INFN activity at the Thomas Jefferson National Accelerator Facility

Marco Contalbrigo - INFN Ferrara

13th US-Italy Join Commission Meeting on Science and Technology Cooperation
Physics and Astrophysics working group
Embassy of Italy, Washington DC, 4-5 December 2018

INFN @ JLab

INFN presence since the beginning (1991)
Increasing interest in 12 GeV era
Exp Users: ~40 FTEs, including ~15 students (PhD and post-doc)
Theo Support: ~ 30 scientists, including ~ 10 students

Spokespersonship: > 20% of approved 12 GeV experiments

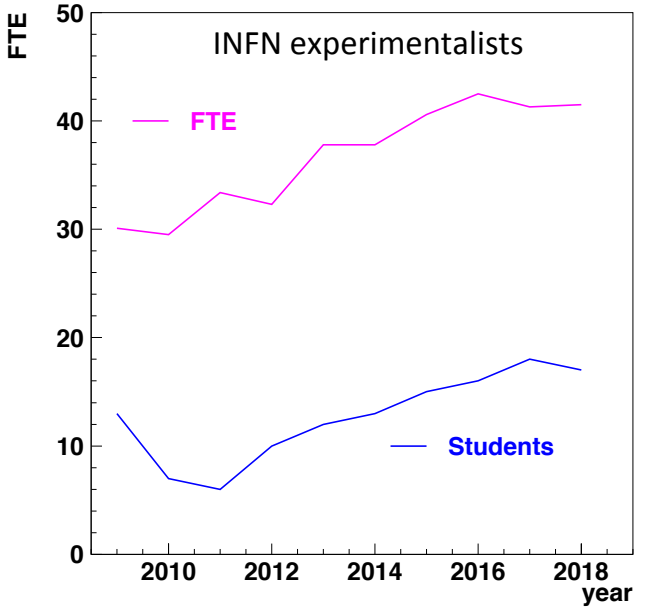
Responsibility roles: Hardware, Analysis, Coordinating

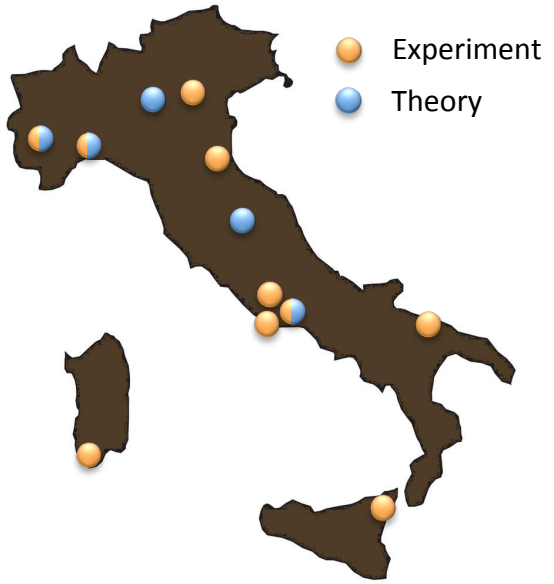
P. Rossi	Deputy Associate Director
R. De Vita:	CLAS collaboration Chair
	Hall-B Software Responsible (interim)
M. Battaglieri:	CLAS Coordinating Committee
	Program Deputy for the Laboratory
M. Contalbrigo:	CLAS Coodinating Committee
M. De Napoli:	HPS Executive Committee member
A. Celentano:	Chair of HPS Publications Committee

MoU: Renovated in September 2017

Management: Regular meetings
last: JLab, May 23-24, 2018
A. Masiero, E. Nappi, M. Taiuti, P. Campana

