The PVEMC Experiment

First Measurement of the Flavor Dependence of Nuclear PDF Modification Using Parity-Violating Deep Inelastic Scattering

Spokespersons: John Arrington, Rakitha Beminiwattha, Dave Gaskell, Juliette Mammei, Paul E. Reimer

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The EMC Effect

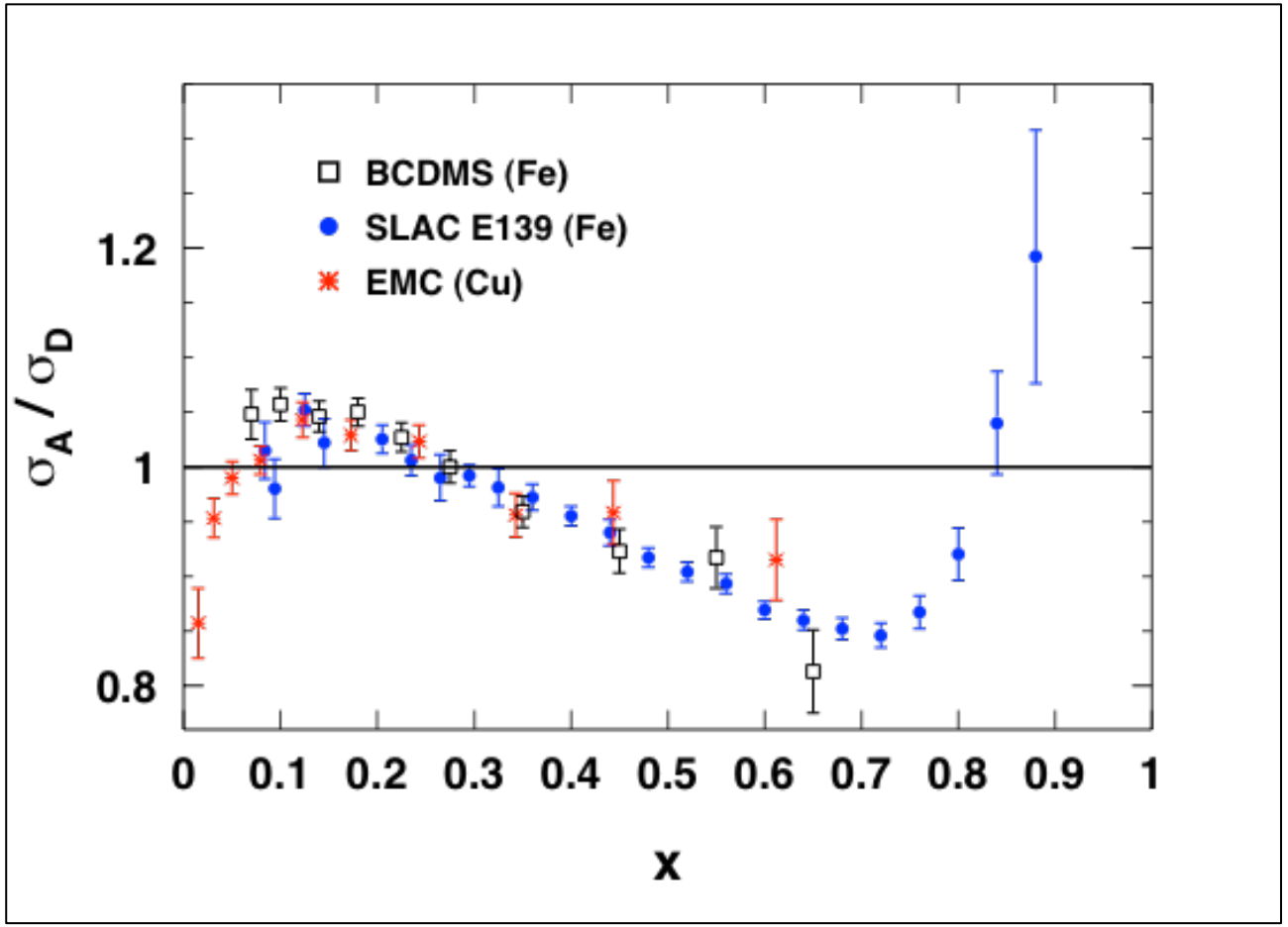
Modification of inelastic structure functions in nuclei

→ Discovered by EMC collaboration in 1983 (almost 40 years ago!)

