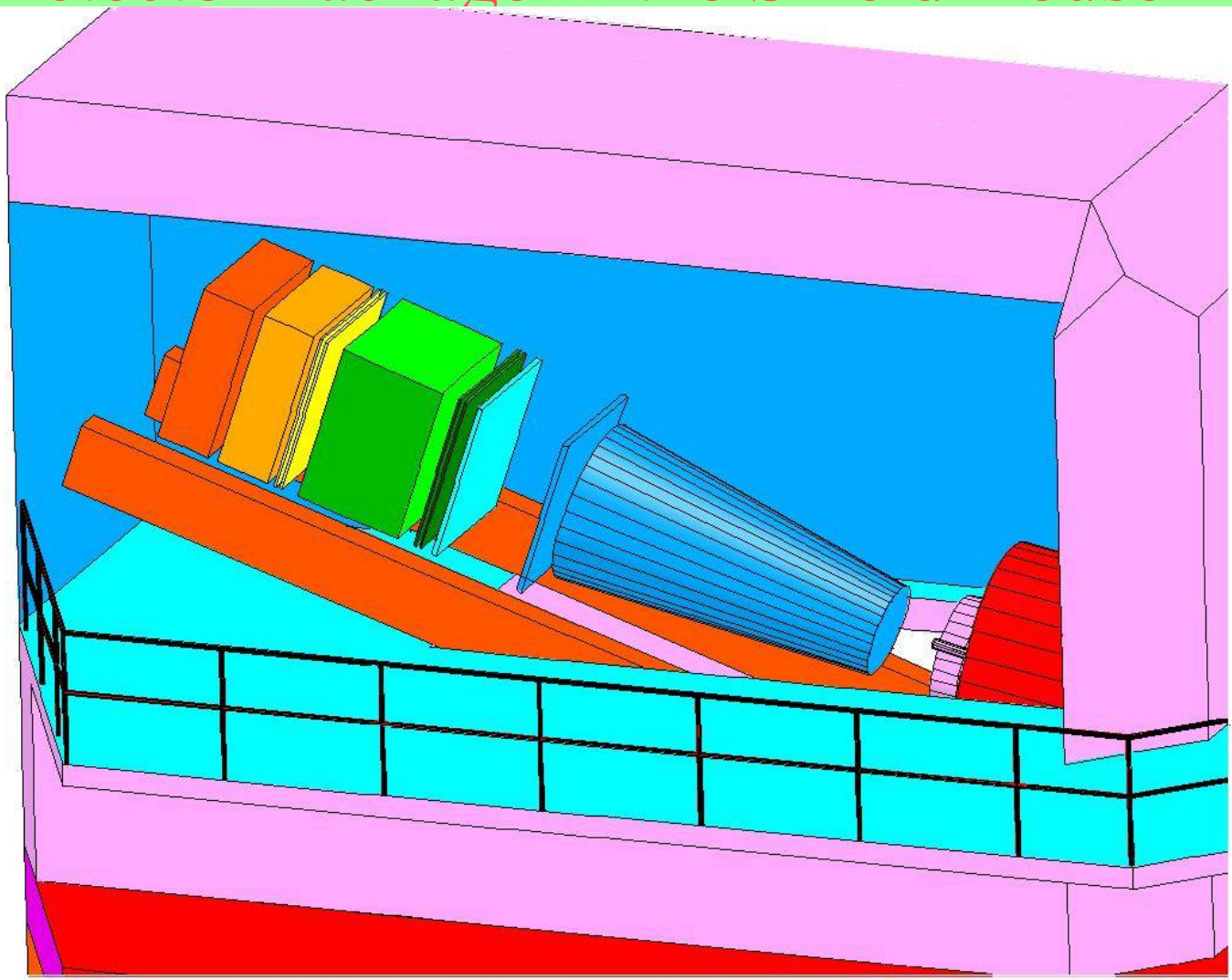
Hall C at 12 GeV: Detectors

Small Solid Angle Tune Resolutions



Hall C at 12 GeV: Detectors:

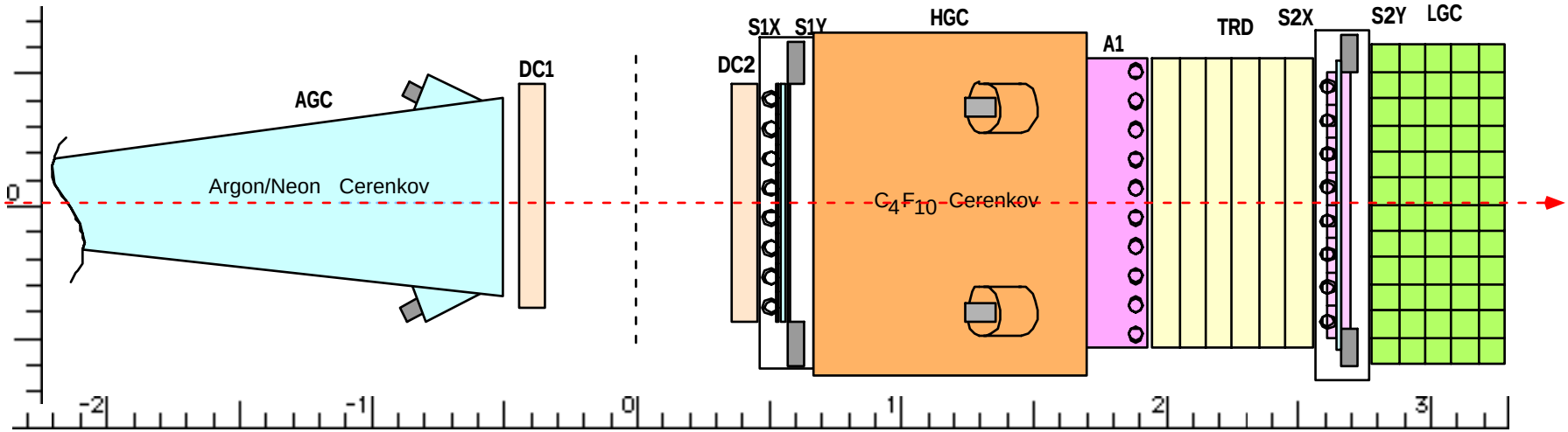
Detector Package in the Shield House



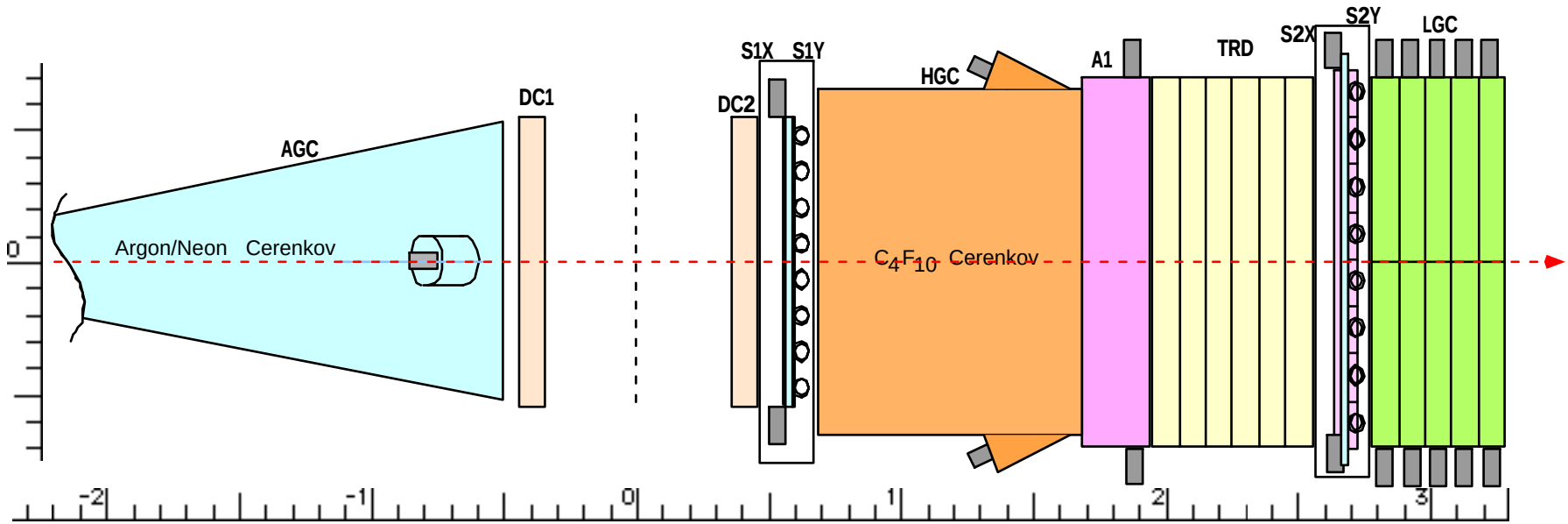
Hall C at 12 GeV: Detectors

SHMS Detector Requirements

Characteristic	Requirement
Tracking Resolution (each of two points)	$\leq 100\ \mu m$
Multiple Scattering	DC < ~ 1% X_0
	Nothing upstream of DC at low momentum.
	Minimum material upstream of Cerenkovs
Size	From 85x110 cm^2 at DC To 115x150 cm^2 at LGC
Particle Identification	Combination of Techniques to cover this wide momentum range.