PAC members: INFN members since 1991
now: **A. Bacchetta**





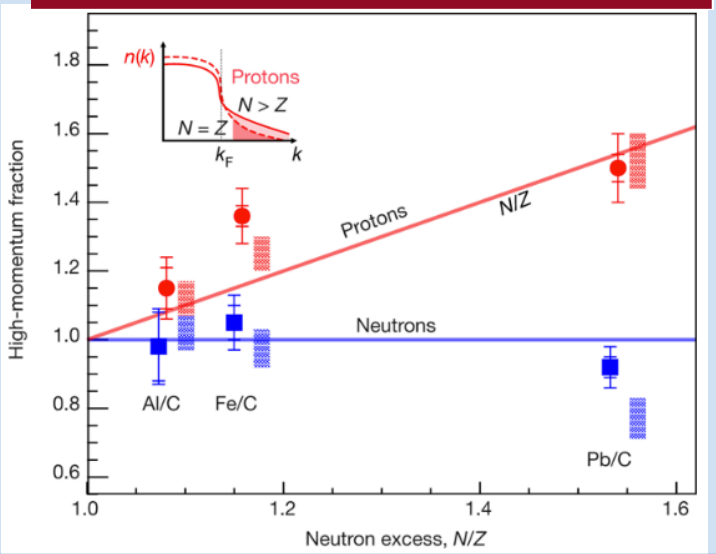
INFN and JLab

nature International journal of science 560 (2018) n.7720, 617-621

http://home.infn.it/it/comunicazione/news/3158

Ultrafast Nucleons in Asymmetric Nuclei,
M. Duer et. al., CLAS Collaboration,
Published: Nature 560 (2018) no.7720, 617-621

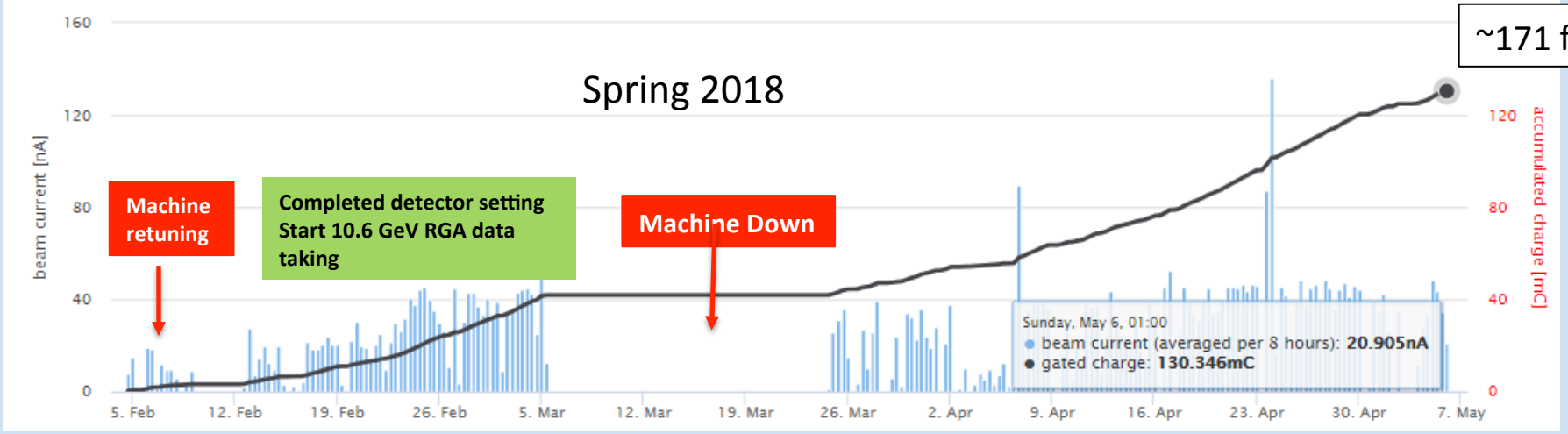
From CLAS data: the % of fast protons increases with neutron density in heavy nuclei. Their role in high-density neutron matter could be more relevant than expected.