→ Clear indication that PDFs (and quark dynamics) modified in nuclei

→ Despite intense experimental and theoretical investigation – ***no consensus on origin of EMC effect***

→ Additional "standard" measurements planned (running this summer/fall)



Progress likely requires ***new observables***

→ Polarized EMC effect

→ Flavor dependence

Flavor Dependence of the EMC Effect

CBT calculation predicts a flavor dependent EMC effect for *N≠Z* nuclei

Cloët, Bentz, and Thomas, PRL 102, 252301 (2009)

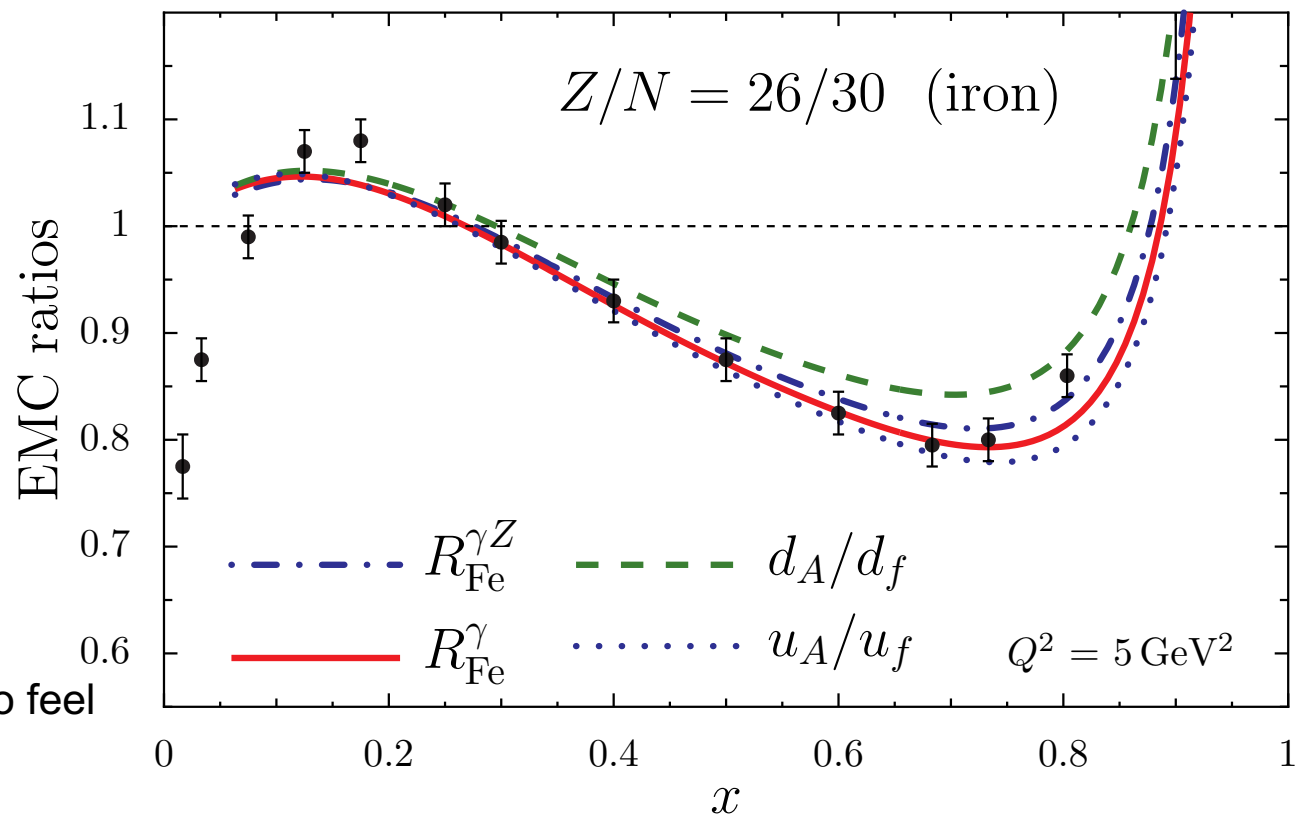
Medium modified quark distributions

$$u_A = \frac{Z\tilde{u}_p + N\tilde{d}_p}{A} \quad d_A = \frac{Z\tilde{d}_p + N\tilde{u}_p}{A}$$

Free nucleon quark distributions

$$u_0 = \frac{Zu_p + Nd_p}{A} \quad d_0 = \frac{Zd_p + Nu_p}{A}$$

Isovector-vector mean field (ρ) causes u (d) quark to feel additional vector attraction (repulsion) in *N≠Z* nuclei