Elevation



Plan

Hall C at 12 GeV: Detectors:

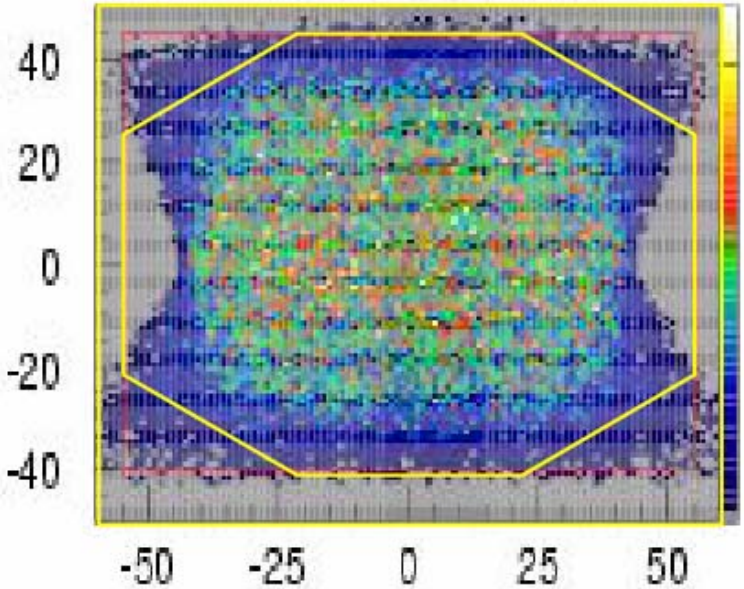
Size Summary

Detector	30-cm Target		50-cm Target	
	X size	Y size	X size	Y size
Atm. Gas Č	75	80	75	100
Drift Chambers	85	80	85	110
Scint. Hodo 1	90	90	90	110
Heavy Gas Č	100	95	100	130
Aerogel Č	110	100	110	140
TRD	110	100	110	140
Scint. Hodo 2	110	100	110	140
Shower Counter	115	120	115	150

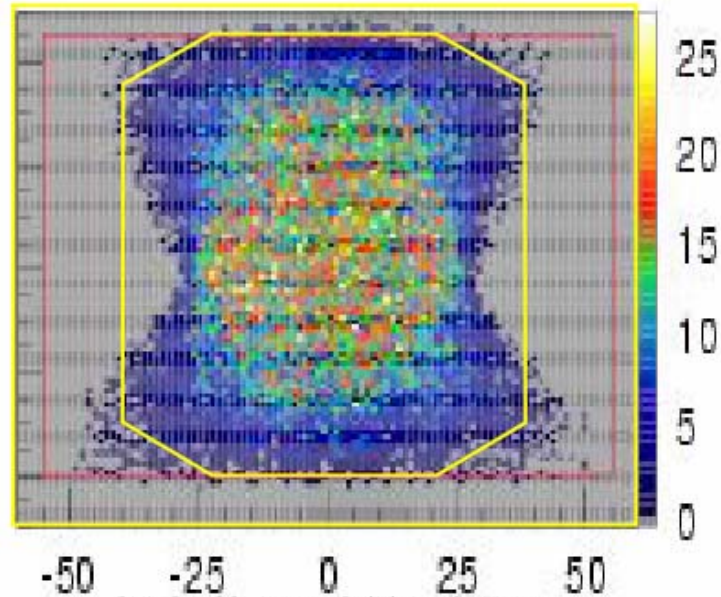
SHMS Detector Active Areas (cm)

- Will design detectors assuming 50-cm target
- Will instrument assuming 30-cm target (both as viewed at 90°)

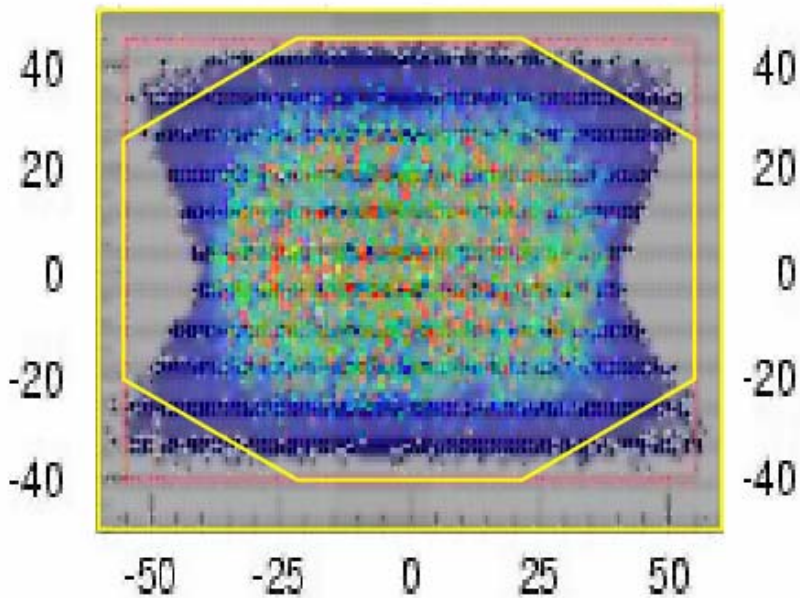
Drift Chamber Sensitive Areas



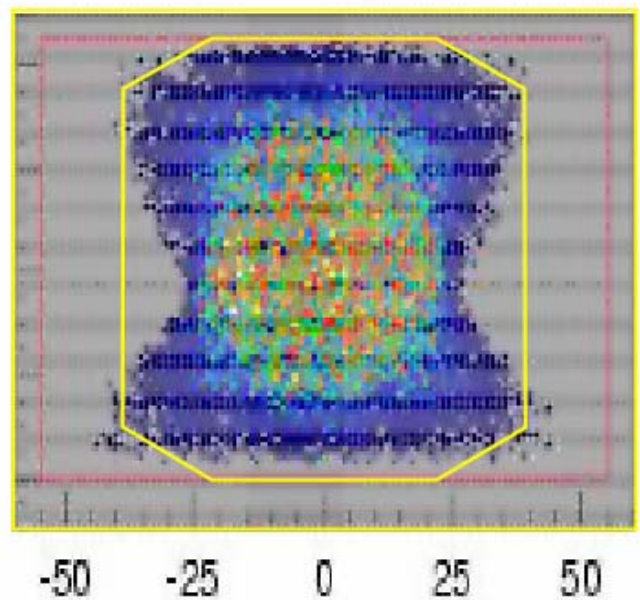
SHMS DC2: Large Solid Angle Tune
50 cm Target



SHMS DC2: Large Solid Angle Tune
30 cm Target



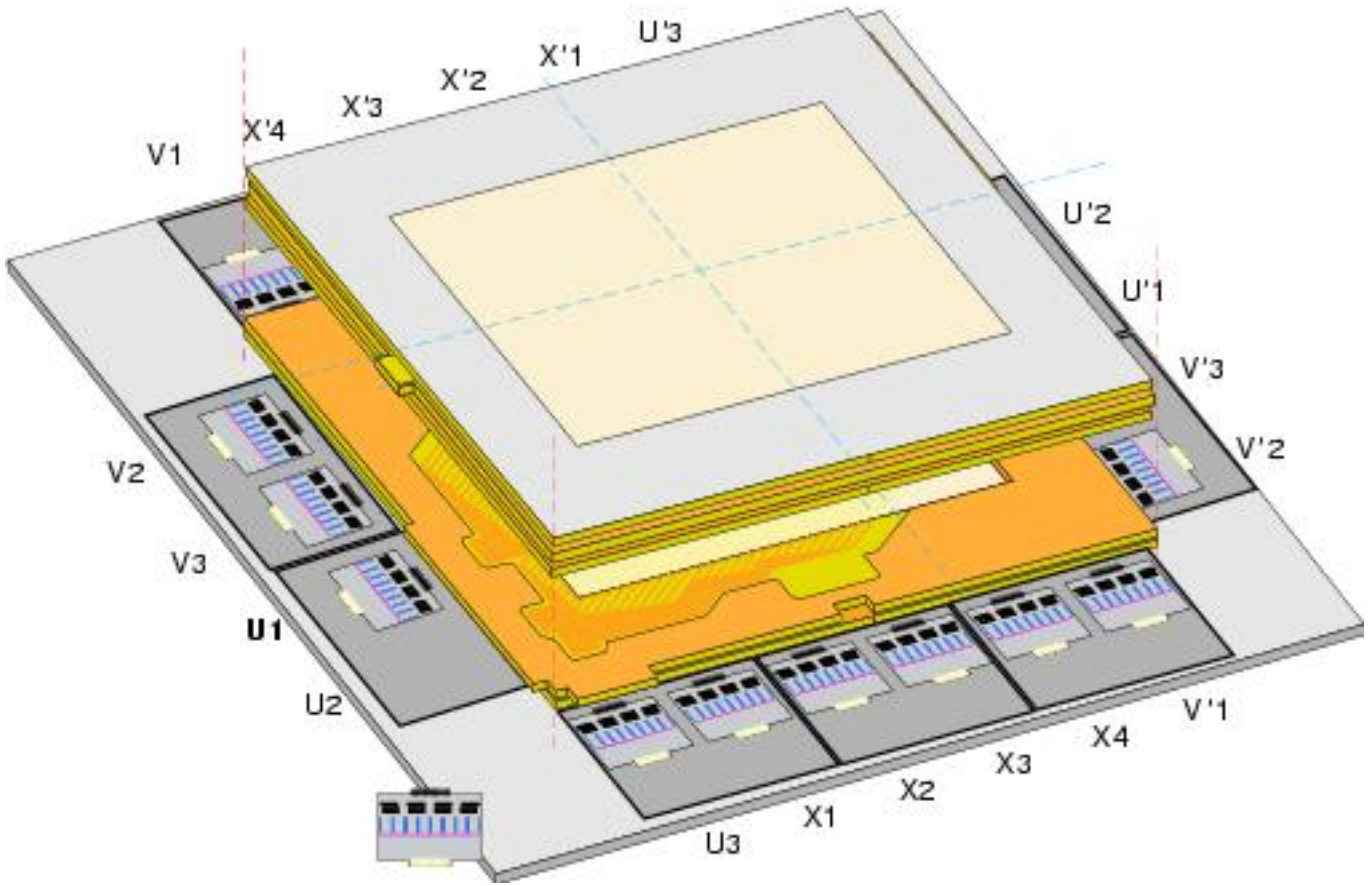
SHMS DC1: Large Solid Angle Tune
50 cm Target