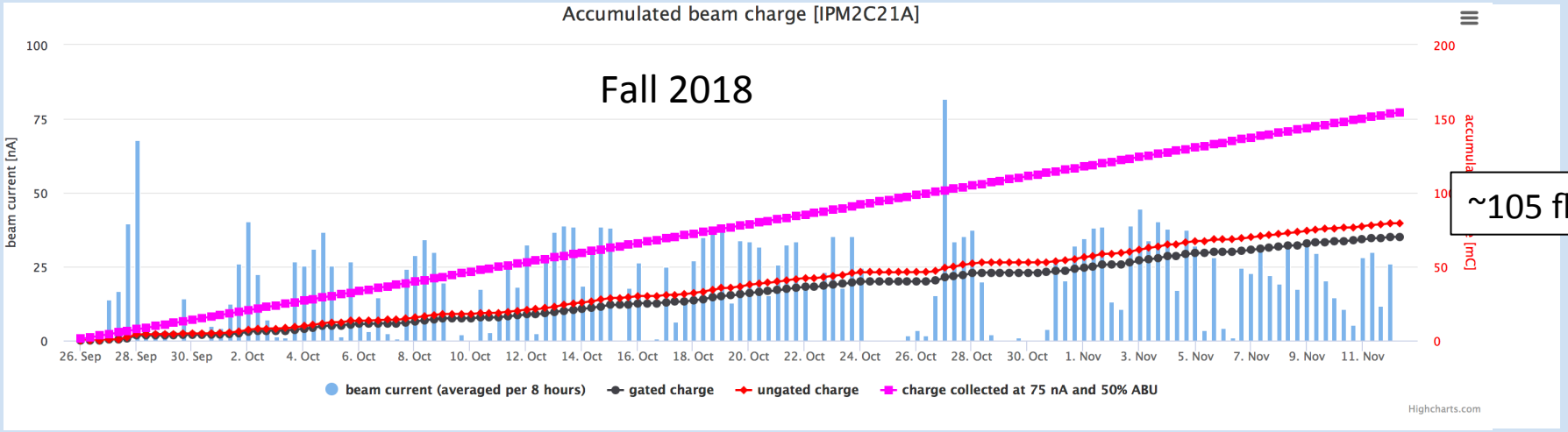


CEBAF @ 12 GeV

Since beginning of 2018: simultaneous beam delivered to the four experimental Hall
Italian users glad to express their grateful acknowledgement for this great achievement !

Example: Hall-B data-taking





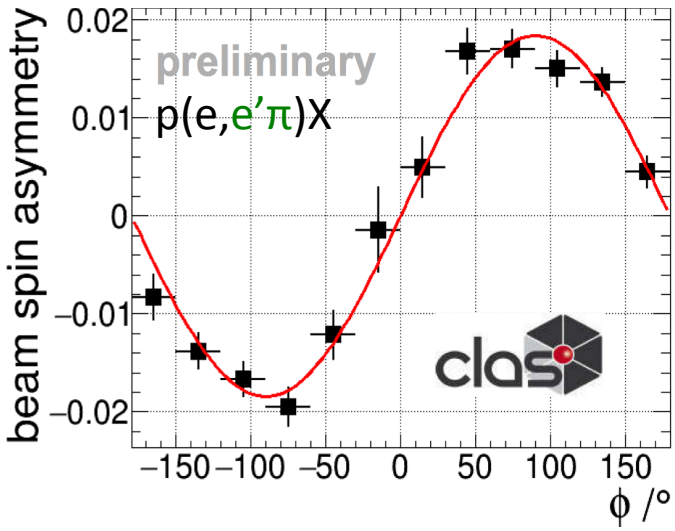
Outcome @ DNP/JPS Meeting

Several started or upcoming experiments
with INFN co-spokesperson ship

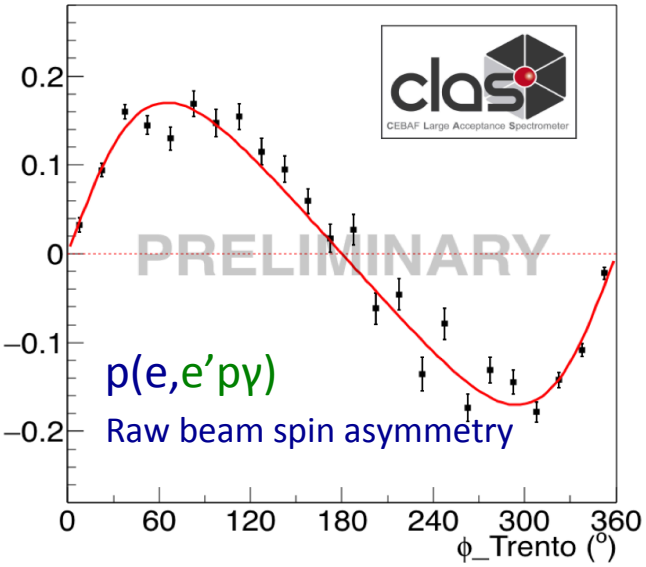
Preliminary data support expected performance