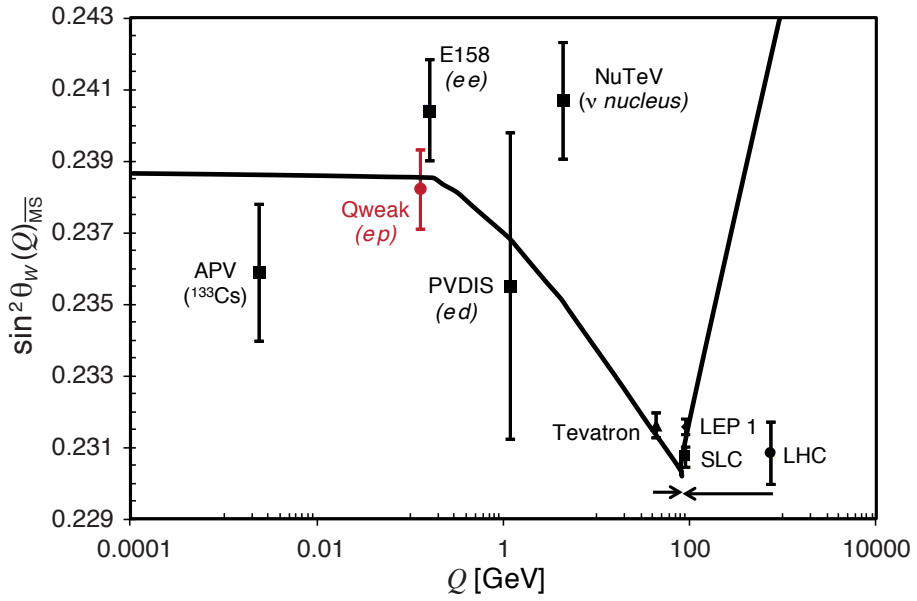


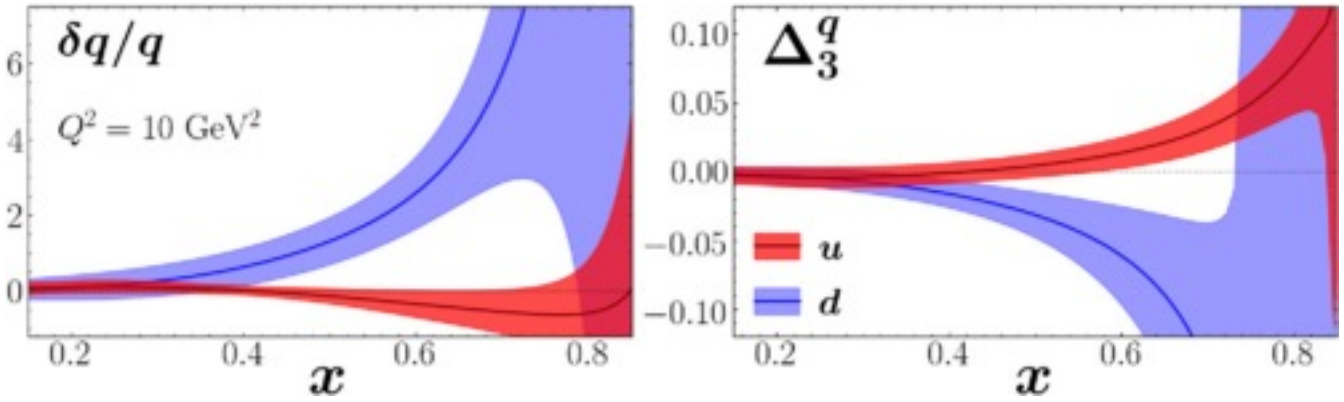
Experimentally, this flavor dependence has not been observed directly

→ Observation of flavor dependence would provide key test of models

Hints of Flavor Dependence of EMC Effect

- Flavor dependence of EMC Effect would explain 2/3 of the NuTeV anomaly *[Cloët, Bentz, and Thomas, PRL 102, 252301 (2009)]*
- Tension between nuclear dependence of electron/muon and neutrino scattering in anti-shadowing region
- Existing pionic Drell-Yan data favors flavor dependence (weakly)
- EMC-SRC correlation – if EMC effect driven by correlated NP pairs, would naturally expect difference between up and down quark distributions
- Global analysis including recent MARATHON data *[Cocuzza, et al PRL 127, 242001]*





Measurement of Flavor Dependence

Several techniques possibly sensitive to flavor dependence of EMC effect

Pionic Drell-Yan:

→ Previous data of limited discriminating power *[Dutta et al, PRC 83, 042201 (2011)]*

→ AMBER @ CERN will make measurements over the range 0.08<x<0.34)

$$\frac{\sigma^{DY}(\pi^+ + A)}{\sigma^{DY}(\pi^- + A)} \approx \frac{d_A(x)}{4u_A(x)}$$

$$\frac{\sigma^{DY}(\pi^- + A)}{\sigma^{DY}(\pi^- + D)} \approx \frac{u_A(x)}{u_D(x)}$$

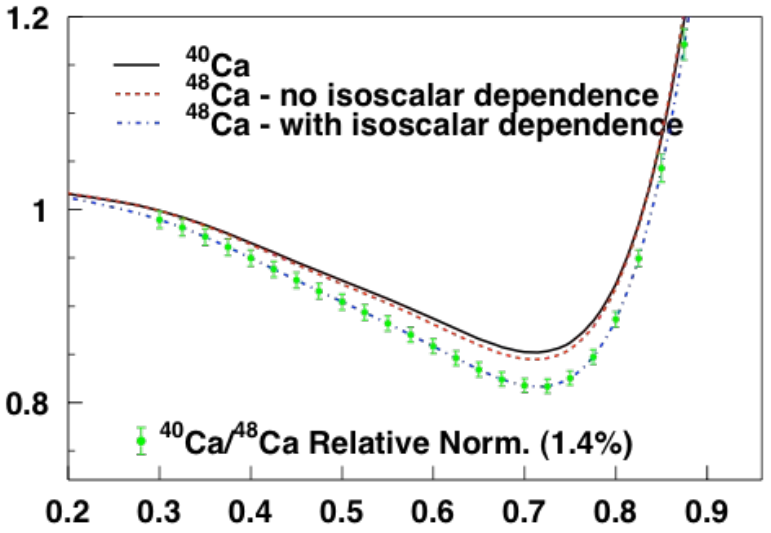
SIDIS:

→ Flavor tag struck quark via π+/π- production

→ Heavy targets: hadron attenuation effects complicate interpretation

→ Light targets: size of the EMC effect is small

→ Any target: factorization of hard scattering and quark hadronization required



Inclusive DIS:

→ Require target with similar *A*, compare *N*=*Z* to *N*≠*Z*

→ At best 2σ measurement (as compared to CBT model)

→ Additional model dependence from *A*-dependence, n/p ratio

PVDIS and Flavor Dependence

PVDIS sensitive to different combination of PDFs
→ Like inclusive DIS, avoids complications due to complicated final states

$$A_{PV} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[a_1(x) + \frac{1-(1-y)^2}{1+(1-y)^2}a_3(x)\right]$$

Suppressed

Expanding about u_A=d_A limit, neglecting sea quarks:

$$a_1(x) \approx \frac{9}{5} - 4\sin^2\theta_W - \frac{12}{25}\frac{u_A^+ - d_A^+}{u_A^+ + d_A^+}$$

$$q^{\pm} = q(x) \pm \bar{q}(x)$$

PVDIS directly sensitive to difference in up and down quark distributions in nuclei

PVEMC with SOLID

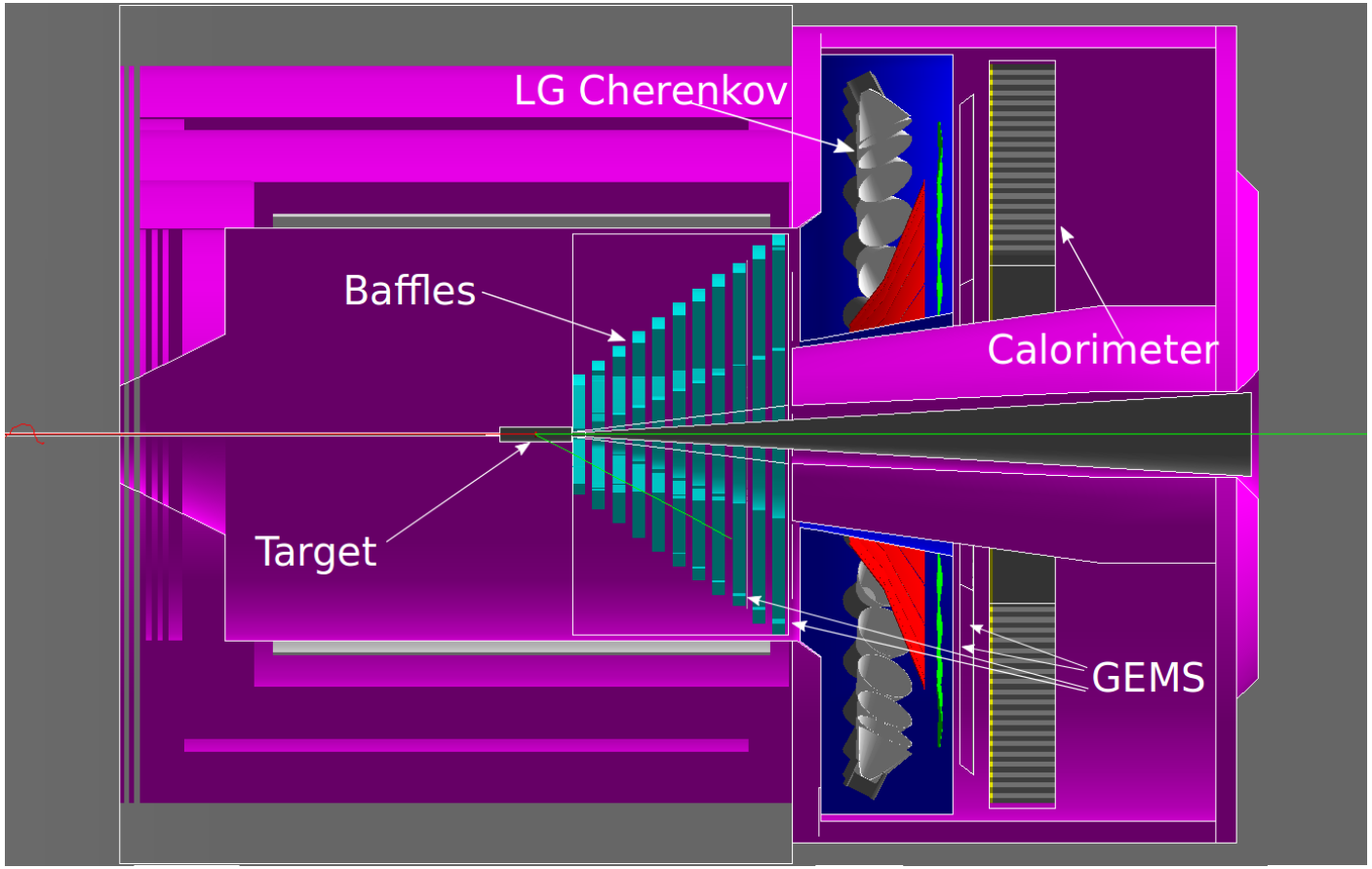
High precision measurement possible with SOLID in PVDIS configuration

→ Identical spectrometer/detector configuration as PVDIS (baffles, etc.)

