22 Settembre 2015

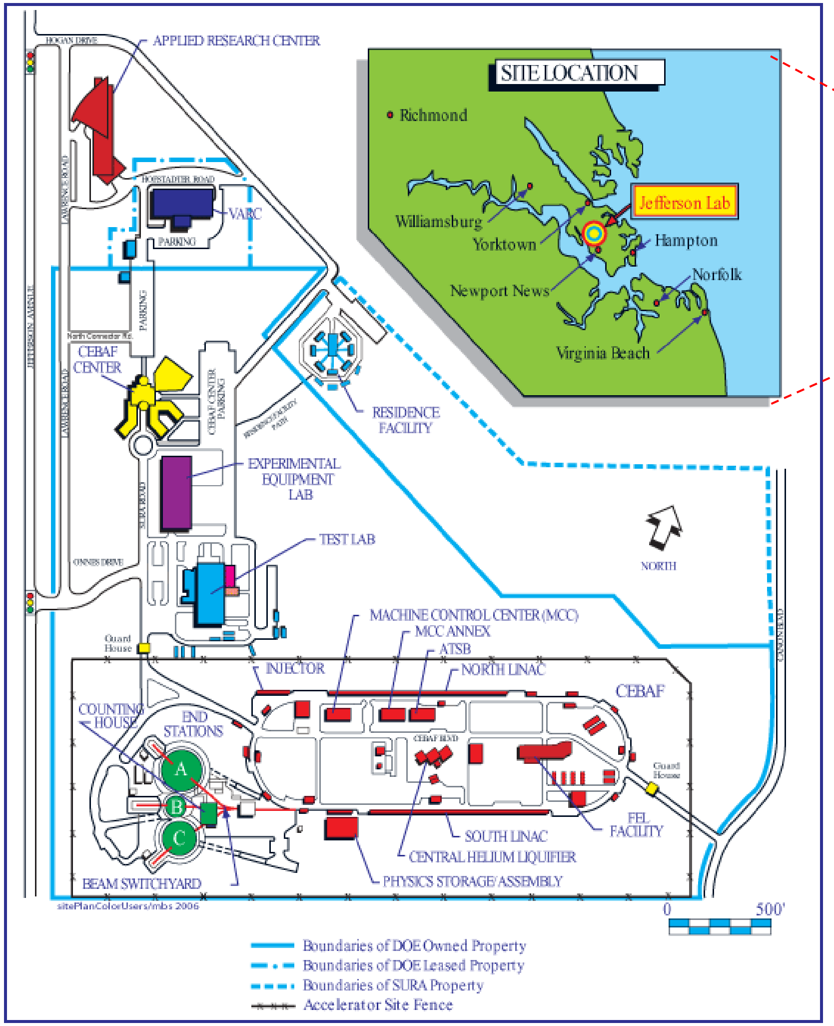
SIF 2015 – Roma

Il programma sperimentale italiano al JLab

Evaristo Cisbani / ISS e INFN-Sanità

- Introduzione al Jefferson Laboratory
- Sperimentazione fisica
  - **Struttura del nucleone**
  - **Violazione di parità nella diffusione dell'elettrone**
  - **Struttura e dinamica nucleare**
  - **Spectroscopia adronica**
  - **Ricerca di materia oscura**

Thomas Jefferson National Accelerator Facility



1987: Inizio costruzione

1995: Primi esperimenti fisica

1997: Energia a 4 GeV (goal di progetto)

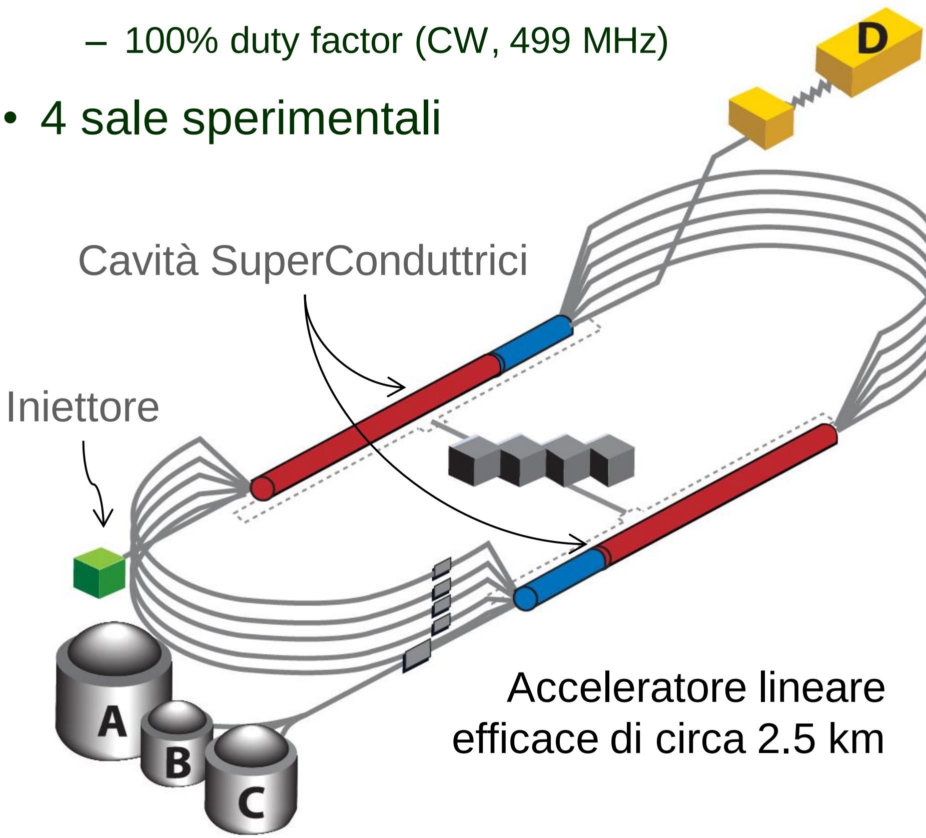
2000: Energia a 6 GeV

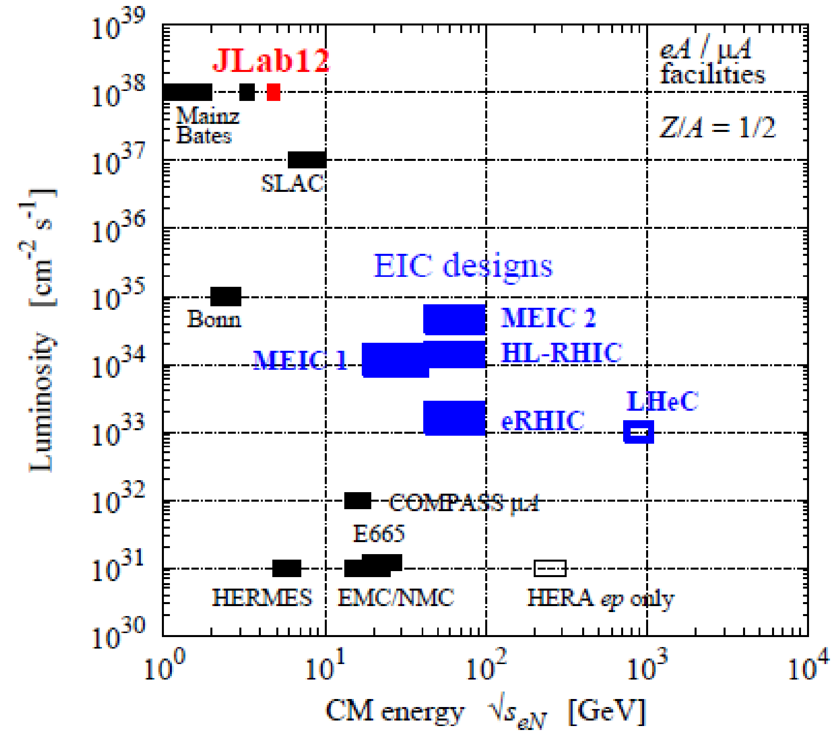
2014: Energia a 12 GeV

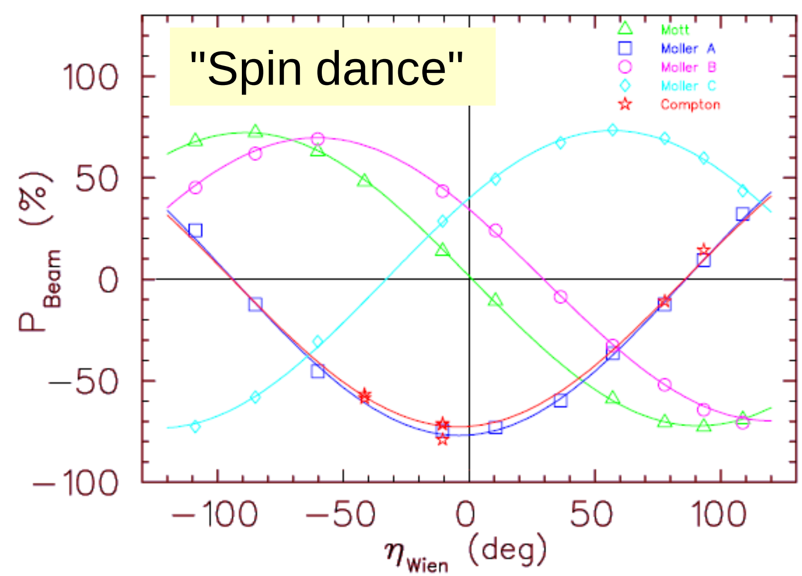
- Newport News / Virginia / USA (3 ore da Washington DC)
- Finanziamento DOE + Enti Locali
- Direttore: H. E. Montgomery (ex associate director for research al Fermilab)
- **2000 Utenti internazionali**
- Ricerca fondamentale con acceleratore di elettroni (CEBAF) e 4 sale sperimentali
- Ricerca applicata con FEL ed altre facility
- Sito Web: www.jlab.org

Acceleratore Lineare Continuo di Elettroni - CEBAF

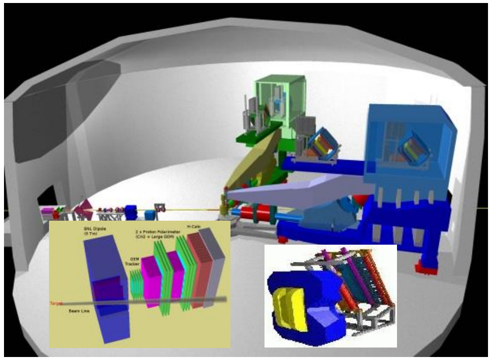
- Energia fino a 12 GeV con $\delta E/E \sim 10^{-4}$
- *Eccellente emittanza:* ~ qualche nm-rad
- Fascio polarizzato long. ~ 85%
  - (1kHz helicity flip)
- Corrente ≤ 100 μA
  - 100% duty factor (CW, 499 MHz)
- 4 sale sperimentali

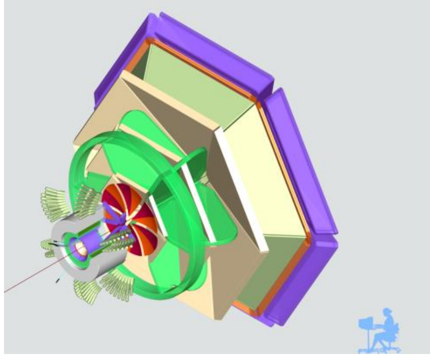


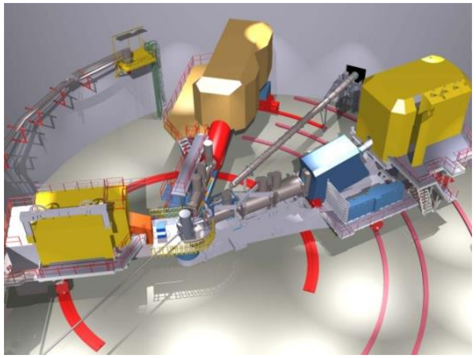


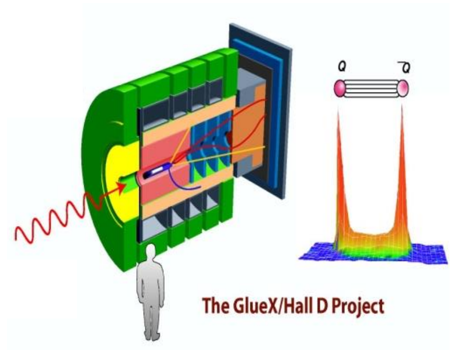


JLab: Sale sperimentali 2014 - 2020









Hall A	Hall B/CLAS12	Hall C	Hall D/GLUEX
Very large equip. and flexible installations, high lumi	**2π coverage, extended particle ID**	**Large and flexible installations, high lumi**	**Real photon beam, new Hall**
2 High momentum resolution spectrometers **1 large acceptance, high lumi spectrometer with hadron ID** **dedicated equipment for neutron and gamma**	**New spectrometer, fixed installation**	Two Asymmetric **High momentum range** and **high resolution spectrometers** **“super high” momentum spectrometer** **dedicated equipment**	**Excellent hermetic coverage,** **Solenoid field** **High multiplicity reconstruction**
High beam current lumi 10^{38} cm^{-2} s^{-1}	**Forward tagger for real photons**	High beam currents (>100 μA), **lumi 10^{37} cm^{-2} s^{-1}**	10^8 linearly pol., up to 12 GeV, real photons/s
3He T/L pol. target, many unpol. targets from H to Pb	**NH3/ND3 pol. Target, trans. polarized H/D target**	NH_3/ND_3 Polarized long. target, high flexibility unpol. from H to Pb	
hallaweb.jlab.org	www.jlab.org/Hall-B	www.jlab.org/Hall-C	www.jlab.org/Hall-D

JLab: Fisica

Struttura del nucleone

Fattori di Forma (FF), Distribuzioni Partoniche dipendenti dal momento trasverso (TMD), Distribuzioni partoniche generalizzate (GPD)

Struttura e dinamica nucleare

La struttura a quark dei nuclei, e loro propagazione nel mezzo nucleare (effetto EMC, trasparenza nucleare)

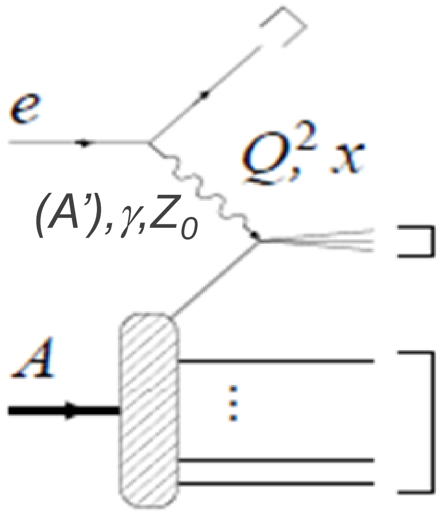
Interazione a corto range N-N e interazione N-Λ