SHMS DC1: Large Solid Angle Tune
30 cm Target

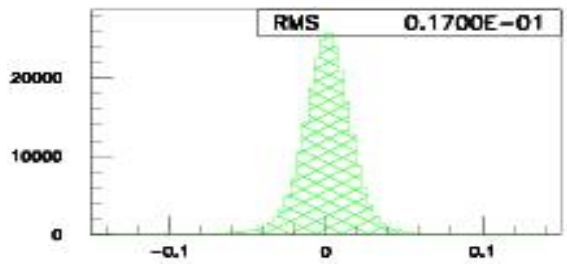
Hall C at 12 GeV: Detectors

Wire Chambers - *Stack-up* Design

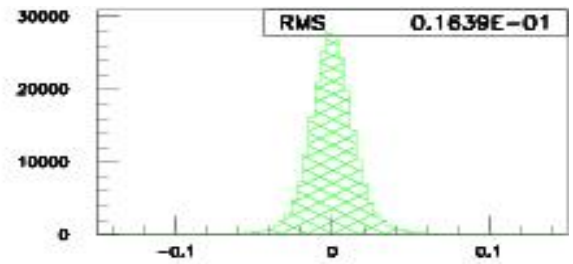


Hall C at 12 GeV: Detectors

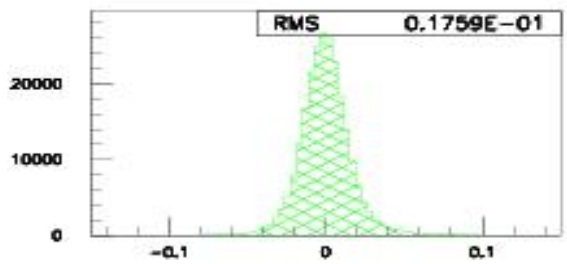
Wire Chambers - SOS Resolution



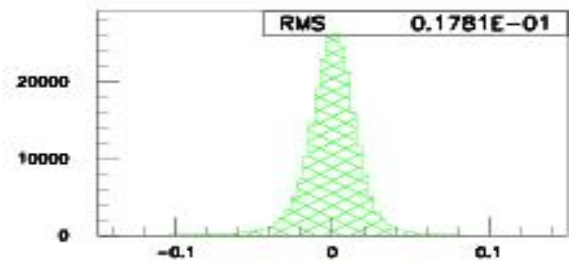
ssres sdc1u1 t=sdcres(1)



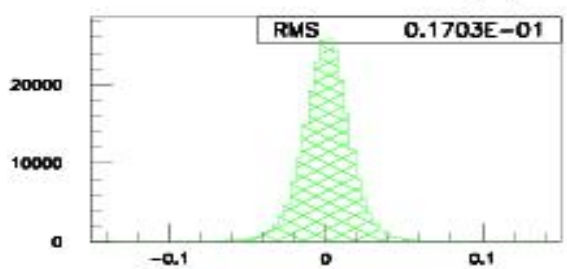
ssres sdc1u2 t=sdcres(2)



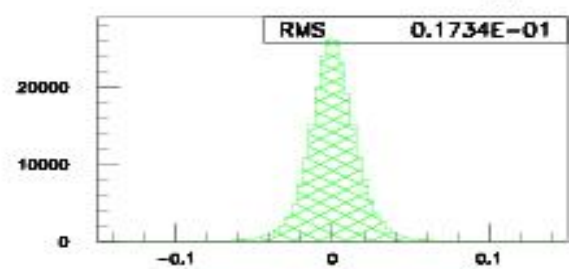
ssres sdc1x1 t=sdcres(3)



ssres sdc1x2 t=sdcres(4)



ssres sdc1v1 t=sdcres(5)



ssres sdc1v2 t=sdcres(6)

Hall C at 12 GeV: Detectors:
Particle Identification

SHMS will use a COMBINATION of PID techniques to cover the entire momentum range of interest.

Electron/Hadron Separation:

- Time-of-Flight at low momentum.
- Shower counter over full range.
- e^- always trigger Cerenkov counters.
- Additional upstream Cerenkov at high energy

Hall C at 12 GeV: Detectors:

Particle Identification

1 to 3 GeV/c	Pion/Kaon	Aerogel Cerenkov
	Kaon/Proton	TOF & Aerogel
3 to 5.5 GeV/c	Pion/Kaon	C_4F_{10} Cerenkov
	Kaon/Proton	Aerogel
5.5 to 11 GeV/c	Pion/Kaon	Atm. Press. Cerenkov, C_4F_{10} Cerenkov and dE/dx
	Kaon/Proton	C_4F_{10} at > 1 atm.

Hall C at 12 GeV: Detectors:

Atmospheric Pressure Cerenkov

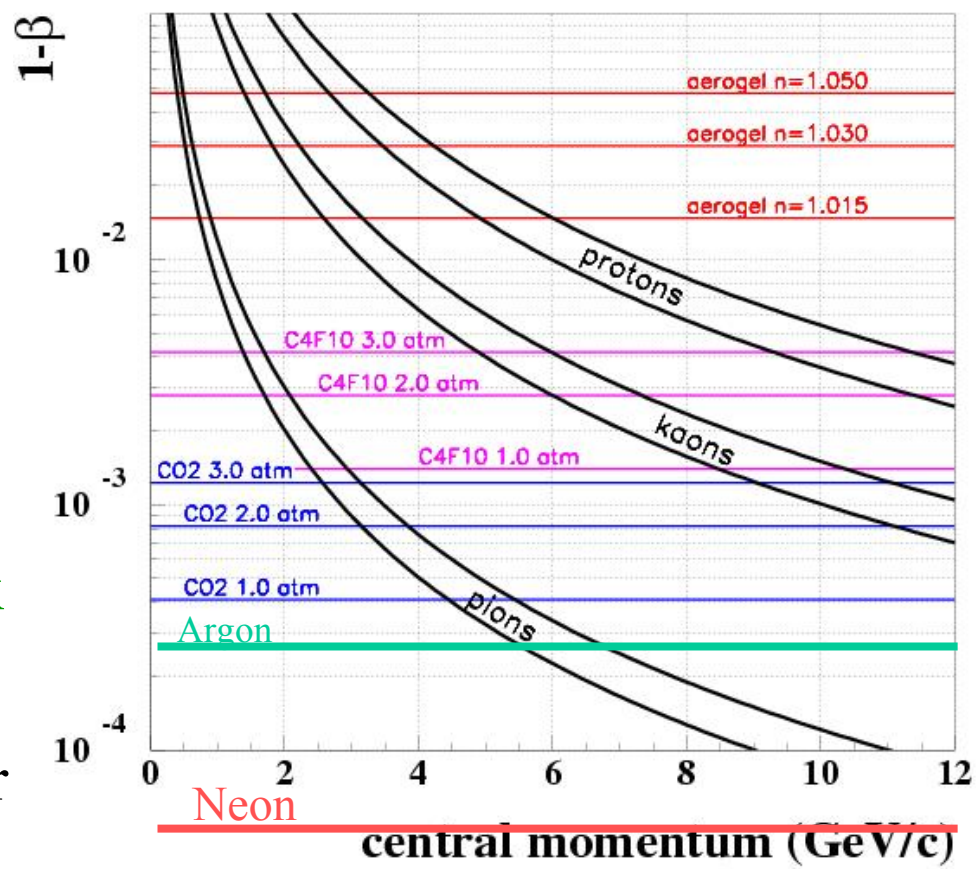
2.5 m long

Ne (n-1= 67 x 10^{-6})