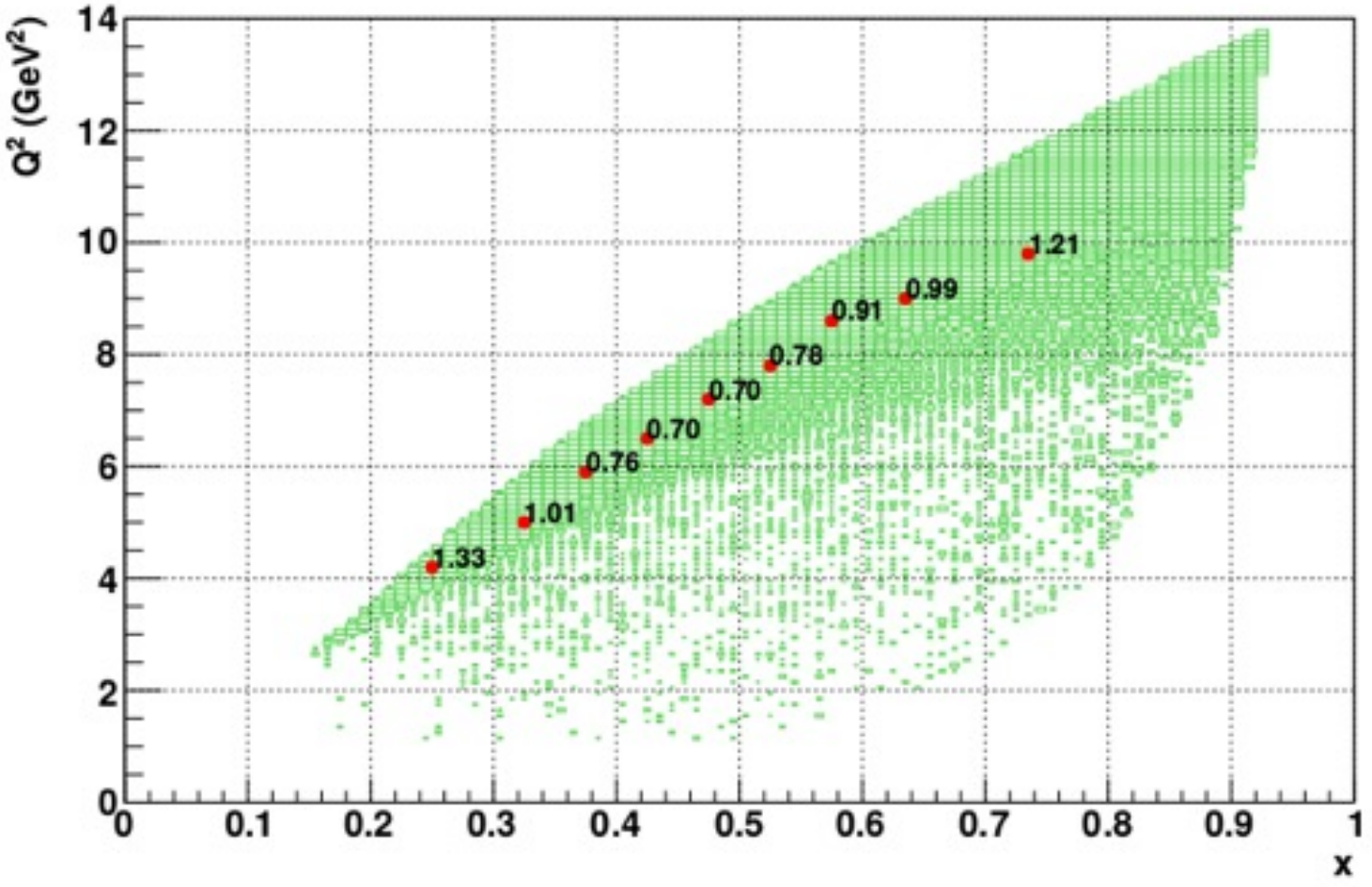
PVEMC measurement requires target with N ≠Z and large EMC effect

→ ^{48}Ca satisfies both requirements with smaller radiation length than heavier targets (e.q., gold or lead)

→ Sufficient ^{48}Ca at JLab to provide 2.4 g/cm^2 thickness – some processing of calcium will be required