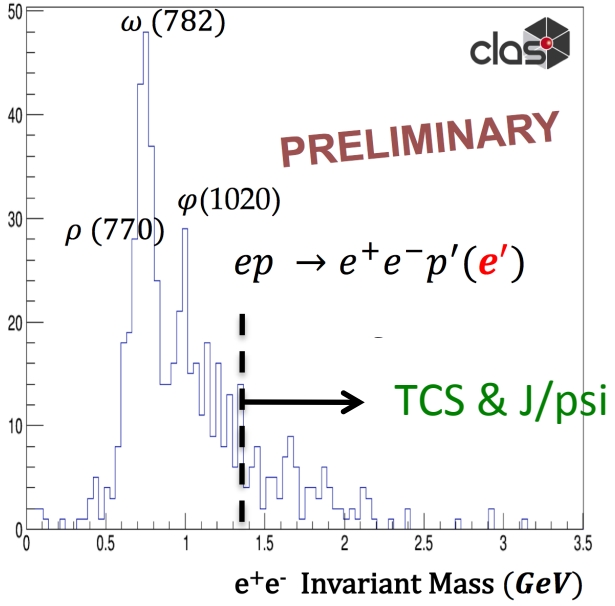
First CLAS12 public outcomes at 2018 Fall DNP Meeting

Semi-inclusive channels



Hard exclusive / Spectroscopy





INFN 12 GeV Projects

Nucleon 3D

RM1, CT, BA — FE, LNF,GE

E07-109	Proton form factor	‘22
E17-004	Neutron form factor	‘22
E09-018	SIDIS off neutron (^{3}He)	’23
E06-112A, B	Quark dynamics	‘18
E07-107, E09-009	TMDs	‘18
E09-007, E09-008	TMDs	‘21
C11-111	TMDs	‘22
C12-009	Di-hadron probes	’22

Nuclear Potentials

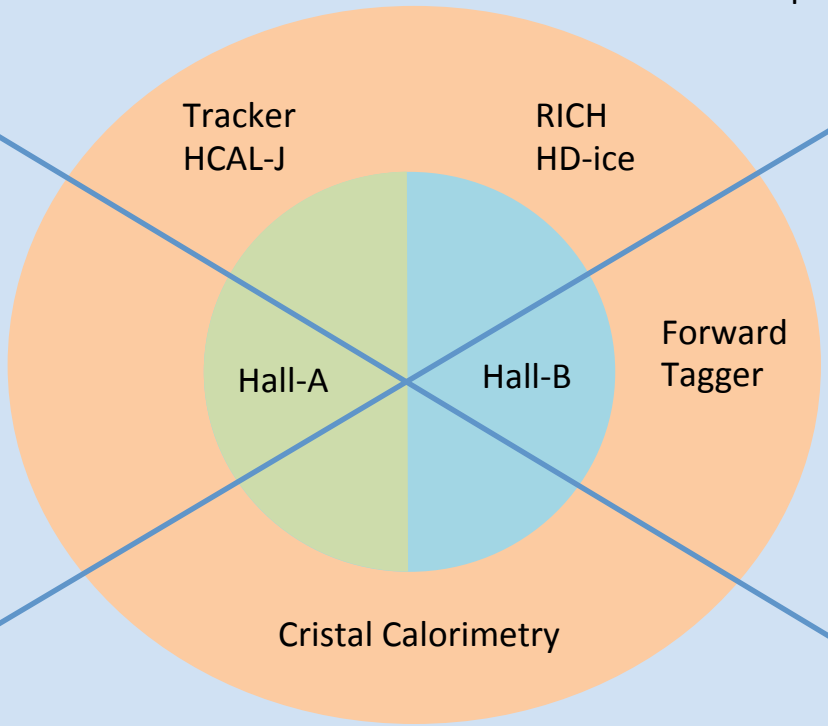
RM1

E17-003 ‘18
Lambda-nn off trithium (^{3}H)