and/or

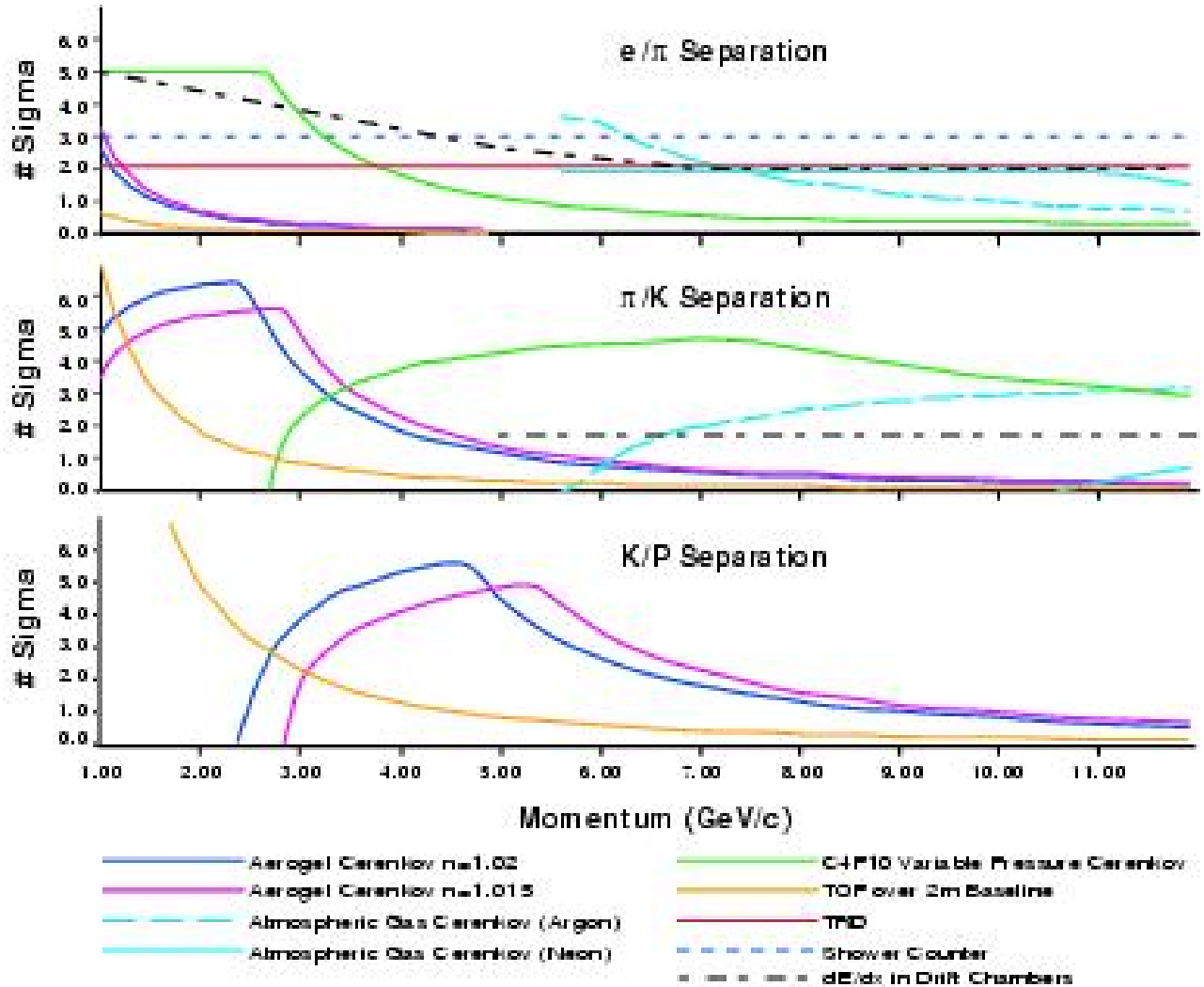
Ar (n-1 = 283 x 10^{-6})

- Atmospheric pressure - thin windows.
- Use only above 6 GeV (e.g., e/π separation for x > 1 experiment)
- Improves e/π (argon) or π/K (neon).
- Expect ~10 p.e.



Hall C at 12 GeV: Detectors:

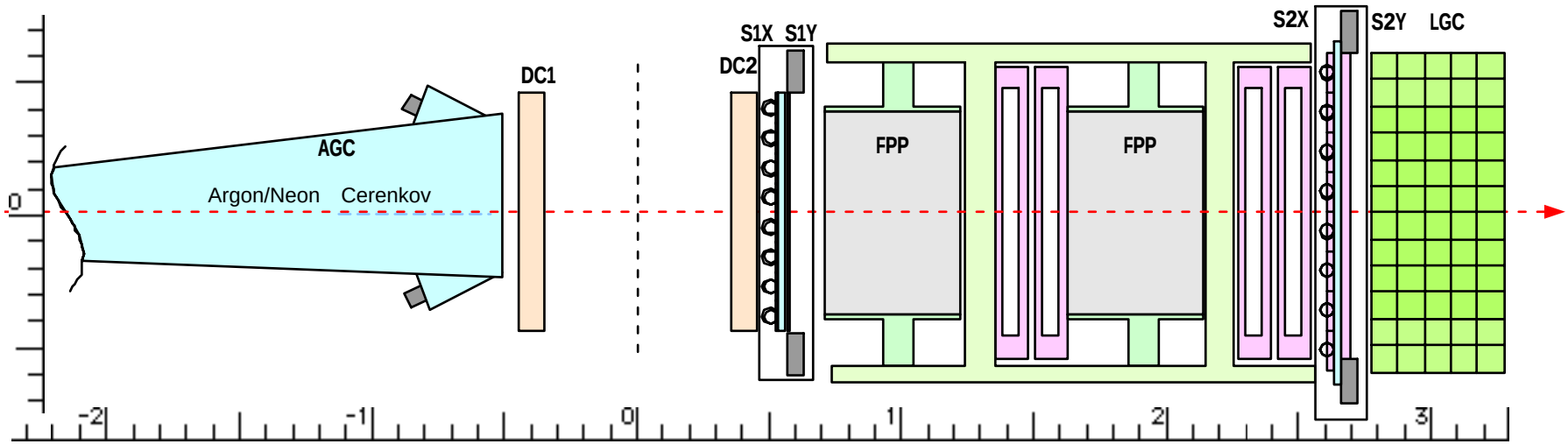
Particle Identification Summary



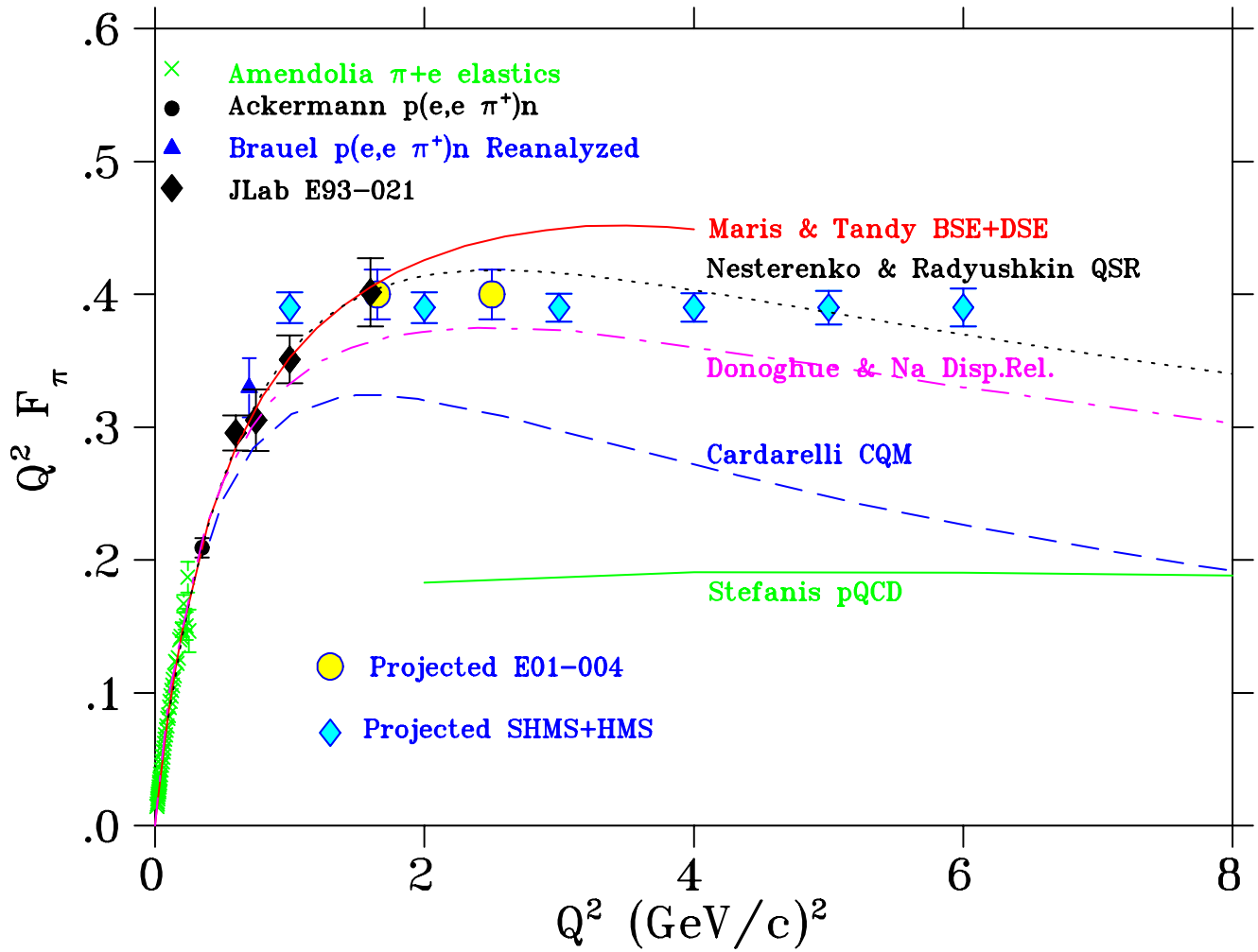
Hall C at 12 GeV: Detectors:

Focal Plane Polarimeter

The FPP being built for the HMS can also fit in the SHMS.



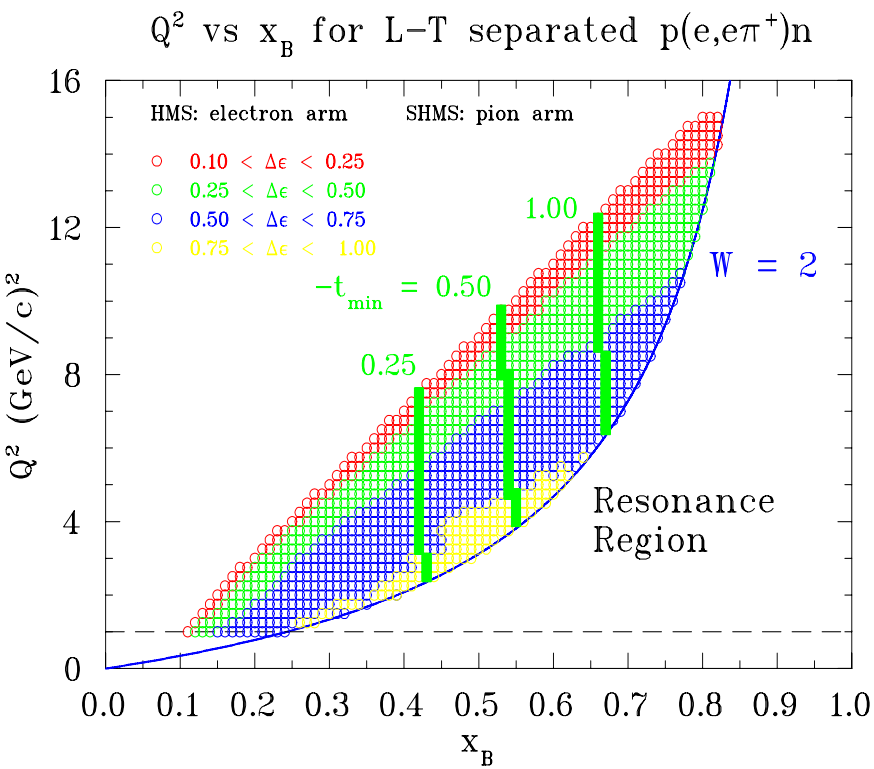
Pion Form Factor

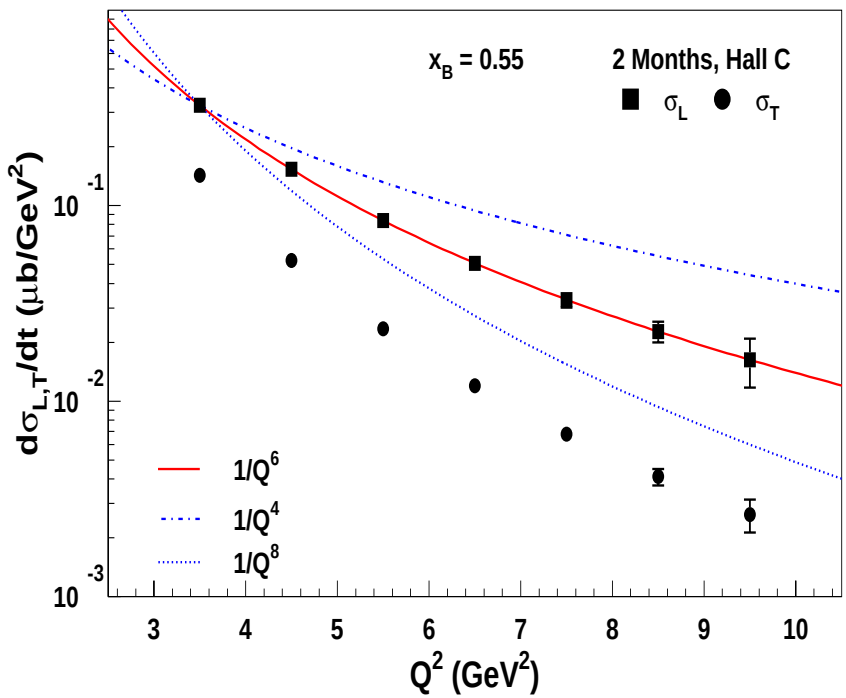


Essential:

- 9 GeV/c (at $Q^2 = 6\ GeV^2$)
- 5.5 degrees (with HMS at 10.5 degrees!)
- precise L/T (smooth acceptances)