Spettroscopia adronica

Ricerca Stati ibridi ed esotici

Test Lattice QCD

Confinamento



Misure di violazione della Parità

Test di alta precisione del modello standard

Studio delle distribuzione di quark-s nel nucleone

Misura della distribuzione dei neutroni in nuclei medio-pesanti

Ricerca di Materia Oscura

<u>Beam</u>:
- High intensity,
- «high» energy
- polarized
- low emittance

<u>Targets</u>:
- from H to Pb
- polarized
- stand high beam intensity

<u>Detectors</u>:
- large acceptances
- support high background
- hadron identification
- precise reconstruction

e⁻ JLab12

Esperimento INFN attivo dal 2009 nasce dalla sinergia dei gruppi già coinvolti al JLab (AIACE + LEDA) per sfruttare al meglio le opportunità sperimentali offerte dall'aggiornamento a 12 GeV del JLab

70 Ricercatori coinvolti (42.7 FTE)
da 11 Gruppi INFN e Università/Istituti
(**BA, CA, CT, FE, GE, LNF, PD, RM1, RM1-Sanità, RM2, TO**)

Coordinatori Nazionali: M. Battaglieri (GE), G.M. Urciuoli (RM1)

http://www.ge.infn.it/jlab12/

- Intensa attività sperimentale prevalentemente nelle sale A e B
- Forte coinvolgimento negli sviluppi di nuovi apparati nelle sale sperimentali legati al raddoppio di energia da 6 a 12 GeV

Attivi al JLab anche diversi gruppi teorici italiani

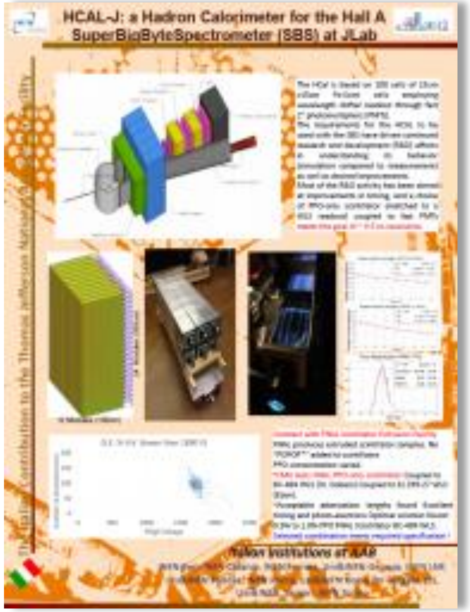
La più grande collaborazione di ricerca Italiana negli USA

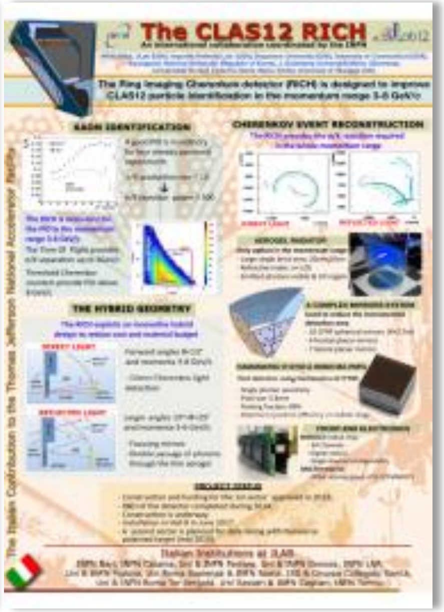
Struttura del nucleone

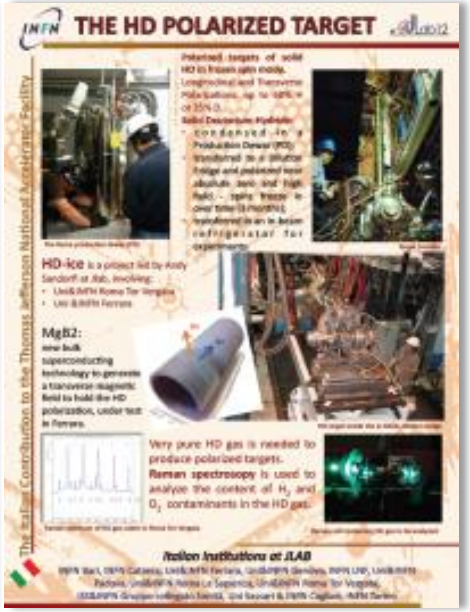
- **Fattori di Forma**
- **TMD**
- **GPD**

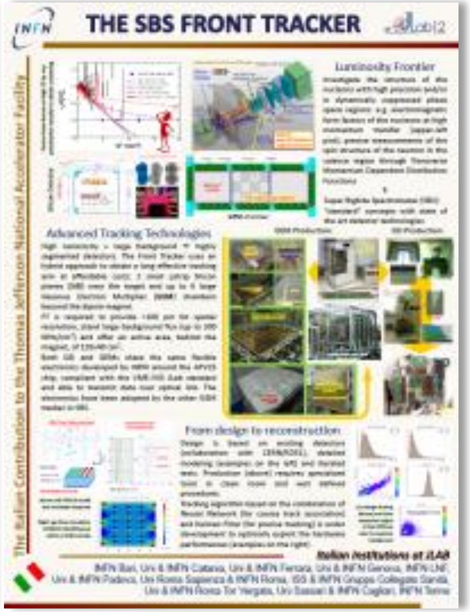
Alta luminosità
Fasci polarizzati
Polarimetria adronica

Bersagli polarizzati
Ampia accettanza
Identificazione adroni

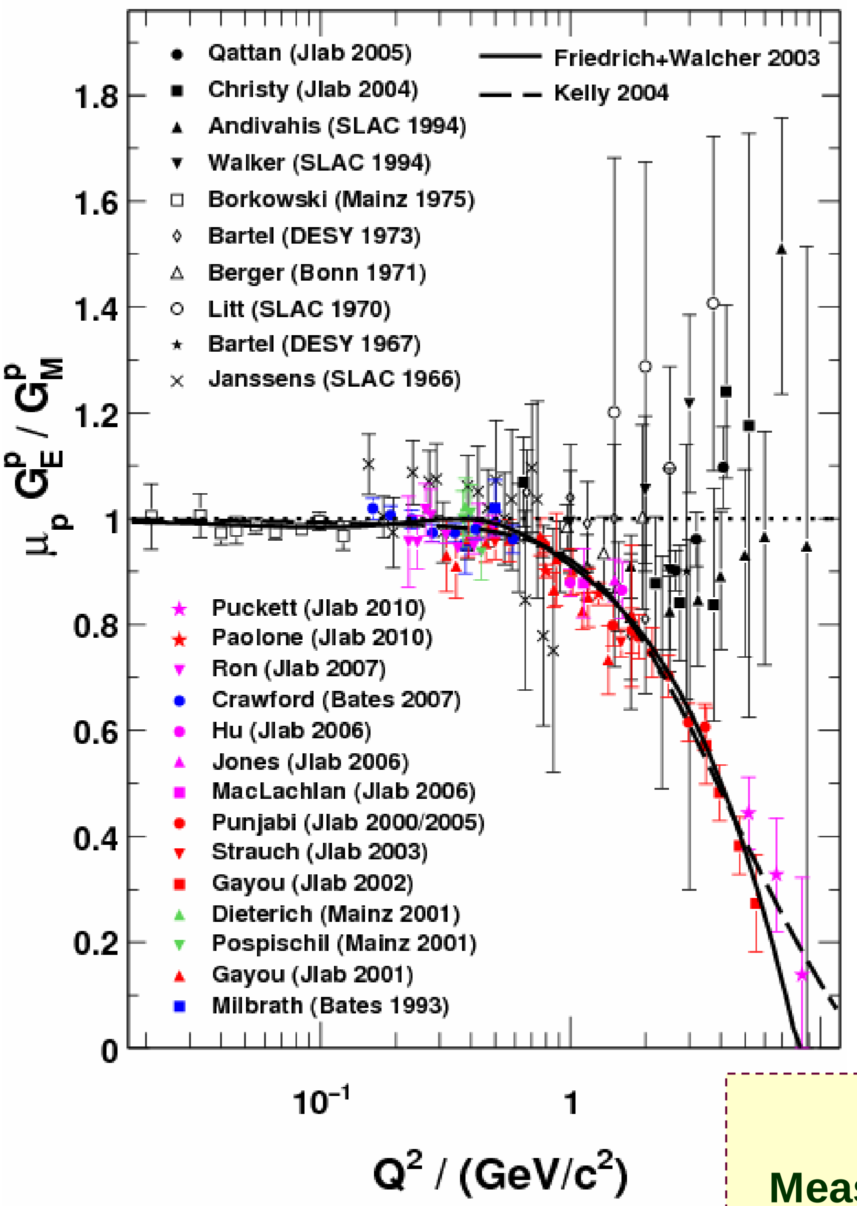








Proton G_E/G_M – an «**unexpected**» **discrepancy**



$e + p \rightarrow e' + p'$ (elastic)

$$\frac{d\sigma}{d\Omega} \propto G_{Ep}^2 + \frac{\tau}{\varepsilon} G_{Mp}^2$$

Rosenbluth Separation: assume single photon approximation

Prior to JLab/2000, expectations were that proton G_E/G_M fairly constant with Q^2

$$\mu \frac{G_{Ep}}{G_{Mp}} = -\mu \frac{P_t}{P_l} \frac{(E_{beam} + E_e)}{2M_p} \tan \frac{\vartheta_e}{2}$$

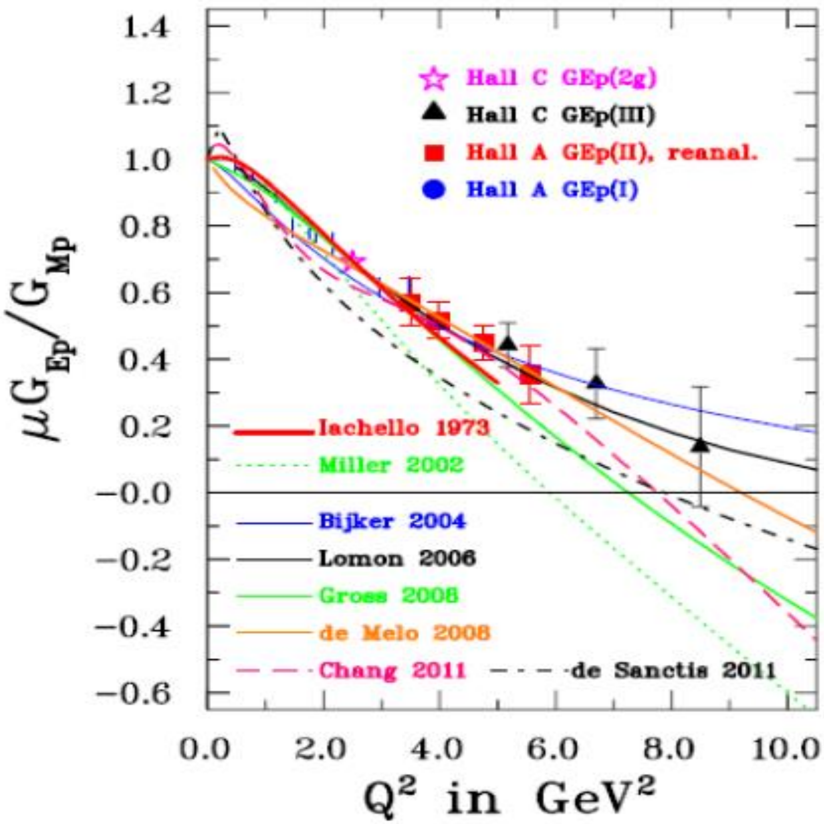
Polarization transfer from the incident electron to the scattered proton

At JLab, new class of experiments show proton G_E/G_M decreasing linearly with Q^2

$$R_p = \mu_p \frac{G_E(Q^2)}{G_M(Q^2)} \approx 1 - \underbrace{0.13\,(Q^2 - 0.29)}_{Pol.\ Transfer\ Discr.}$$

Dramatic evidence of data discrepancy: Measurements? QED Approximation? Other model?

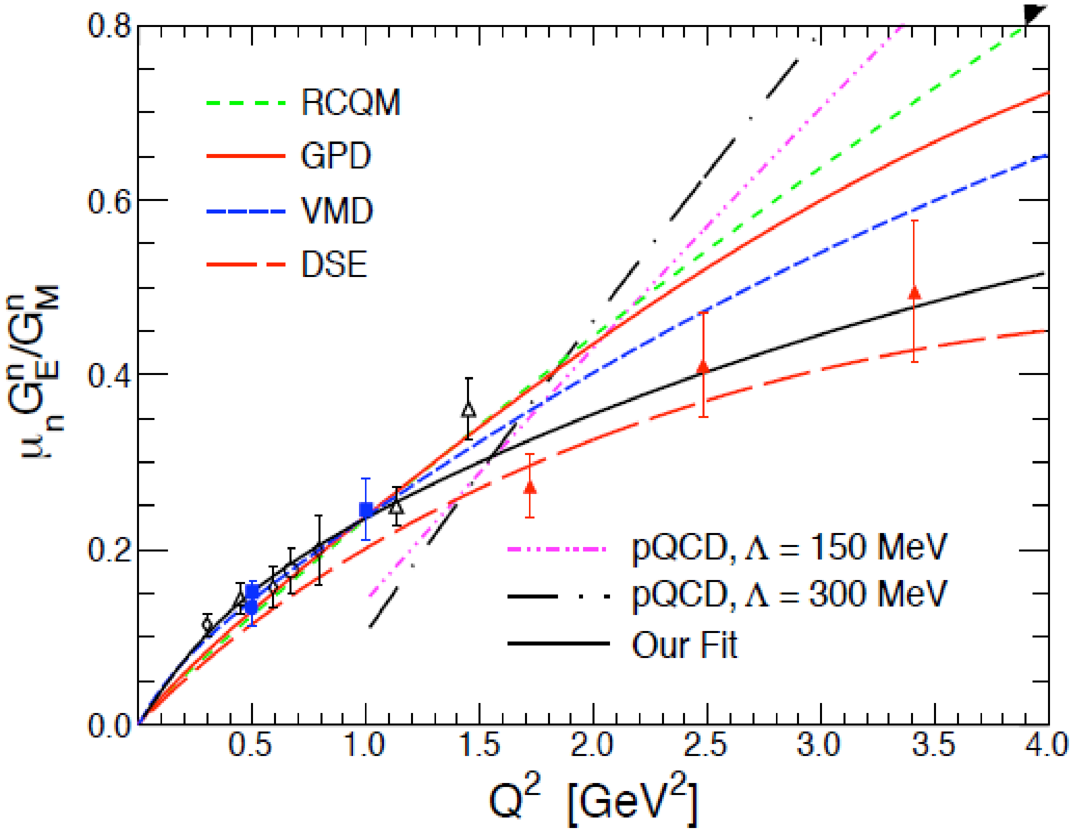
Proton G_E/G_M Form Factors



- Many theoretical models
  - VMD (Iachello, Lomon, Bijker), generally good description of all FF
  - Relativistic CQM (Miller, Gross, ...) spin dependent quark density
  - Lattice QCD, start to give prediction
  - Dyson-Schwinger, dressed quarks, diquark correlation, ...
  - pQCD-based: $G_E/G_M \rightarrow$ const, $Q^2 \rightarrow \infty$
  - GPD-based: direct connection to quark OAM, FF’s constraint GPD’s