Kinematic Coverage and Precision



Red points indicate projected x-bins and precision on A_{PV}

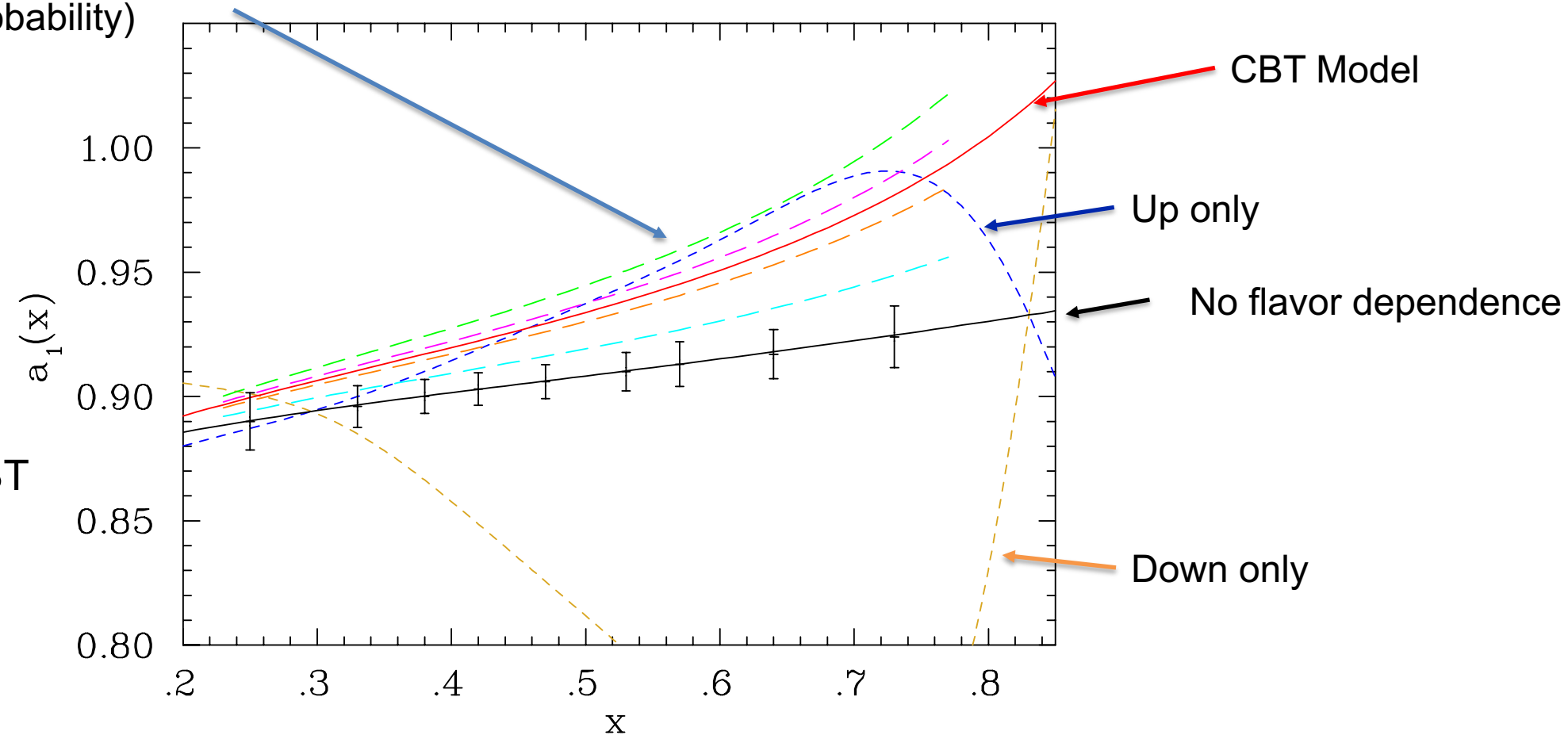
68 days of production on ^{48}Ca at 80 μA with maximum long. polarization

→ Excellent coverage in relevant x-range

→ Better than 1% statistical precision in most bins

Projections - Sensitivity

Scaling models (p>300 MeV, kinetic energy, average density, overlap probability)



8σ sensitivity to CBT model (neglecting normalization uncertainty)

Systematic Uncertainties

Effect	Uncertainty (%)	
Beam polarimetry	0.4	Same as PVDIS on LD2
$R^{\gamma Z}/R^{\gamma}$	0.2	*PRD 84:074008, 2011*
Pions (bin-to-bin)	0.1-0.5	
Charge-symmetric background	<0.1	Constrained by measurements at opposite field
Radiative corrections (bin-to-bin)	0.5-0.1	
Other corrections (including CSV)	0.2	
PDF uncertainties	0.2	Constrained by MARATHON, PVDIS, BONUS12
Total Systematic	**0.6-0.7**	

Statistical uncertainty = 0.7-1.3%

Total systematic uncertainty expected to be comparable or smaller than statistical uncertainty

Beamtime Request

Request 83 days total for first measurement of flavor dependence of EMC effect via PVDIS from ^{48}Ca
→ Time included for spectrometer optics, charge symmetric background measurements, commissioning and polarimetry