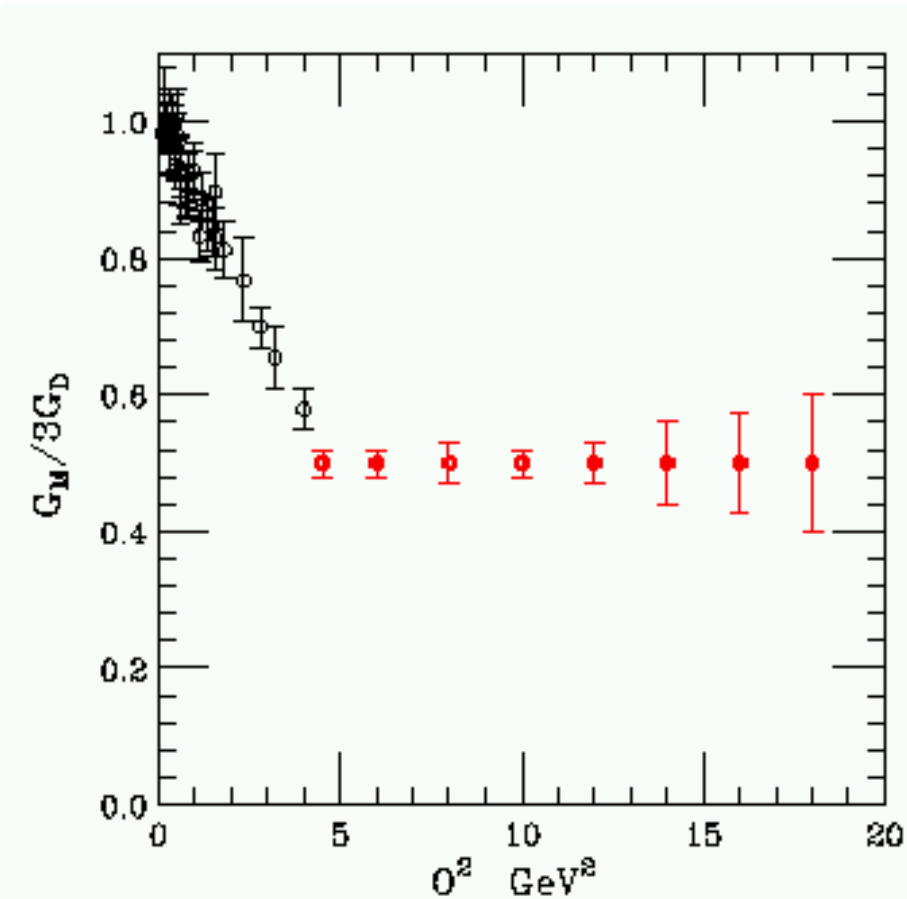
(Semi-)Exclusive Meson Production

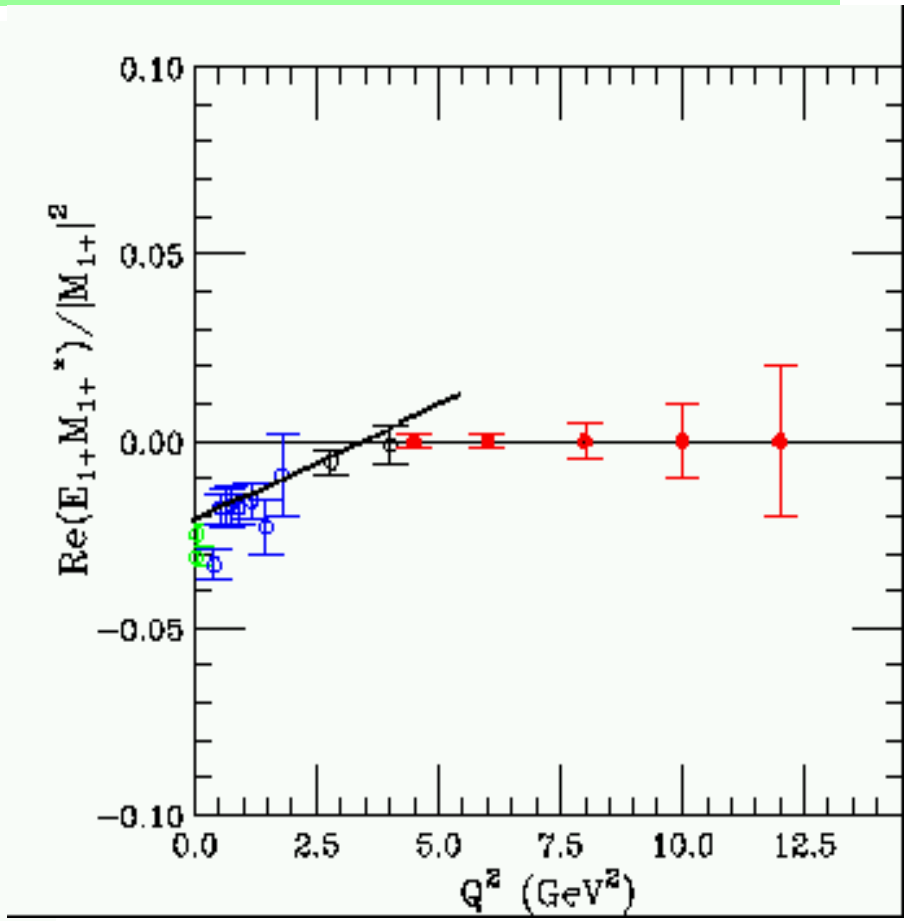




- Can access deep exclusive charged π/K electroproduction to $Q^2 \sim 10$
- Large range in z (0.3-0.8), x (0.2-0.7), Q^2 (3-10 GeV^2), and p_T in semi-exclusive meson electroproduction for duality and factorization studies and, if applicable, spin/flavor parton distributions

Proton-Delta Transition

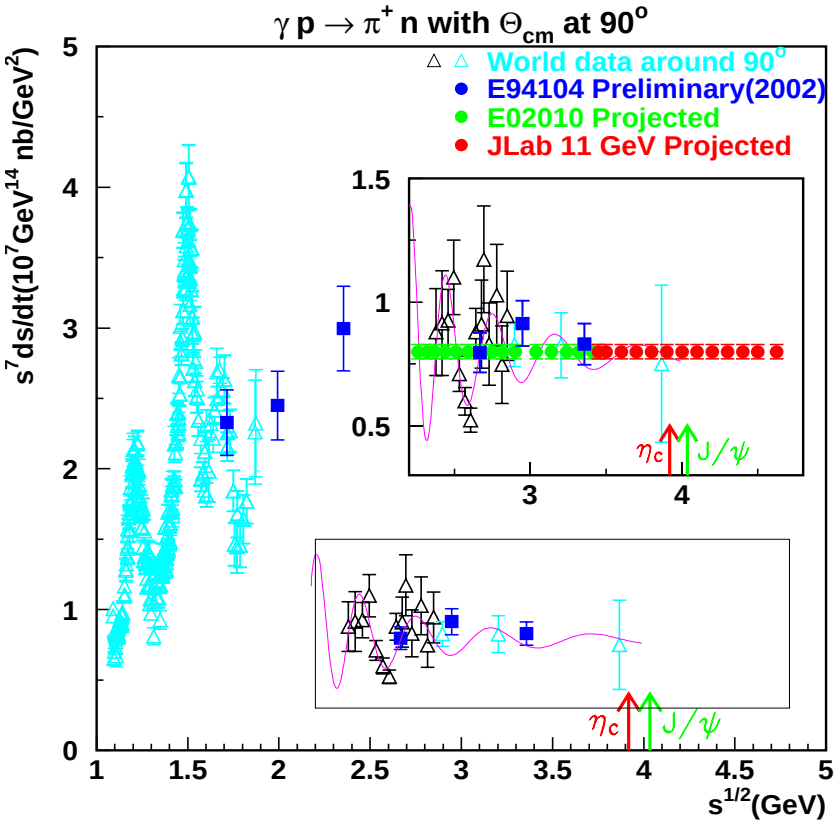


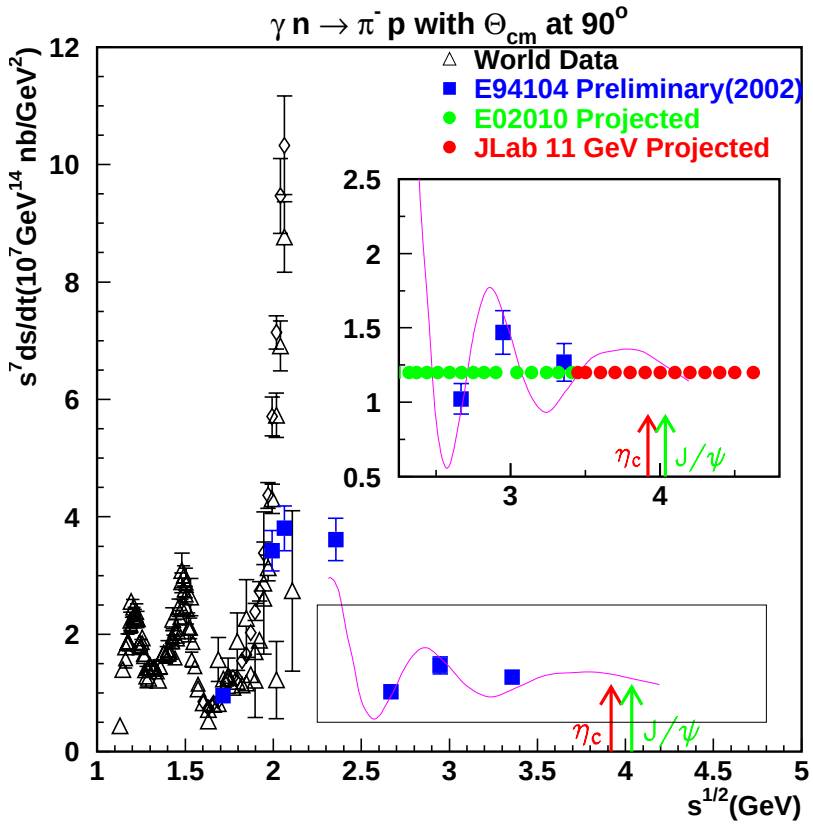


Can access magnetic transition form factor up to $Q^2 = 18$ GeV^2 (typ. $Q^2 \sim 15$ GeV^2)

Assumption: E2/M1 remains small. If not → higher Q^2 may be possible

Crossing Charm Threshold





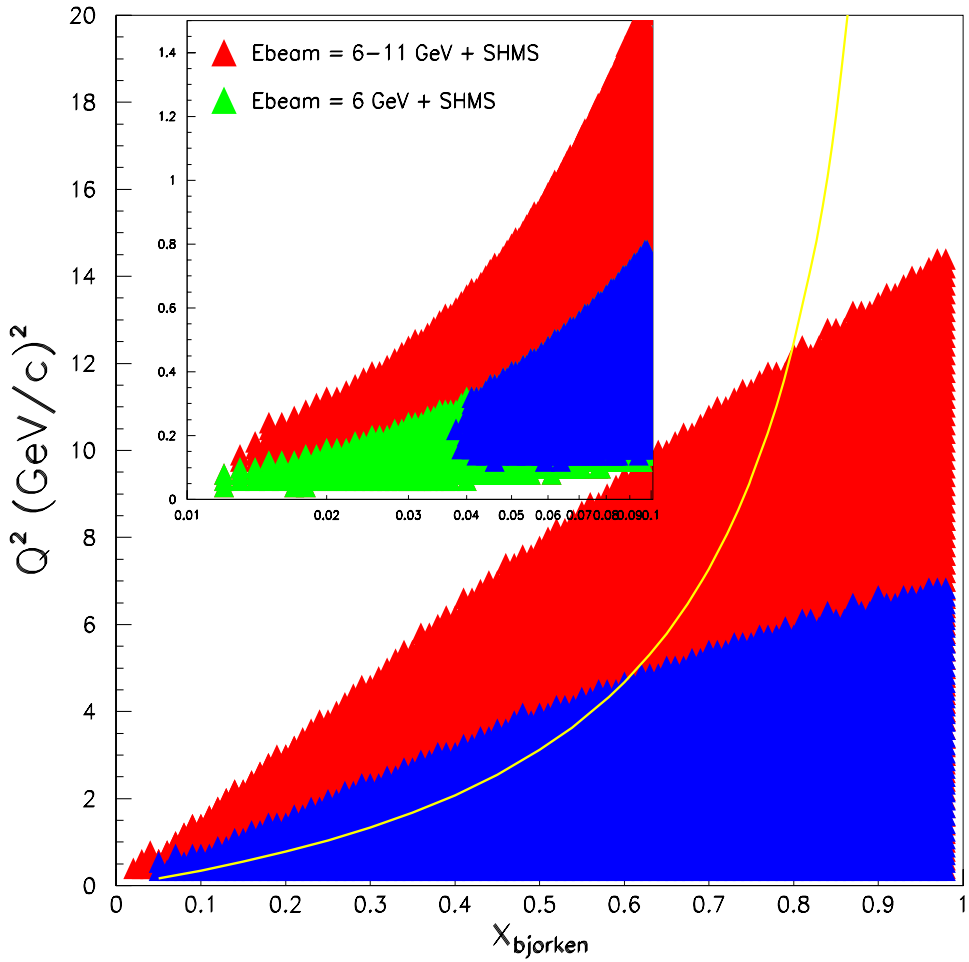
Small Cross Sections require high luminosity hall