Most of them agree with current data but diverge at higher, unexplored, Q^2

Neutron G_E/G_M Form Factors



Importance to go to high Q^2

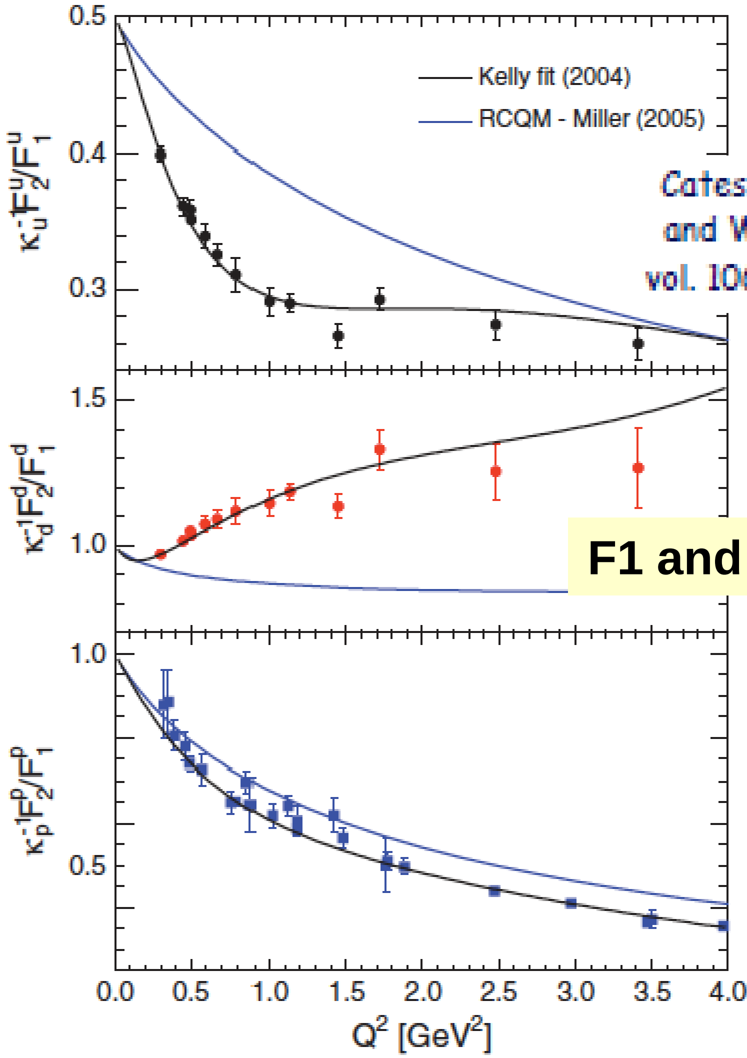
- All double polarization
- Rosenbluth separation affected by large nuclear structure correlations.

- Different models reproduce data, but at large Q^2 models predictions diverge
- pQCD log scaling too large for neutron
- Relativistic CQM works better but tends to overestimate

FF Flavor decomposition

- Enough FF data to separate the different flavor u and d contributions (assuming negligible s-quark) up to $Q^2 \sim 3.5$ GeV

$$F^{u,d} = 2F^{p,n} + F^{n,p}$$

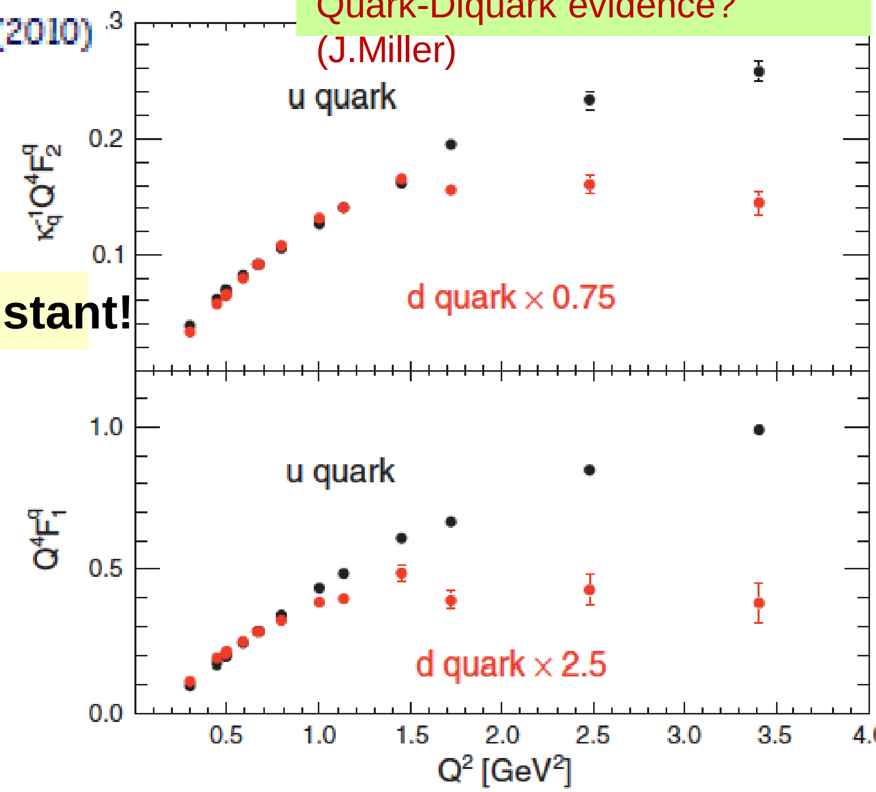


Cates, de Jager, Riordan and Wojtsekhowski, PRL vol. 106, pg 252003 (2010)

F1 and F2 → constant!

Different Q^2 scaling of the two flavors

Quark-Diquark evidence? (J.Miller)



EMFF measurements at high Q^2 by pol. methods

Method:	Polarization Transfer: $p(\vec{e}, e'\vec{p})$	Target Perp. Polarization: $p^{\uparrow}(\vec{e}, e'p)$
Measure (one photon approx.)	$\frac{P_t}{P_l}\tan\left(\frac{\theta}{2}\right) \propto \frac{G_E^p}{G_M^p}$ P_t, P_l : trans. and long. polarization of the recoil proton	$A = \frac{N^+ - N^-}{N^+ + N^-} \sim \frac{G_E^p}{G_M^p}$ N^+ and N^- : events with opposite transverse target polarization
Many systematics effects (theory and exp.) cancel in ratio		
Figure of Merit (stat.) Ω: acceptance L: Luminosity σ: elastic xsec $\sim E^2/Q^{12}$ Pb: beam polarization	$\Omega\, L\, \sigma\, P_b^2\, \epsilon\, A_y^2$ $\sim \frac{\mathbf{\Omega\, L\, \epsilon}}{\mathbf{Q^{16}}}$ A_y: polarimeter analyzing power ϵ: polarimeter efficiency	$\Omega\, L\, \sigma\, P_b^2\, P_T^2$ $\sim \frac{\mathbf{\Omega\, L}}{\mathbf{Q^{12}}}\mathbf{P_T^2}$ P_T : Target polarization
At $Q^2 \sim 10$ GeV^2 expected: $FoM_{pol\_trans} \sim 10 \times FoM_{targ\_pol}$ (target polarization cannot tolerate large L)		

(similar for neutron)

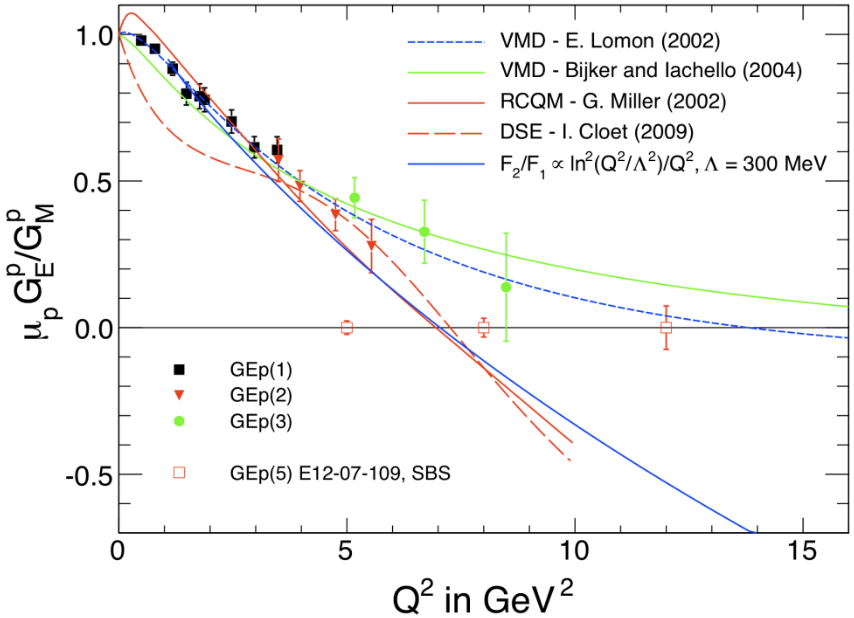
Challenges at high Q^2: need to maximize
- **(coincidence) acceptance (solid angle)**
- **luminosity**
- polarization efficiency
- beam polarization

(... having the needed beam energy)

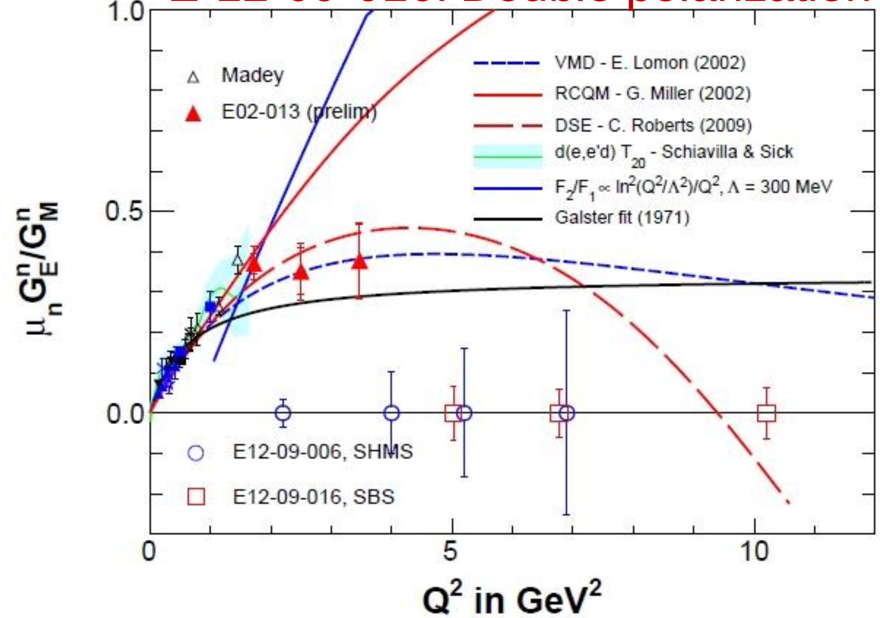
... keeping costs at «affordable» level

Electromagnetic Nucleon Form Factors @12GeV

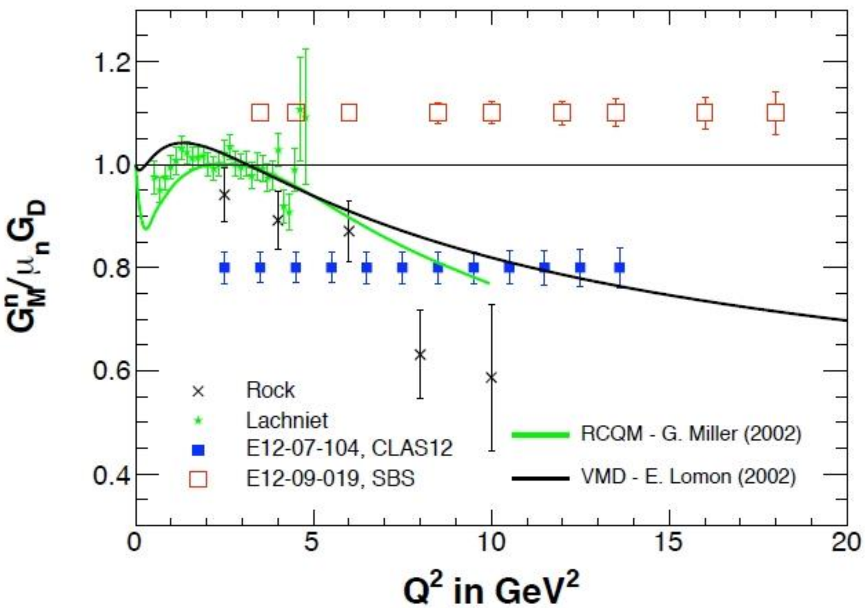
E-12-07-109: Polarization transfer



E-12-09-016: Double polarization



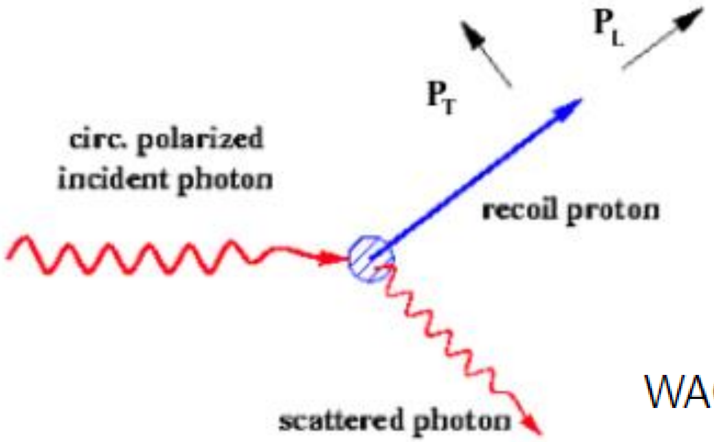
E-12-09-019: Cross section ratio



- **Test per molti modelli (che includono differenti contributi di momento angolare dei quark)**
- **Studio regione di transizione tra la descrizione non- e perturbativa della QCD**
- **Vincoli alle distribuzioni generalizzate H ed E**