E11-101 ‘19
PREX-II: neutron skin

E15-008 ‘24
Lambda hypernuclei

E14-012 ’24
^{40}Ar cross-section for ν



Spectroscopy

GE, RM2, TO, PV

E11-005 ‘18
MESONX

E12-001A ‘18
J/psi and penta-quark

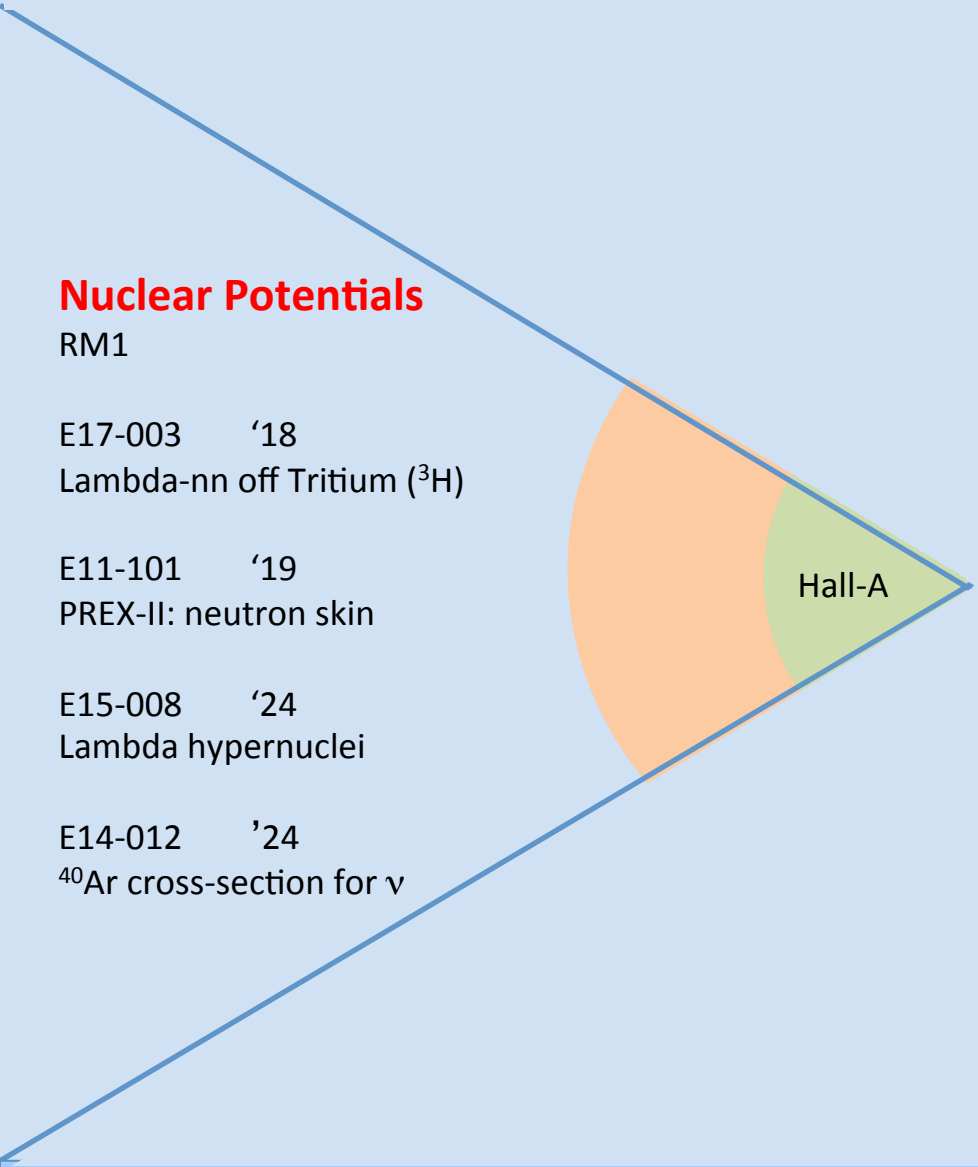
E16-010 ‘18
Hybrid Baryons

Dark Sector

GE, CT, PV, LNS, RM2, TO, PD

E11-006 HPS ‘17 — E16-001 BDX ‘24

INFN 12 GeV Projects



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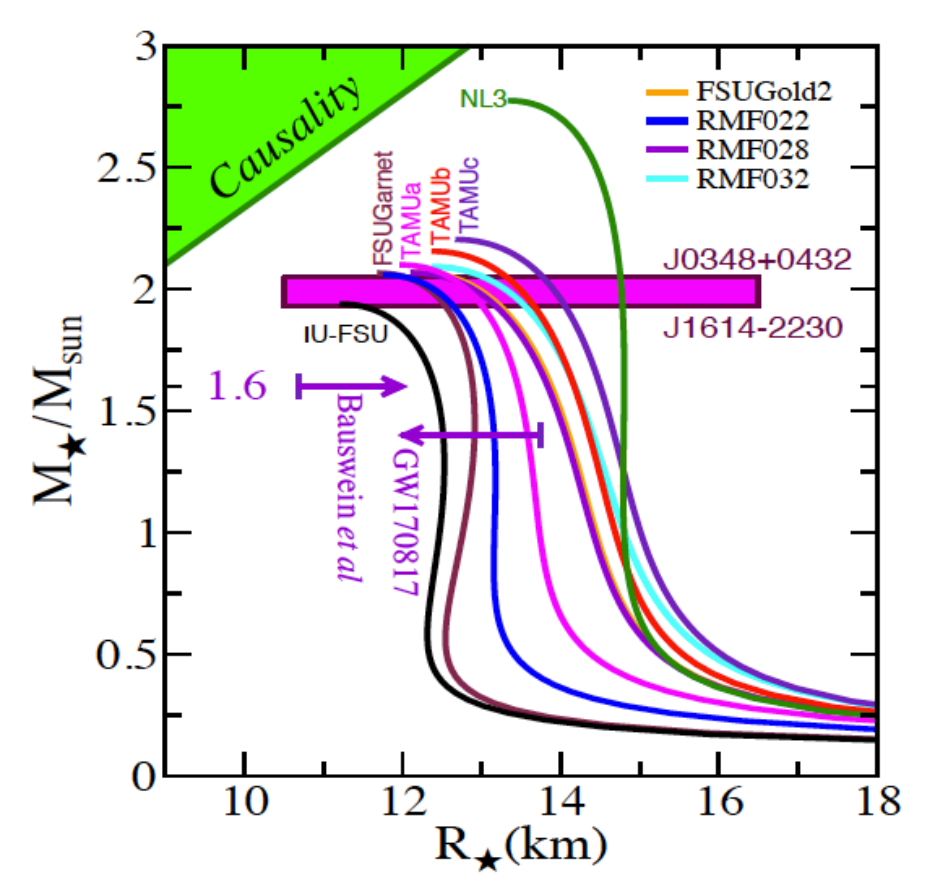
From Quarks to Cosmos

Two of the *eleven science question for the next century* by National Academies Committee:
- What are the new state of matter at exceedingly high density and temperature ?
- How were the elements from iron to uranium made ?

INFN NP white paper in preparation

Both connected to the largely unknown ultra-dense matter equation of state (EOS) and evolution,

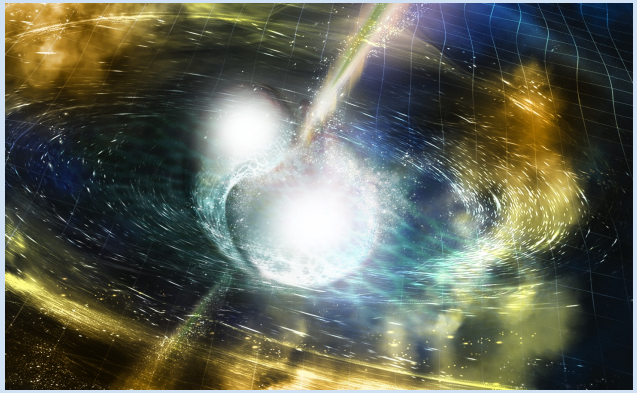


Example:

Neutron star EOS
Neutron star merger and r-nucleosynthesis

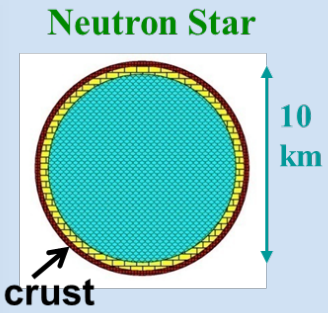
New astrophysical constraints
expected in the multi-messenger era