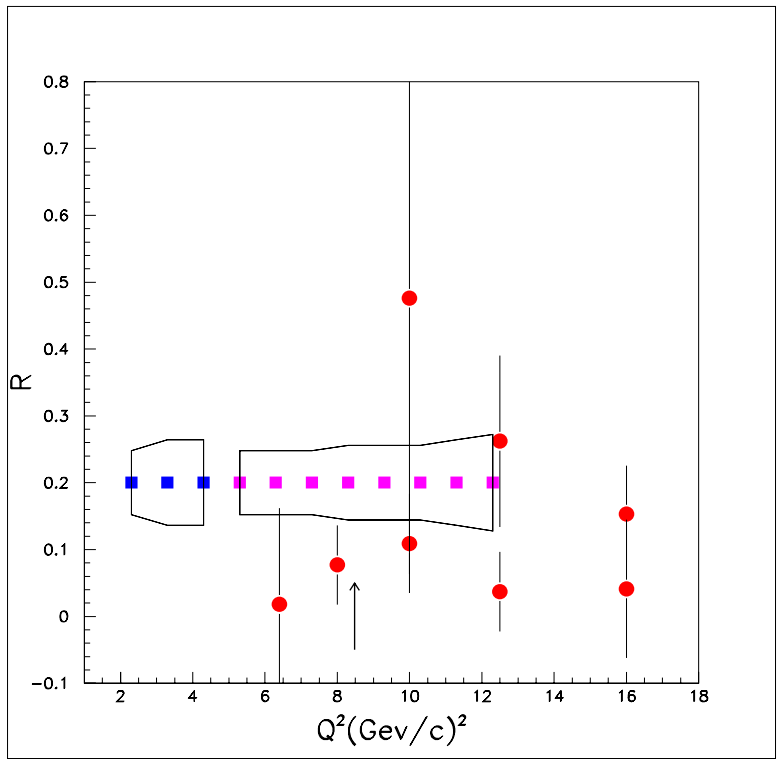
Requires detection of two charged particles with ~6.5 GeV/c momentum

$\gamma p \rightarrow \pi^o p$ also possible using BigCal (under construction)

Separated Structure Functions

$\Delta\varepsilon > 0.3$ H,D(e,e') $x = 0.8$





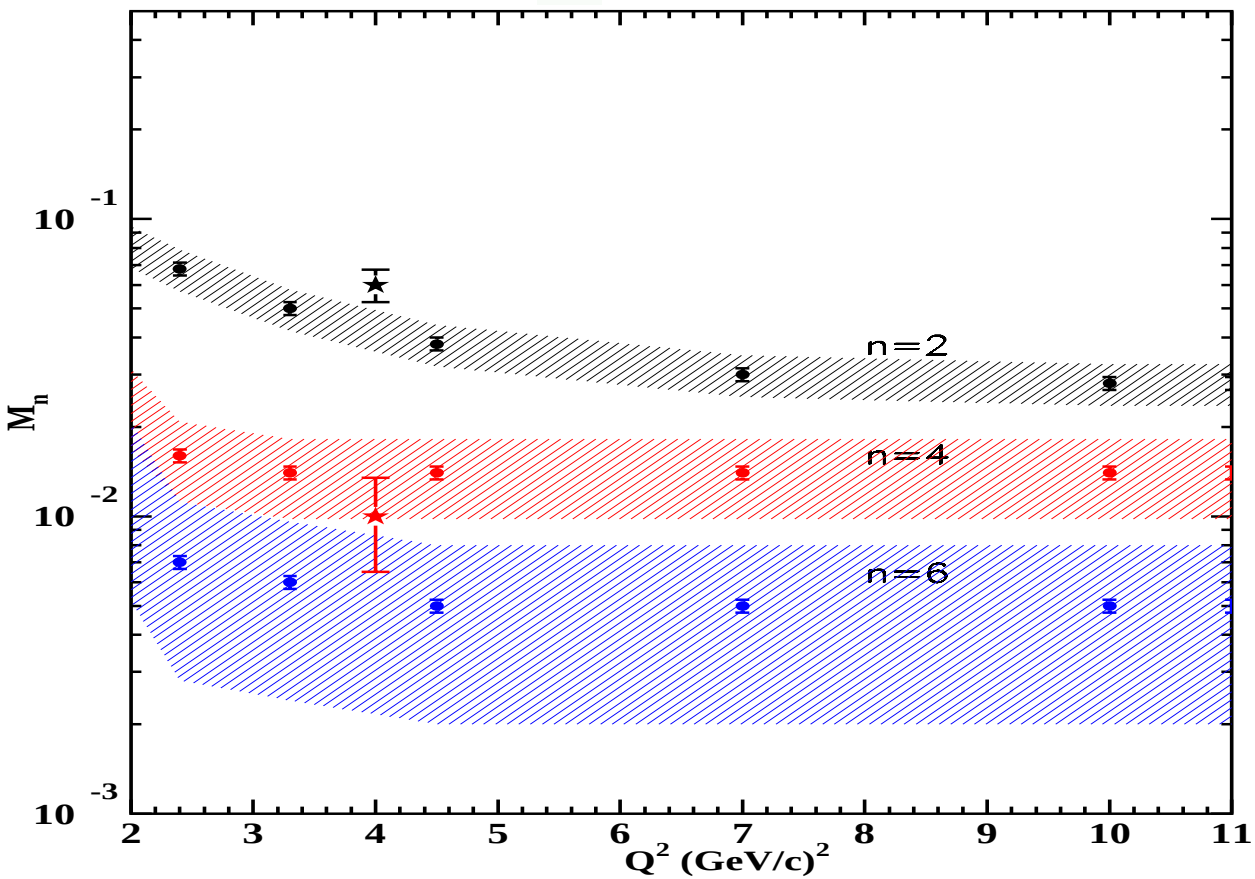
$\sigma + R \rightarrow F_1$ and F_2 (F_1 and F_L)