Wide Angle Compton Scattering / E07-002

One of the «simplest» process ... poorly understood and measured



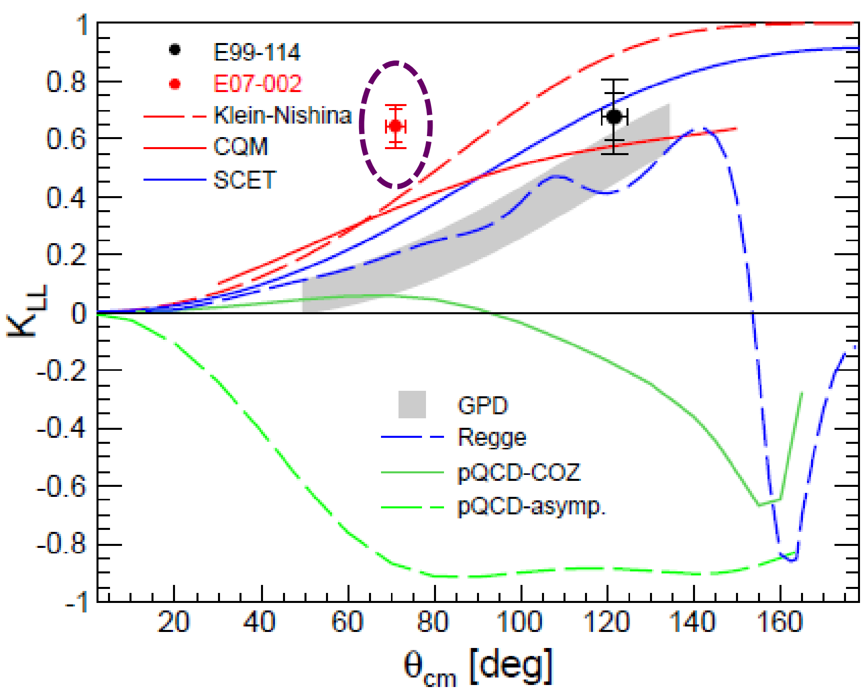
$$K_{LL} = \frac{1}{2}\left[\frac{\frac{d\sigma(\uparrow\uparrow)}{dt}-\frac{d\sigma(\uparrow\downarrow)}{dt}}{\frac{d\sigma(\uparrow\uparrow)}{dt}+\frac{d\sigma(\uparrow\downarrow)}{dt}} - \frac{\frac{d\sigma(\downarrow\uparrow)}{dt}-\frac{d\sigma(\downarrow\downarrow)}{dt}}{\frac{d\sigma(\downarrow\uparrow)}{dt}+\frac{d\sigma(\downarrow\downarrow)}{dt}}\right]$$

[first (second) arrow: incident photon (recoil proton) spin orientation along L-axis]

WACS: 'wide-angle' regime (s, -t, -u >> m^2 nucleon)

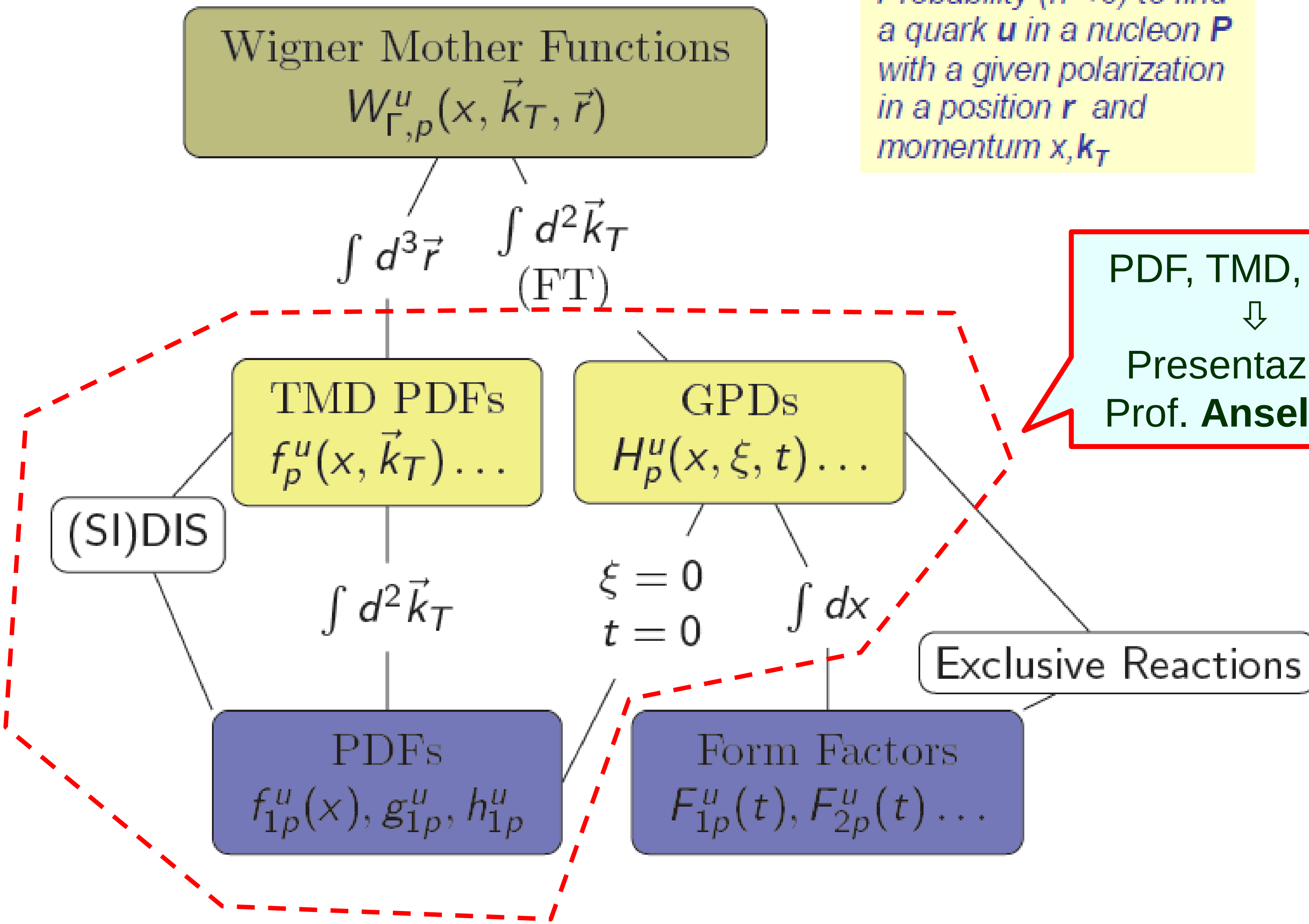
Under this condition, we have: $T_{if}(s,t) = \Psi_f \otimes K(s,t) \otimes \Psi_i$

Accepted by PRL



- Klein Nishina: hard scattering from a point-like proton.
- CQM: constituent quark model, similar to KN but with quarks with specific masses.
- SCET: soft collinear effective theory.
- GPD: Generalized Parton Distributions. The grey area shows possible GPD based predictions calculated with x=1.
- Regge: interaction of γ/N with an intermediate vector meson.
- COZ: based on pQCD, very small value expected for K_{LL}.
- ASY: based on pQCD, asymptotic approach: distribution amplitude for asymptotically large energy scales.

The “ultimate” **description** of the nucleon



*Probability (h→0) to find a quark **u** in a nucleon **P** with a given polarization in a position **r** and momentum x,$\mathbf{k_T}$*

PDF, TMD, GPD
⇩
Presentazione Prof. **Anselmino**

Probe the nucleon structure by SIDIS

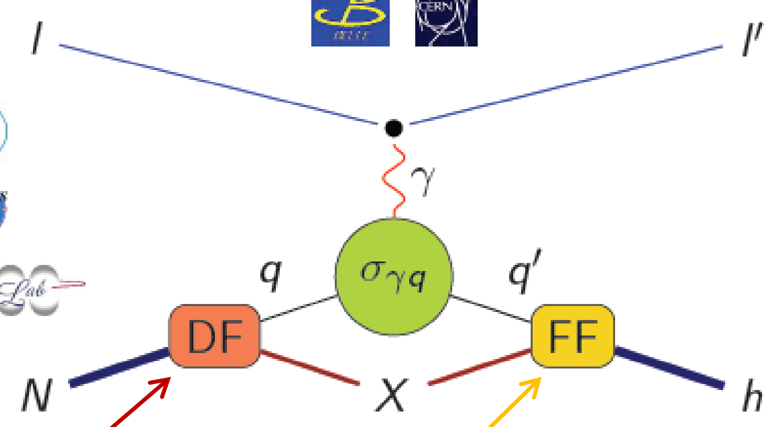
$$S_3 = \tfrac{1}{2} = \underbrace{\frac{1}{2}\Delta\Sigma}_{\sim 0.15} + \underbrace{\Delta G}_{\sim 0} + \underbrace{L_q + L_G}_{?}$$

$\Delta\Sigma$: quark spin fraction

ΔG: gluon spin fraction

$L_q + L_G$: angular momentum

Nature of the nucleon spin?
Dynamics of quarks and gluons in the nucleon?



FNAL GSI BNL J-PARC

$$\sigma(lN \to lhX) \sim \sum_q e_q^2 \cdot DF_q(x, k_\perp) \otimes \sigma_{\gamma q} \otimes FF_{q\to h}(z, K_\perp)$$

DF_q: quark distribution function

$FF_{q\to h}$: quark fragmentation function

(Universality problematic in $k_\perp$ dependent DF/FF)

Twist-2 approx. 8-PDFs

N \ q	U	L	T
U	$f_1(x)$		$h_1^\perp(x, k_\perp)$
L		$g_1(x)$	$h_{1L}^\perp(x, k_\perp)$
T	$f_{1T}^\perp(x, k_\perp)$	$g_{1T}(x, k_\perp)$	$h_1(x)$, $h_{1T}^\perp(x, k_\perp)$

$\otimes$

h / q	U	L	T	q
	$D_1(z)$		$D_{1T}^\perp(z, K_\perp)$	U
		$G_1(z)$	$G_{1T}(z, K_\perp)$	L
	$H_1^\perp(z, K_\perp)$	$H_{1L}^\perp(z, K_\perp)$	$H_1(z)$, $H_{1T}^\perp(z, K_\perp)$	T

SIDIS cross section linear combination of convolutions of DF's and FF's, modulated by sin/cos of azimuthal angles

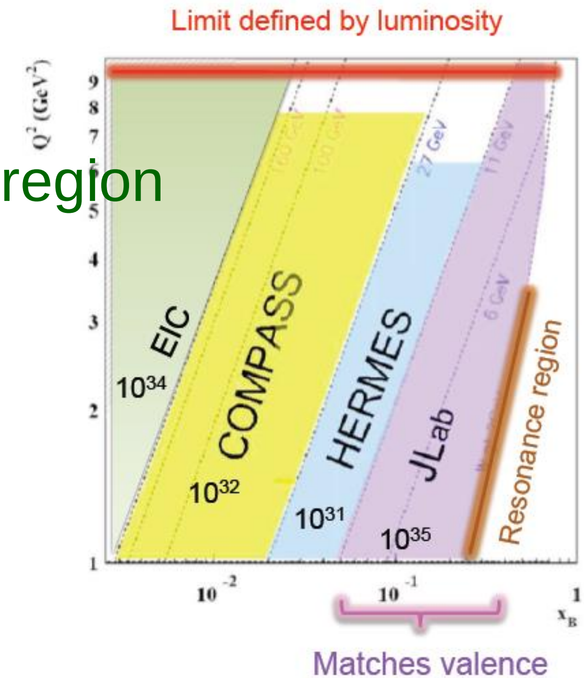
(some) Experimental directions

Improve statistics

- Simultaneous extraction of different moments
- Disentangle dependencies on relevant variables
- Reduce statistical errors

Access unexplored phase space

- Toward high x / Valence region
- P_T dependence
- Q^2 dependence
- z dependence



Measure poorly known TMDs / extract different flavours

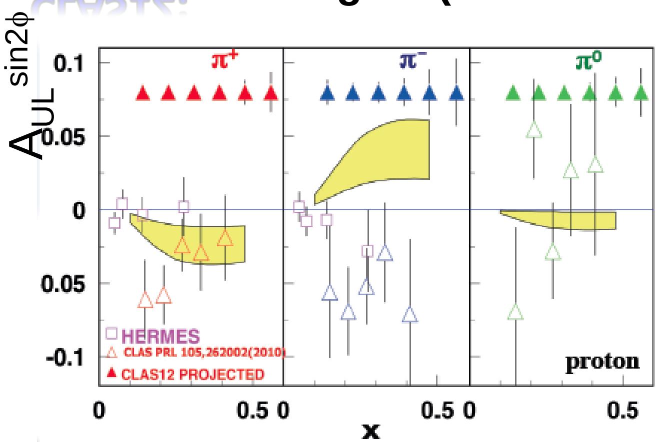
- Measure moments by:
  - Different beam/target spin states
  - Different final state hadron(s) (π,K)
- Access Higher twists

TMDs MultiHall exp. at JLab/12GeV

		Quark			Experiment								
		U	L	T	Test SIDIS		Complete TMDs investigation			Precise Measurements			
Nucleon	U	f_1		$h^{\perp}_1$ Boer-Mulders	$\pi^{\pm}$ $K^{\pm}$	π^0	$\pi^{\pm,0}$ $K^{\pm,0}$						
	L		G_1 Helicity	$h^{\perp}_{1L}$ Worm-gear				$\pi^{\pm,0}$ $K^{\pm,0}$			$\pi^{\pm}$		
	T	$f^{\perp}_{1T}$ Sivers	$g^{\perp}_{1T}$ Worm-gear	h_1, $h^{\perp}_{1T}$					$\pi^{\pm,0}$ $K^{\pm}$	$\pi^{\pm,(0)}$ $K^{\pm}$	$\pi^{\pm}$	$\pi^{\pm}$	
Target					LH2, LD2	LH2, LD2	LH_2 + LD_2	NH_3, ND_3 or ^{6}LiD or HD	HD	**^{3}He**	**^{3}He**	**NH_3**	
Detector					HMS SHMS	HMS SHMS + π^0 detector	CLAS12	CLAS12 + RICH	CLAS12 + RICH	SBS + HERMES RICH	SoLID	SoLID	
Lumi ($cm^{-2}s^{-1}$)					10^{36}	10^{36}	10^{35}	10^{35}	10^{34}	**$4\ 10^{36}$**	**$2\ 10^{36}$**	**10^{35}**	
Experiment ID					E12-06-104 E12-09-017	C12-12-102	E12-06-112, E12-09-008	E12-07-107, E12-09-009	C12-11-111	E12-09-018 (SIDIS)	E12-10-006 E12-11-007 (SoLID n)	C12-11-108 (SoLID p)	

Sivers Moments Expected Stats.