Activity	Time (days)	E (GeV)	Current (μA)
^{48}Ca Production	68	11	80
Optics	2	4.4	Up to 80
Positive polarity	4	11	80
Møller Polarimetry	4	11	2
Commissioning	5	11	Up to 80
Total	**83**		

Summary

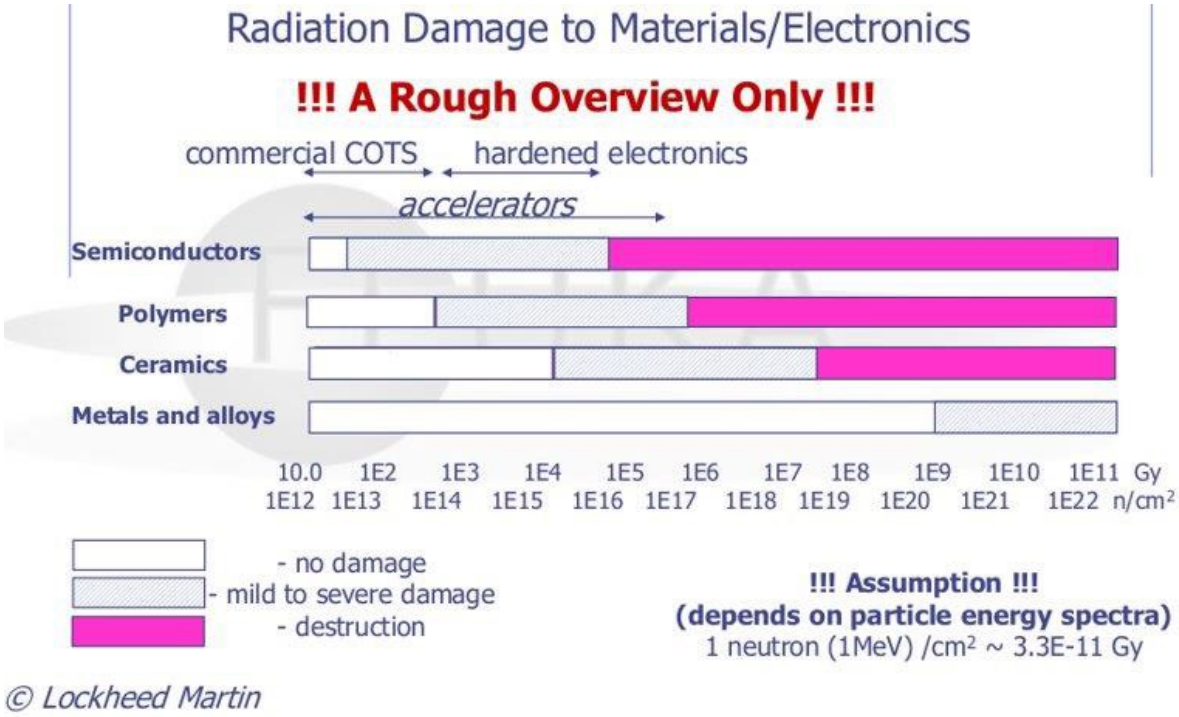
- Despite renewed interest in recent years, no consensus on the origin or flavor dependence of the EMC Effect
- New observables required to provide more insight
- PVDIS offers a precise, interpretable measurement of possible flavor dependence of the EMC effect
- PR12-22-002: Measurement of PVDIS from ^{48}Ca using SOLID apparatus
  - 83 days total (68 days production)
  - Will provide 7-8 σ test of CBT model
  - Several aspects less challenging than approved PVDIS on LD2 experiment: lower rates, no target boiling, shorter target (better control of acceptance and collimation)