$+ A_{//} + A_{\perp} \rightarrow g_1$ and g_2

$+ x > 1$ in Nucleus

Structure Function Moments

$$M_n(Q^2) = \int_0^1 dx\, x^{n-2} F_2(x,Q^2)$$



Lattice QCD

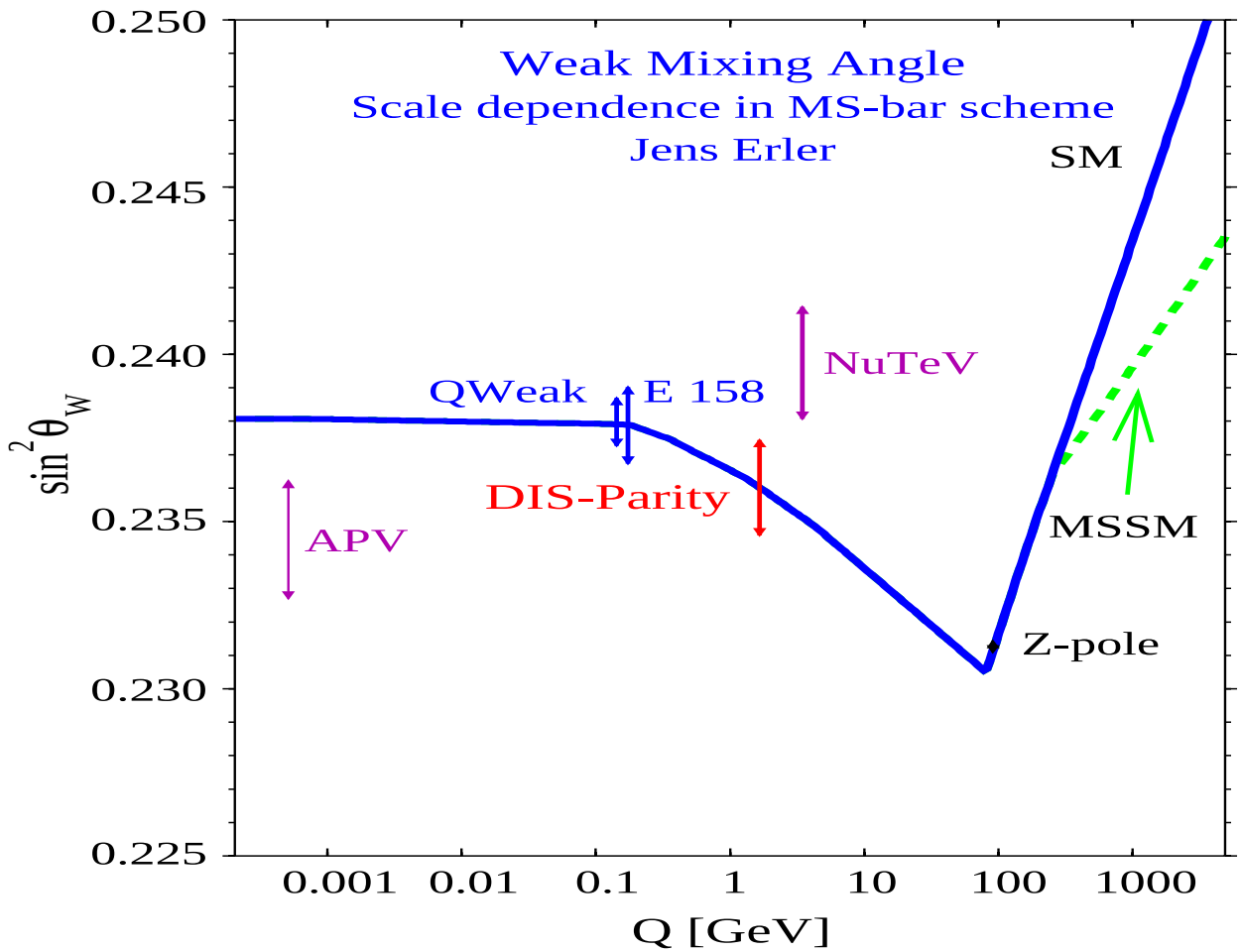
- F_2
- $p - n$
- $Q^2 = 4$ GeV^2
  ($x_{@W^2=4} = 0.56$)
- $n = 2, 4$

Experiment

- "F_2"
- $2p - d$
  (or CTEQ/MRST/GRVS)
- Lack of large x
  (resonances and elastic!)

+ Structure Functions + Duality Studies + Q^2 Evolution Studies

DIS-Parity

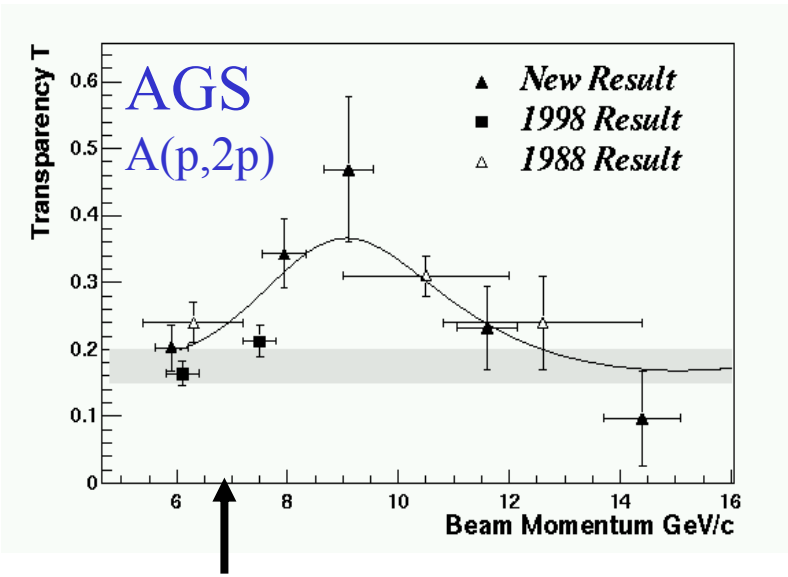


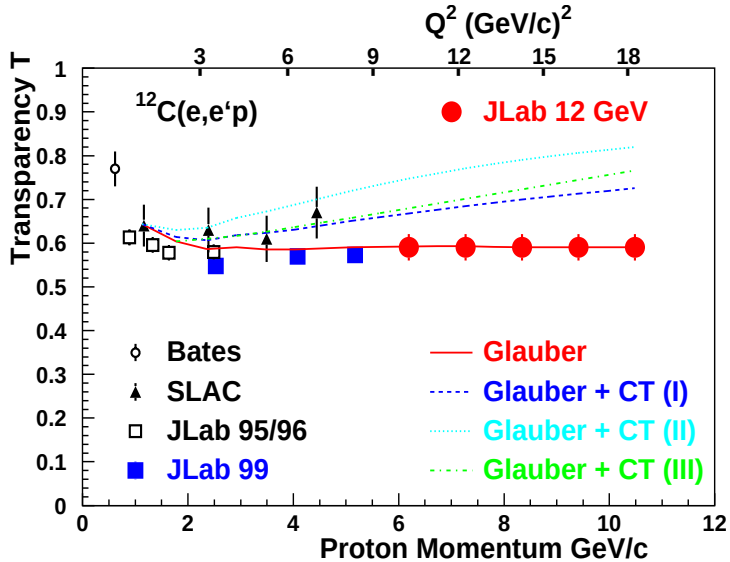
Requirements:

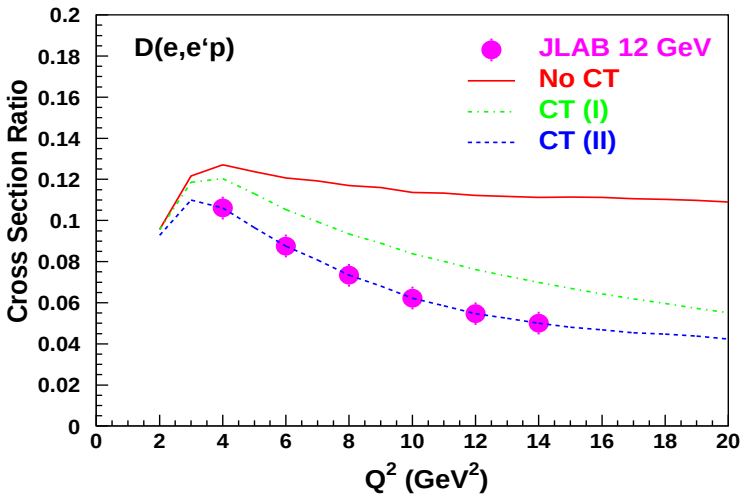
- spectrometers at 12.5 degrees
  (HMS + SHMS = 12 msr)
- ~2 kW cryogenic cooling
  (QWeak wants 2.2 kW, ~ 90 μA and 60 cm LD2)
- 1% Polarimetry
  (Qweak wants 1.4%)

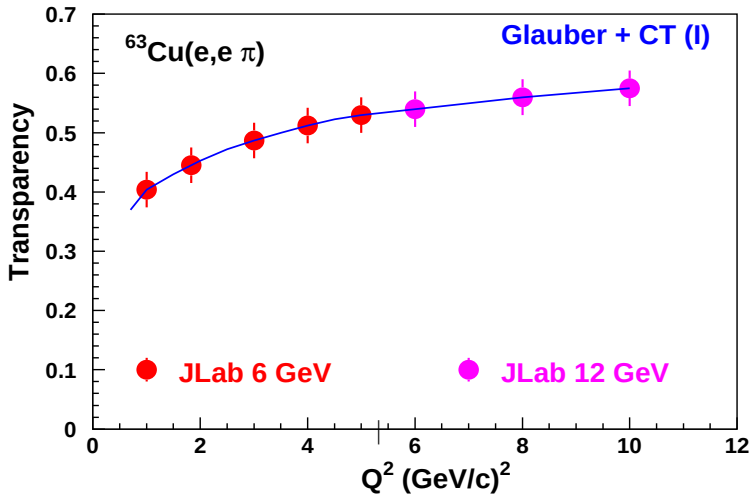
Utilizes Hall C infrastructure

Color Transparency









A(e,e'p) requires $Q^2 > 12$ GeV^2

A(e,e'π) can reach $Q^2 = 14$ GeV^2 at larger t

Hall C at 12 GeV:

HMS + SHMS

- Charged particle detection with momentum up to beam energy $z = E_h/\nu = 1$
- Small angle capability essential to measure charged particle along momentum transfer θ_h // $\mathbf{q} \pm$ few ^{o}
- Precision L/T separations

$$\sigma = \Gamma\left(\sigma_T + \varepsilon\sigma_L + \varepsilon \cos(2\phi)\sigma_{TT} + [\varepsilon(\varepsilon+1)/2]^{1/2}\cos(\phi)\sigma_{LT}\right)$$

- General Infrastructure for Dedicated Experiments

→Exclusive and Semi-Exclusive Reactions ($z > 0.3$) at high Q^2
→Separation of Polarized and Unpolarized Structure Functions over large range of x and Q^2