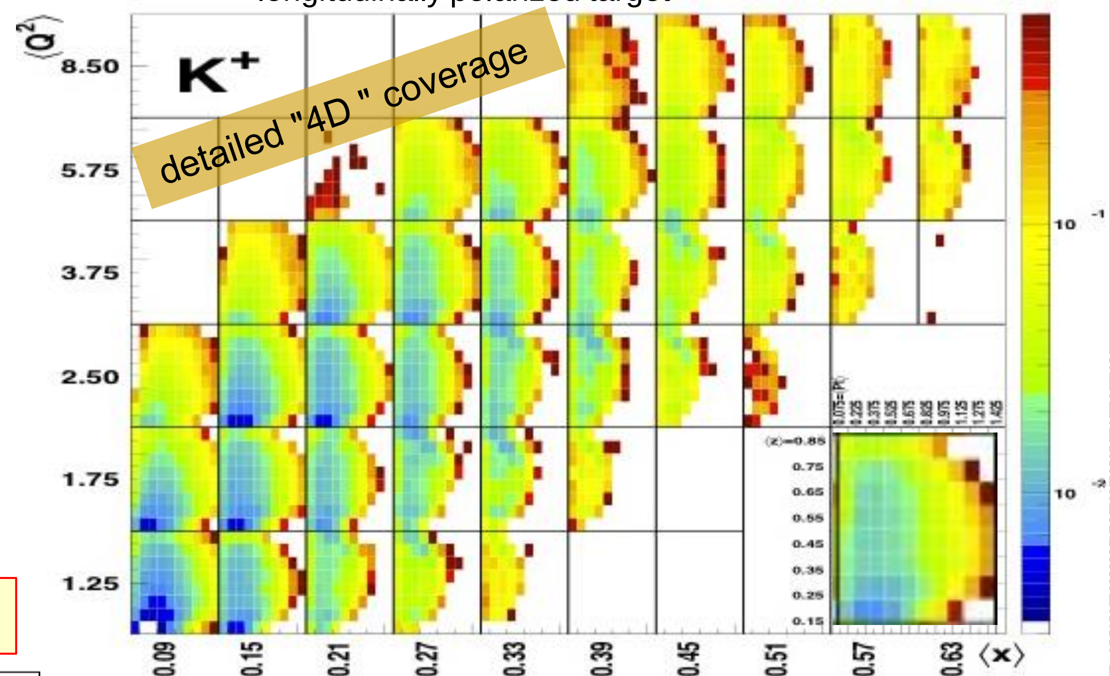
CLAS12: Worm-gear (E12-07-107)



CLAS12: e p →e'$K^{+/-}$X

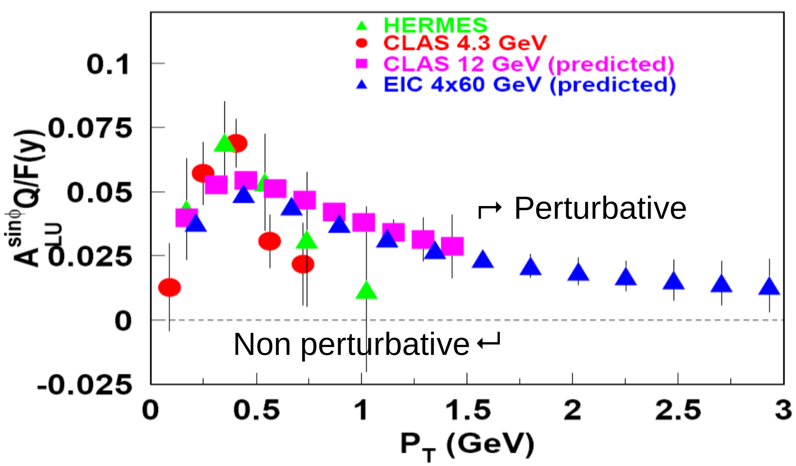
longitudinally polarized target

C12-11-111

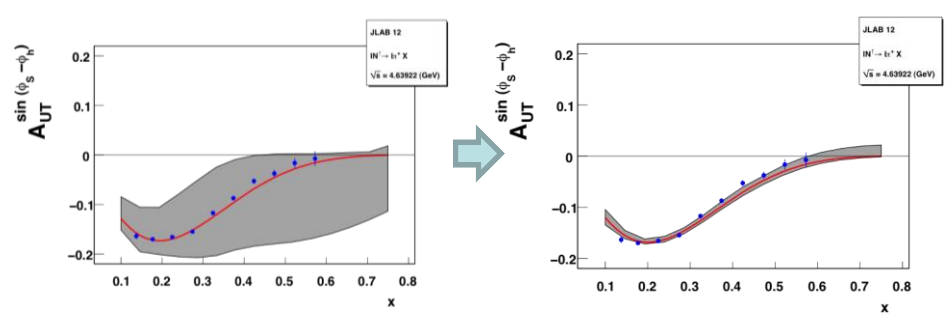


Study perturbative-non perturbative transition

E12-06-112



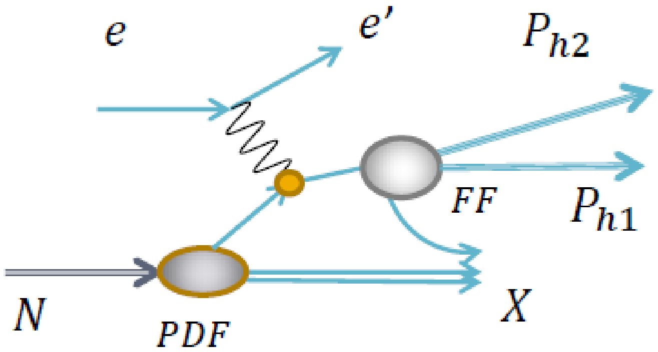
SBS: e^{3}He →e'$K^{+/-}$ X(transverse target)



E12-09-018

Di-hadron and Higher Twist PDFs

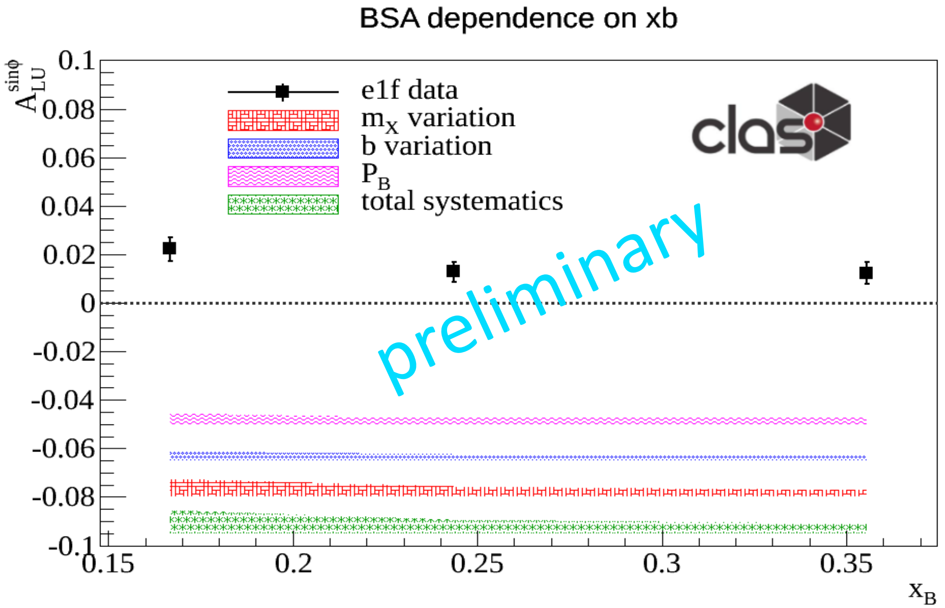
DiHadron SIDIS
e p→e' π π X

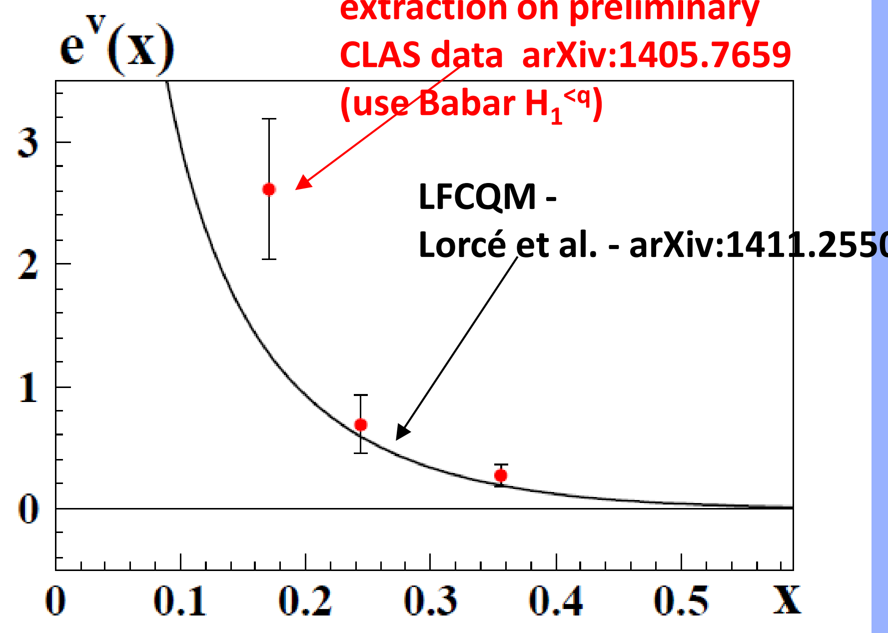


Beam Spin Asymmetry
- long. polarized beam, unpolarized hydrogen target
- Twist-3 observable

$$A_{LU} \propto F_{LU} = e(x) H_1^{\sphericalangle q} + f_1(x) \tilde{G}^{\sphericalangle q}$$

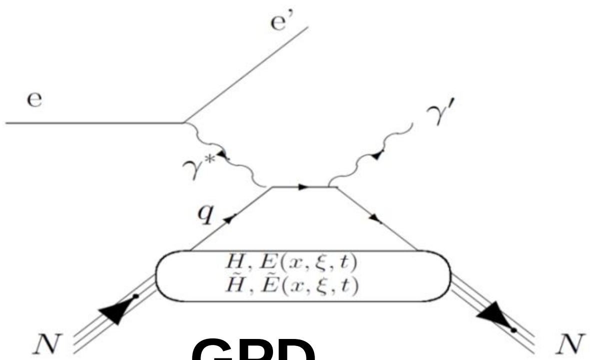
e(x) → quark-gluon correlations, nucleon scalar charge; moments connected to N-π σ-term (nucleon mass, strange content …)





DVCS and GPDs

Deeply Virtual Compton Scattering
e p→e' p' γ



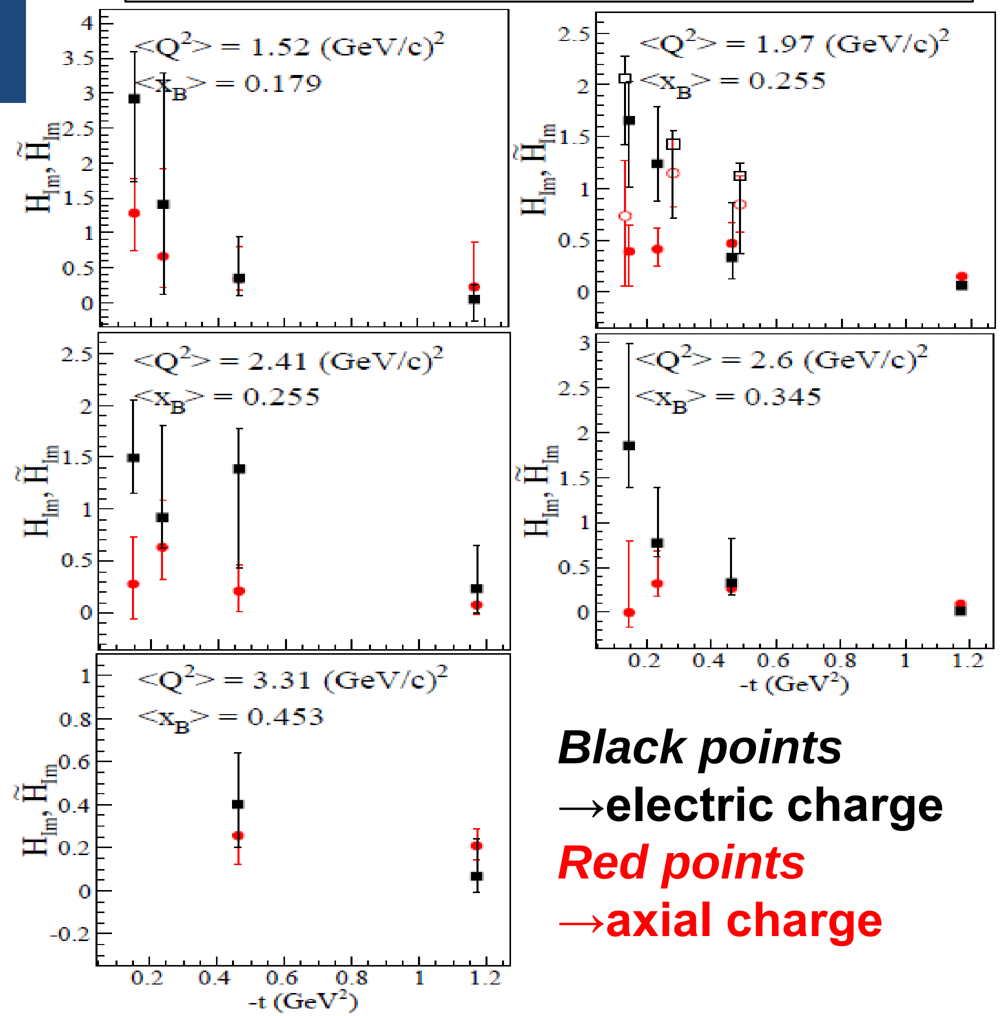
GPD

Beam, Target and Double Spin Asymmetry

- Long. polarized beam and/or long. polarized target

- Compton Form Factors (CFF) →Integrals of GPDs

CLAS – S. Pisano et al. - PRD 91, 052014 (2015)