EXTRA

Radiation

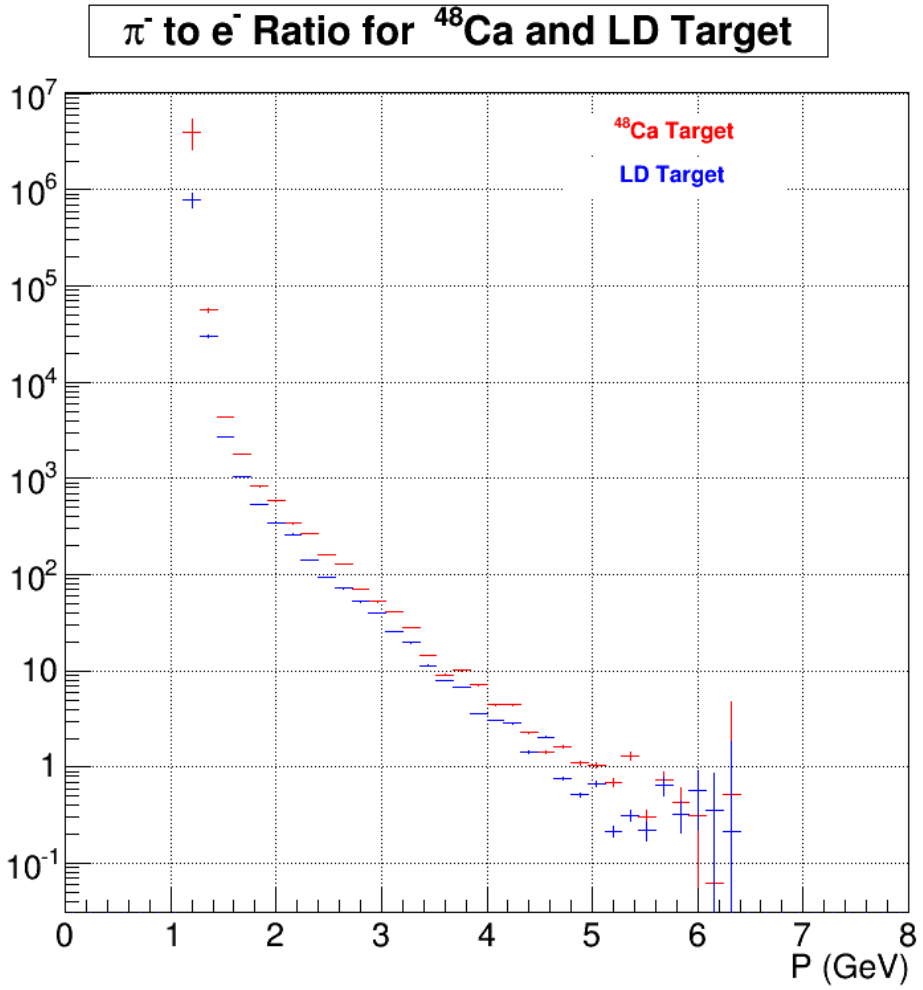
Experiment	Top of the Hall Neutron Dose (m^{-2})	Estimated Boundary DOSE (mrem)	Measured Boundary DOSE (mrem)
PREX-I	4.50E+12	4.2	1.3
PREX-II	5.80E+12	2.0	1.2
CREX	1.50E+13	1.8	1.0
LD-PVDIS 6 GeV	1.90E+12	0.7	n/a
LD-PVDIS 11 GeV	3.40E+12	1.3	n/a
^{48}Ca-PVDIS 11 GeV	6.00E+12	2.5	n/a

Comparison to previous experiments

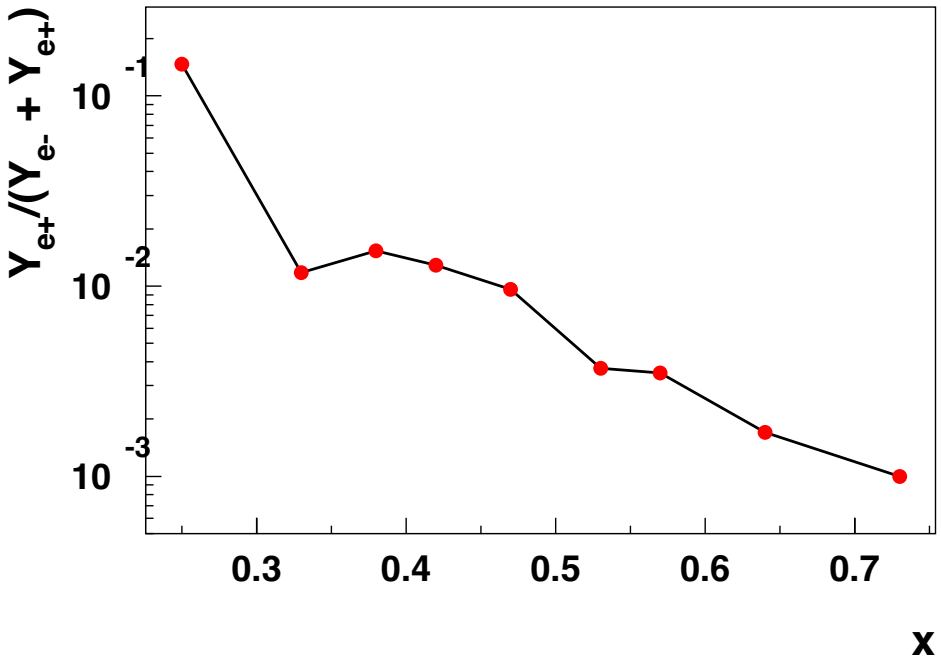


Electronics damage threshold exceeded only in area near downstream beamline (FLUKA simulations)

Backgrounds



Pion fraction no worse than 4%.
Pion rejection: Cherenkov - 1000-400:1, calorimeter (100:1)



Estimated charge symmetric background
→ Model scaled to agree w/Hall C e+/e- ratios

Inclusive DIS – Sensitivity to Flavor Dependence

E12-10-008 will inclusive DIS from $^{48}Ca/^{40}Ca$
→ Assuming n/p ratio known, *A* dependence known, sensitive to flavor dependence of EMC effect

Plot shows projections assuming 4x proposed statistics

→ Approximately *2.3*σ sensitivity (when normalization uncertainty included)