Black points
→electric charge

Red points
→axial charge

Fourier-Transform of CFF→Spatial distributions

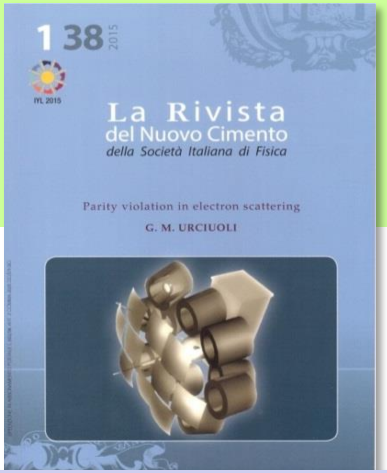
- electric charge distributed in the nucleon volume

- axial charge concentrated in the nucleon center

PVES (Parity Violating Electron Scattering)

- **“Skin” del neutrone in Pb**
- Contributo quark-s nei nucleoni
- Test Modello Standard

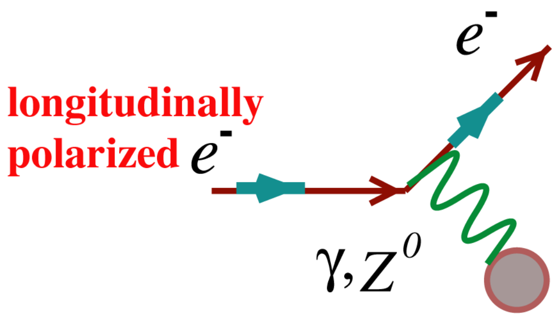
Fascio polarizzato
Alta luminosità
Apparati con performance molto stabili

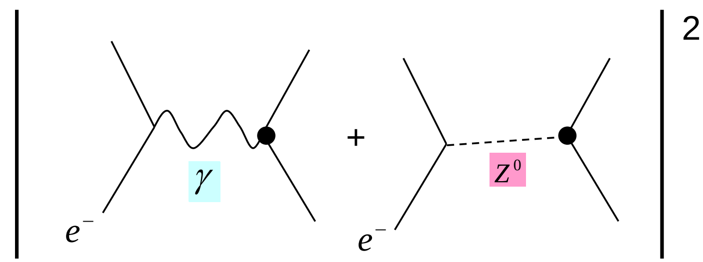


G. M. Urciuoli
Parity violation in electron scattering
DOI: 10.1393/ncr/i2015-10108-x

Esperimenti di Violazione della Parità

- Misura accurata della asimmetria nei processi elastici (e DIS) di elettroni polarizzati longitudinalmente su nucleone/nucleo non polarizzato





$$-A_{LR} = A_{PV} = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow} \sim \frac{A_{Z^0}}{A_\gamma} \sim \frac{G_F Q^2}{4\pi\alpha}\left[1 - 4\sin^2\theta_W + \dots\right]$$

$$Q^2 \sim 0.01 \div 1\ \mathrm{GeV}^2 \rightarrow A_{PV} \sim 10^{-7} \div 10^{-4}$$

- Accesso alle costanti di accoppiamento deboli elettroni-quark (u/d) delle correnti neutre, ovvero alla corrente debole del protone, ovvero all'angolo di mixing debole
- Pone limiti su esistenza di nuova fisica (QWeak, SOLID, Möller)
- Ha permesso la misura del contributo dei quark s ai fattori di forma del nucleone (HAPPEX, G0)
- Ha permesso la misura di importanti grandezze nucleari soppresse nei processi elettromagnetici ⇒ PREX

Lead (^{208}Pb) Radius Experiment: PREX

Elastic Scattering Parity Violating Asymmetry E = 850 MeV, ϑ=6° electrons on Pb

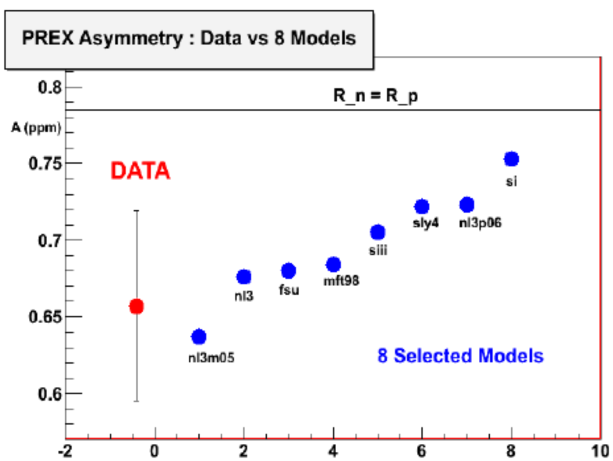
Z_0 is a clean probe that couples mainly to neutrons

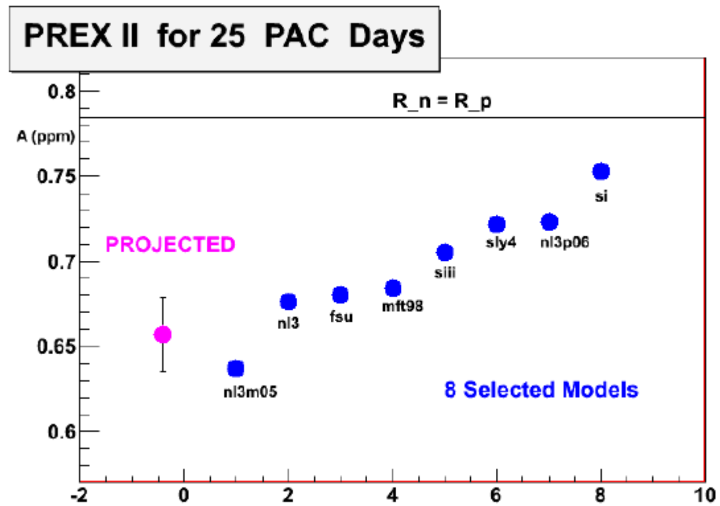
$$A_{PV} \sim \frac{G_F Q^2}{4\pi\alpha}\left[\underbrace{1-4\sin^2\theta_W}_{\sim 0}+\frac{\mathbf{F_n(Q^2)}}{F_p(Q^2)}\right]$$

→ Statistics limited (9%)

→ Systematic error 2%!

$$= 0.6571\ ppm \pm 0.0604(stat) \pm 0.0130(syst)$$

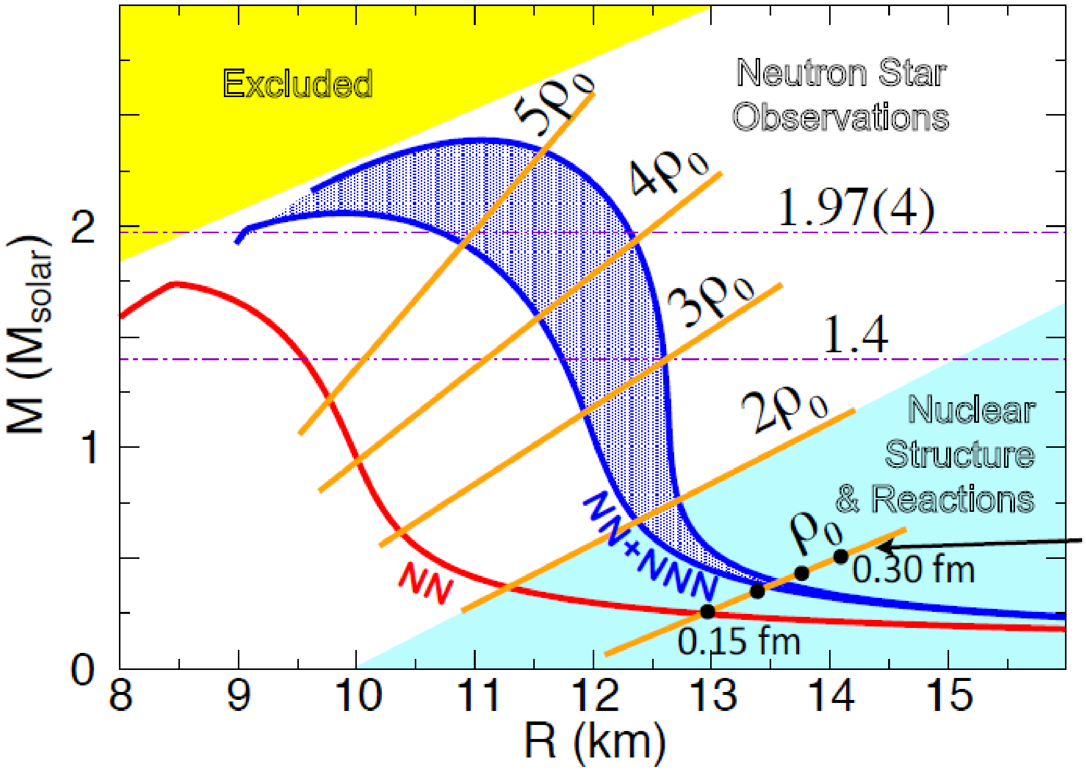




⇨ The radius of the neutron distribution in Pb is relevant to constraint astrophysics models

Adapted from G.M. Urciuoli

Stelle Di Neutroni e Neutron Skin



I raggi delle stelle di neutroni sono tra 10.4 e 12.9 km ⇨ Rn(^{208}Pb) < 0.2 fm
Inconsistente con la misura di PREX

La neutron skin è legata direttamente all’energia di simmetria (costo di rompere la simmetria Z=N)

Maggiore la pressione di simmetria, più spessa la “pelle” poiché i neutroni sono spinti verso l’esterno, contro la tensione superficiale

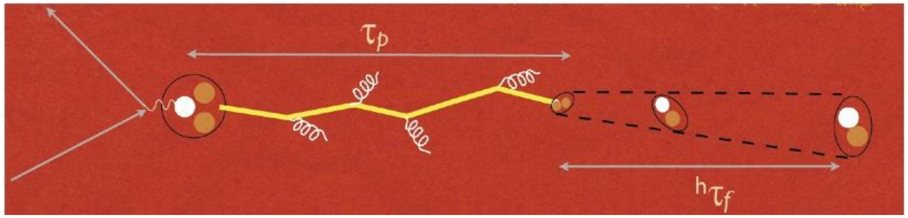
Struttura e dinamica nucleare

- Adronizzazione
- Ipernuclei
- ...

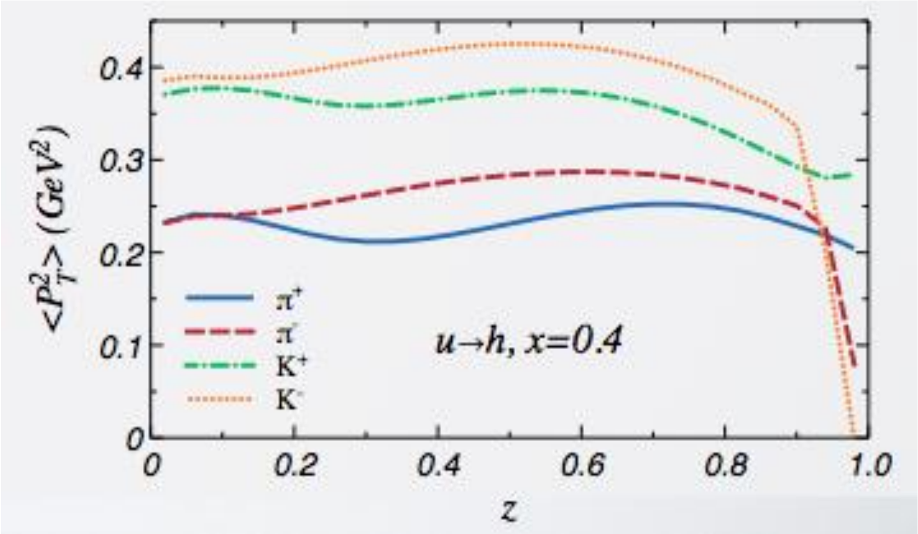
Fasci intensi (polarizzati)
Rivelatori a grande accettanza
Identificazione di adroni
Alta precisione (energia, impulso)

Hadronization of quarks

How hadrons form in scattering processes ?



Transverse momentum distributions in hadronization may be flavor dependent



H. Matevosyan et al., Phys. Rev. D85 (2012) 014021

Employ nuclei as analyzers of hadronization processes, to probe:

- The hadronization formation length (0-10 fm)
- The **time scale** on which a qq pair becomes dressed with its own gluonic field

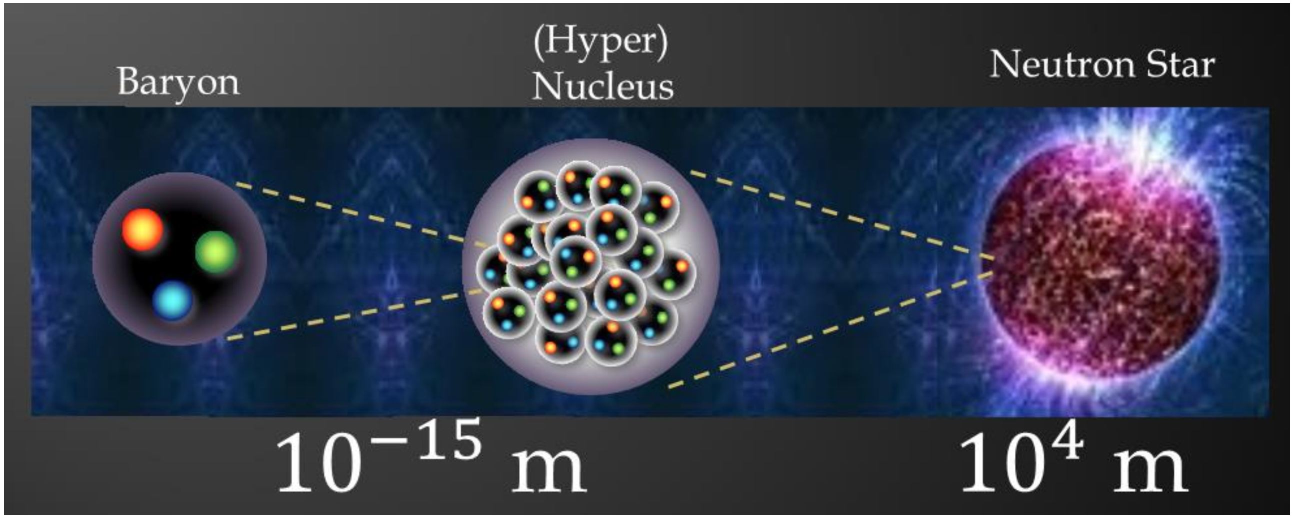
Study the SIDIS reaction on nuclei; observables:

- The hadronic multiplicity ratio
- The transverse momentum broadening

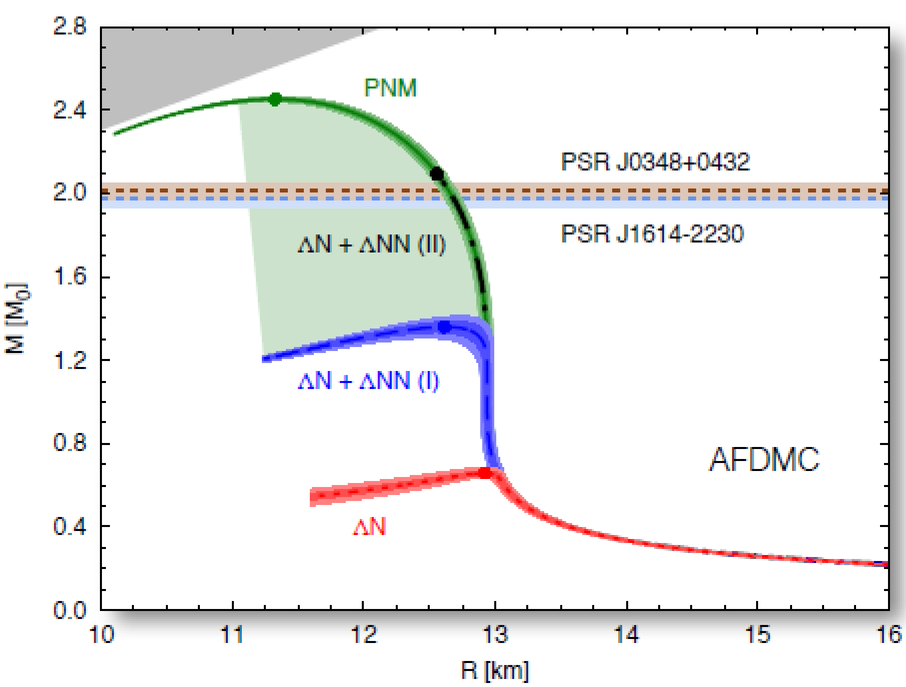
E12-06-117

Adapted from P. Rossi, JLab 2012

Spettroscopia Ipernucleare e stelle di neutroni



D. L., A. Lovato, S. Gandolfi, F. Pederiva, Phys. Rev. Lett. 114, 092301 (2015)

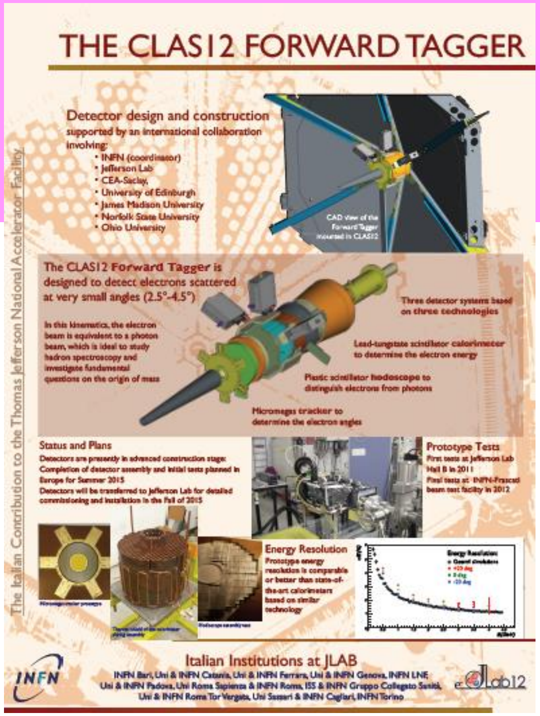


- Le stelle di neutroni osservate hanno masse intorno a 2 M_{sole}
- Ci sono evidenze che lasciano ipotizzare un core ricco di iperoni
- Modelli di interazione Λ-NN e Λ-NNN tendono a spiegare i valori osservati di massa
- Necessità di conoscere meglio il potenziale Λ-N
- Programma di misure di B_Λ su $^{40\text{-}48}$Ca approvato

PR12-15-008

Spettroscopia Adronica

- **Stati ibridi ed esotici**
- **Lattice QCD**
- **Confinamento**

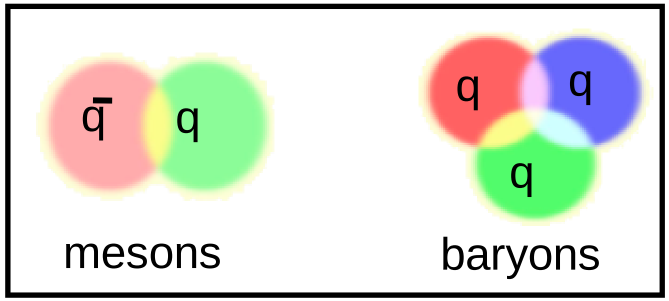


Fasci intensi di fotoni quasi-reali, polarizzati
Rivelatori grande accettanza per carichi e neutri
Forte collaborazione Teorici-Sperimentali per l'analisi

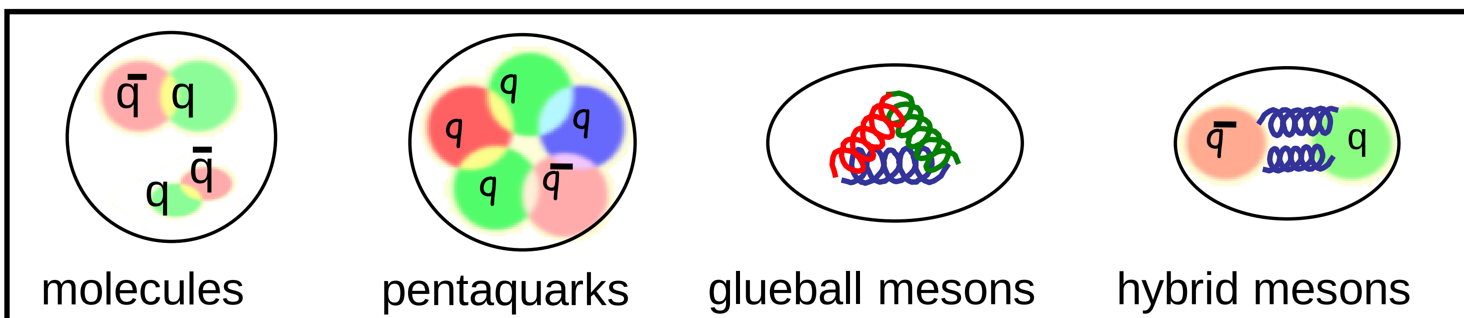
The HASPECT project
(HAdron SPEctroscopy CenTer)
DOI: 10.1088/1742-6596/527/1/012028

Beyond the quark model: hybrids and exotics

Quarks are confined inside colorless hadrons
they combine to 'neutralize' color force



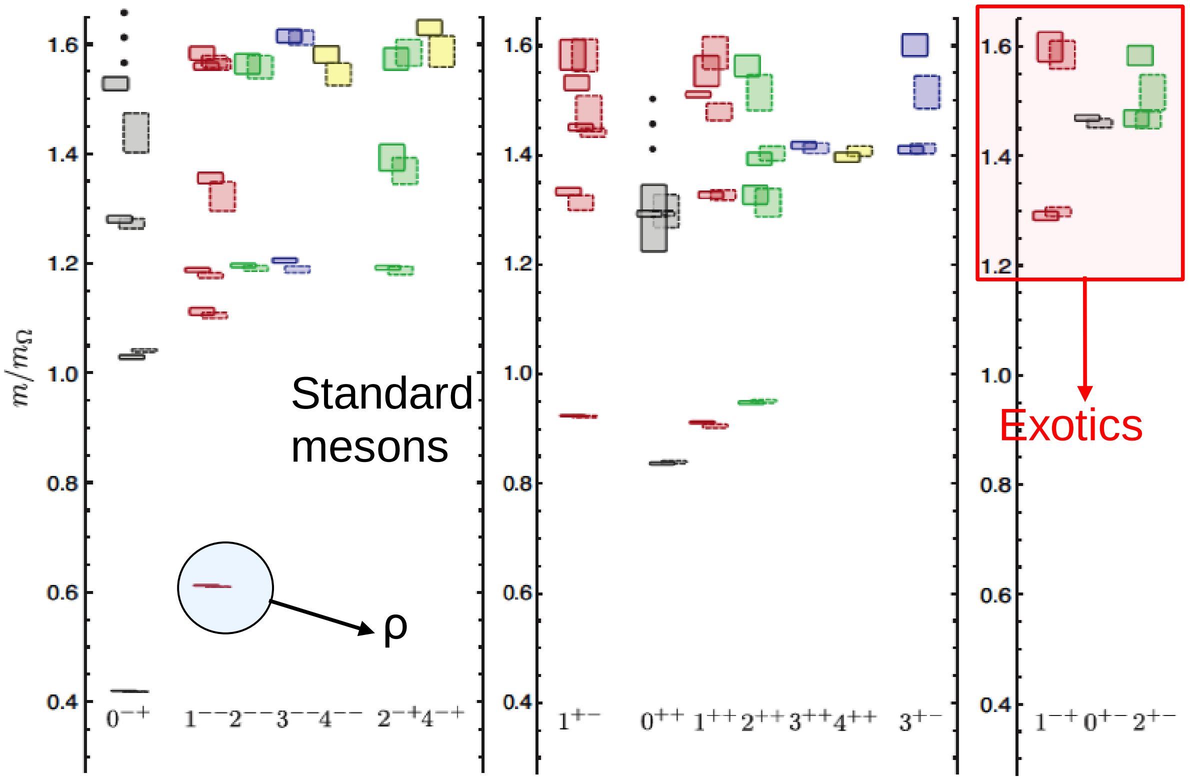
Other quark-gluon configurations can give colorless objects



QCD does not prohibit such states but not yet unambiguously observed

Adapted from M. Battaglieri

QCD Lattice calculations



J.Dudek et al Phys.Rev.D82 (2010) 034508

Lattice-QCD predictions for the lowest exotics meson states:

0^{+-} 1.9 GeV
1^{-+} 1.6 GeV

Hybrid mesons and glueballs mass range 1.4 – 3.0 GeV

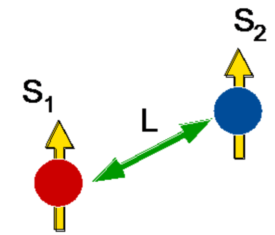
This mass range is accessible in photoproduction experiments with a beam energy in the range 5 GeV < E_γ <12 GeV

Perfectly matched to JLab12 energy!

Adapted from M. Battaglieri

Origine del confinamento in QCD

I mesoni leggeri sono stati di due quark (q-qbar)
I numeri quantici del mesone sono determinati dai numeri quantici della coppia q-qbar



$S = S_1 + S_2$

$J = L + S$

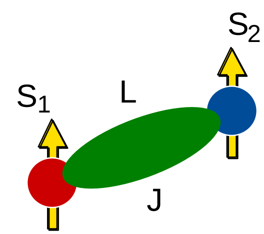
$P = (-1)^{L+1}$

$C = (-1)^{L+S}$

	J^{PC}	L: 0	1	2 ...
S	0	0^{-+}	1^{+-}	2^{-+} ...
	1	1^{--}	2^{++}	3^{--} ...

I quark in tali mesoni sono sorgenti di un flusso di carica di colore intrappolato in un tubo (stringa) che collega i due quark.

La formazione del tubo di flusso è legata alla auto-interazione dei gluoni attraverso la loro carica di colore (stati ibridi q-g-qbar)



VM $\oplus$ (J_{Tube}=1)

I numeri quantici del mesone ibrido sono determinati dai numeri quantici della coppia q-qbar ed eventuali stati eccitati del tubo di flusso gluonico

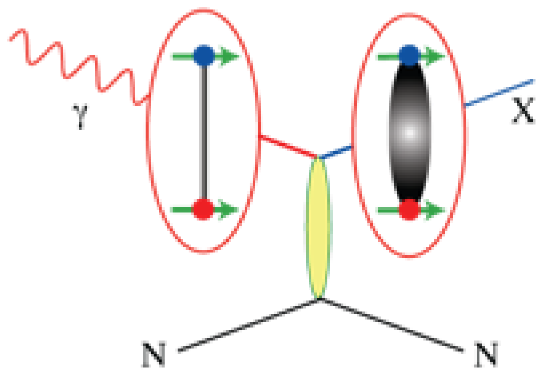
$$J^{PC}_{\text{hybrid}} = \begin{cases} 0^{-+} & 1^{+-} & 2^{-+} \\ 0^{+-} & 1^{-+} & 2^{+-} \end{cases}$$

mesoni esotici

Tra questi, alcuni sono peculiari dei modi di eccitazione del tubo di flusso

Confinamento: Ricerca di Mesoni Ibridi Esotici

- Uso di fotoni polarizzati linearmente (8-9 GeV) che possono fluttuare in mesoni vettori
- I mesoni vettori interagiscono con il nucleone
- Il mesone diffuso (energie fino a 2.5 GeV) può risultare in un mesone ibrido esotico



$$X = \begin{cases} f_1\eta \to KK\eta \to KK\pi\pi\pi \\ b_1\pi \to \omega\bar{\pi} \to \pi\pi\bar{\pi}\pi \\ \rho\pi \to \pi\pi\pi \end{cases}$$

- ✓ Uso di rivelatore a grande accettanza per particelle cariche e neutre
- ✓ Necessità di alta luminosità e quindi supporto di alta acquisition-rate
- ✓ Partial-wave analysis dei dati

Programma fondamentale della nuova sala D/GlueX ed in parte della attuale e futura sala B/CLAS12

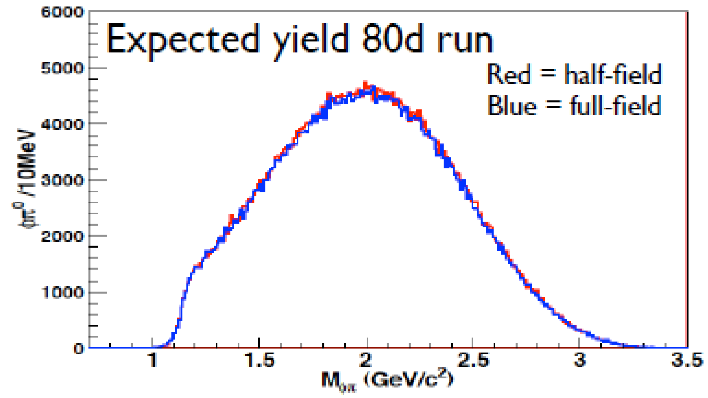
Programma di spettroscopia / CLAS12

Quasi-real photoproduction ⇒ intense source of linearly polarized photons

Meson Spectroscopy:

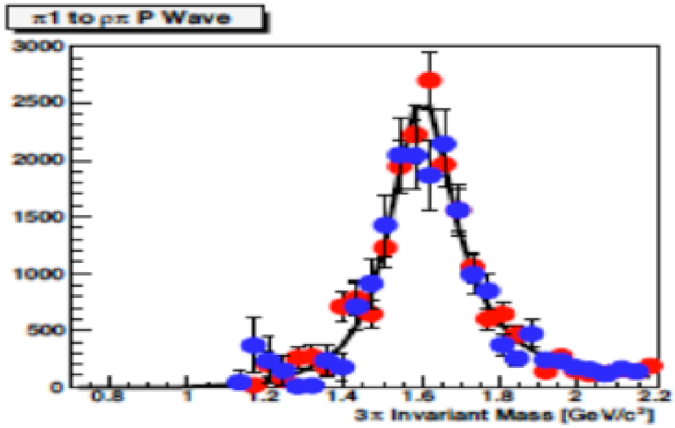
Study of the meson spectrum in the mass range 1-3 GeV:

- ★ Study of the strangeonium spectrum and of strangeness rich states
- ★ Search for exotic states
- ★ Search for hybrid mesons (qqg)



Baryon Spectroscopy:

- ★ Study of the spectrum of baryons with very high strangeness content (Ξ and Ω)
- ★ Search for exotic baryons

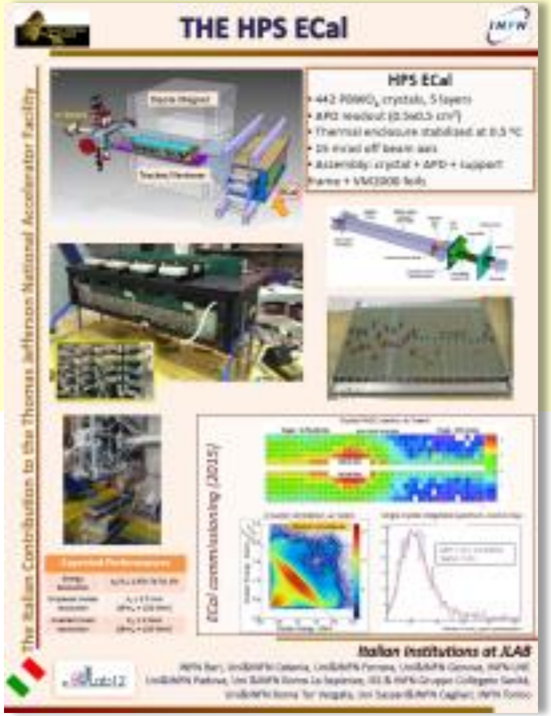


Forward Tagger

FT will be used to detect high energy photons to measure DVCS and study GPDs

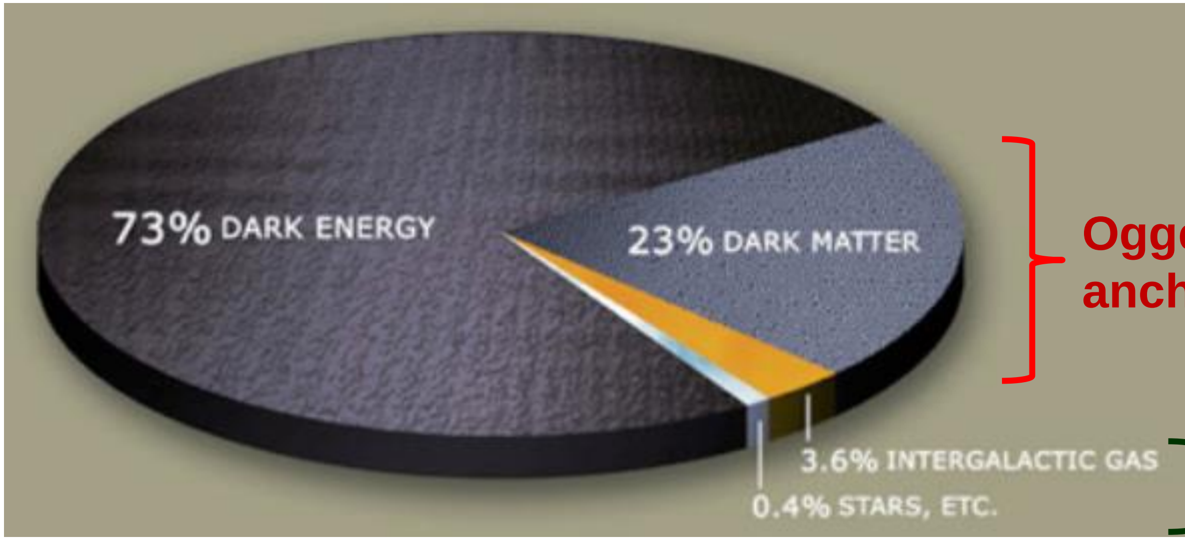
Raffaella De Vita (2015)

Ricerca Materia Oscura



Fasci intensi
Rivelatori dedicati

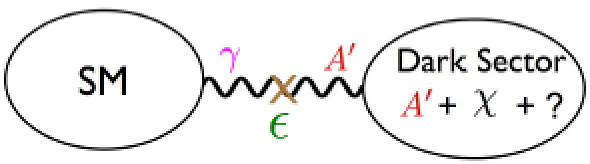
Oltre la materia «adronica»

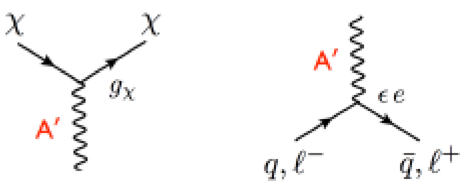


Oggetto di indagine recente anche al JLab

Se ne è parlato fin qui

Se si assume che la DM è composta da particelle si può ipotizzare una teoria di DM analogo al modello standard e ad un qualche mediatore tra SM e DM (dark photon)

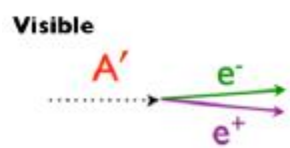




4 parameters: $m_\chi, m_{A'}, \epsilon, g_\chi$

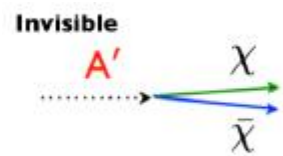
$$m_{A'}^2 \sim \epsilon M_W^2 \sim \mathrm{MeV}^2 - \mathrm{GeV}^2$$

Esperimenti HPS/Apex

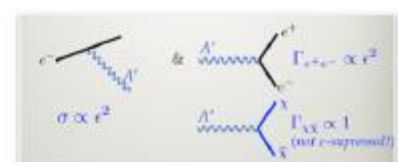


- *Minimal* decay
- Decay regulated by ε^2
- Independent on m_χ
- Requires $m_{A'}<2m_\chi$

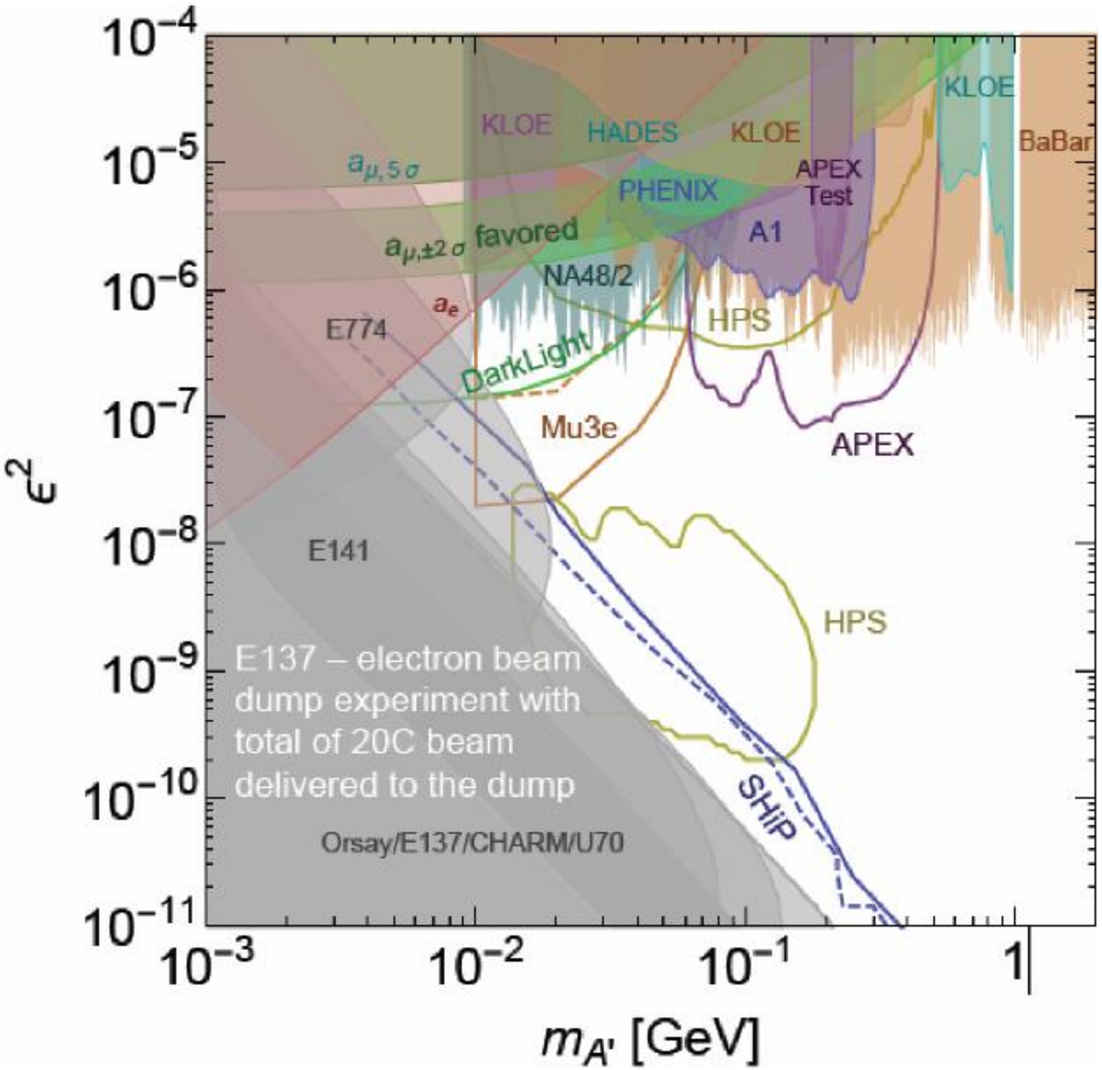
Proposta BDX



- $m_\chi<2m_{A'}$
- i) stable and invisible
- ii) decays to SM particles
- Independent on ε

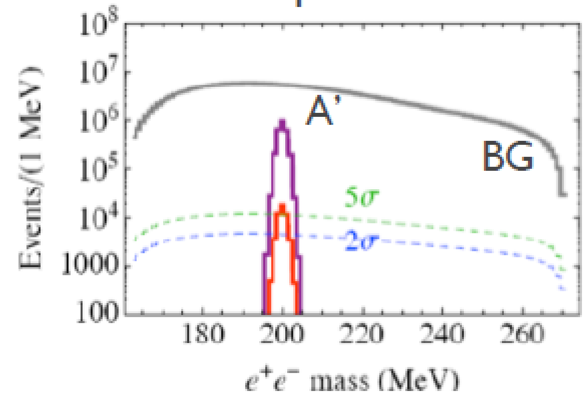


APEX/HPS mappa di esclusione

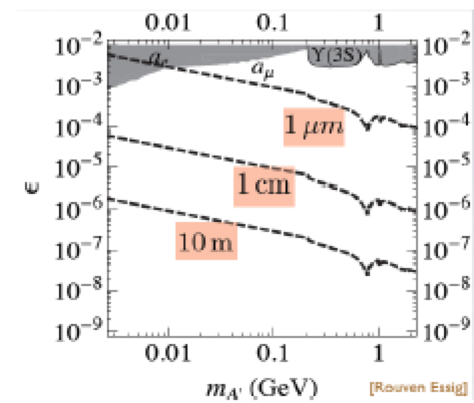


HPS

Bump Hunt

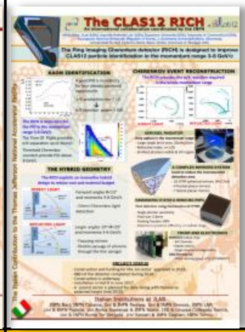
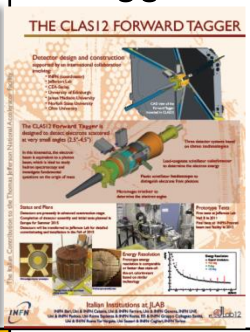
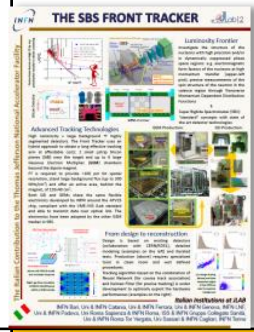
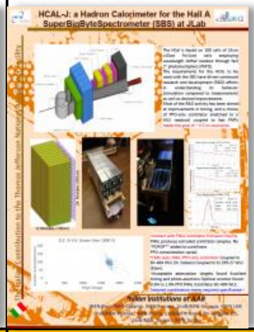
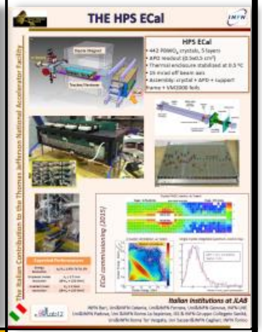


Decay lenght



Smaller the coupling e, vertex outside target

Equipment / Physics Matrix @ 12 GeV

Equipment \ Physics	HD Target 	RICH 	Forward Tagger 	GEM/Si Tracker 	HCAL 	HPS 
TMDs, nucleon spin structure	X	X		X	X	
Spectroscopy		X	X			
Form Factors				X	X	
Parity Violating Electron Scattering				X		
Light Dark Matter						X

Intensa attività di sviluppo tecnologico per un esteso programma di fisica

Asymptotic Freedom

JLab

Confinement

Small Distance
High Energy

Large Distance
Low Energy

Perturbative QCD
DIS Scattering
Parton models

+ Test Standard Model
+ Dark matter search

Strong QCD
Spectroscopy
Phenomenological Models

$\sigma \sim$ QED $\otimes$ QCD

JLab offers:
- High luminosity
- Polarization (initial and final states)
- High beam stability
- Complementary Equipment
- Dedicated, optimized detectors