To be complemented with constraints
from nuclear laboratories



From Quarks to Cosmos

Tidal deformability $\Lambda \sim R^5$ from wave phase

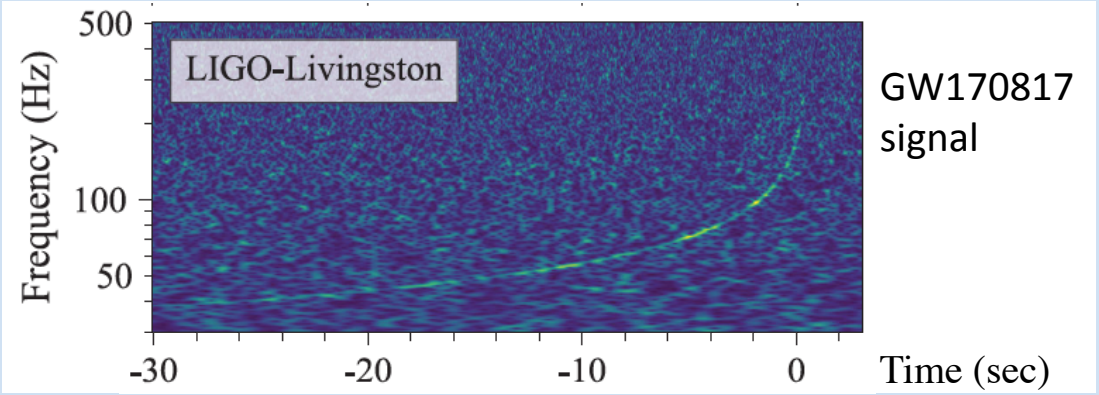


(LIGO) (JLab)

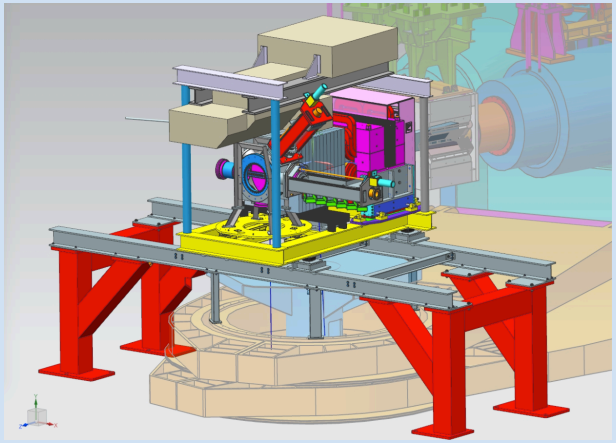
Despite 10^{19} scale difference, common origin from pressure of neutron rich matter vs surface tension or gravity

EOS constrained by JLab neutron skin as from GW measurements

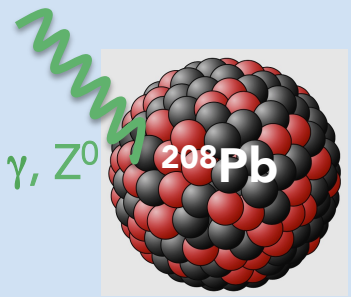
PReX experiment



GW170817 signal



Heavy Nuclei Neutron Skin



	Proton	Neutron
Electric charge	1	0
Weak charge	~0.08	-1

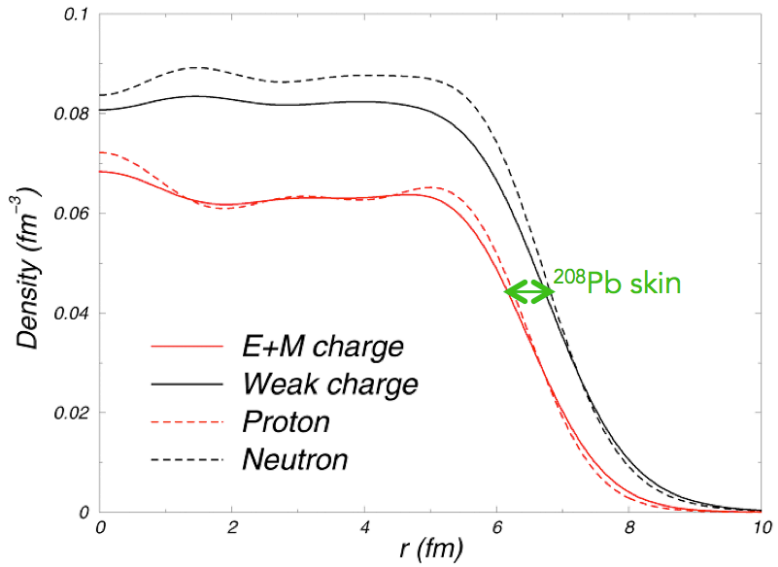
$Q_w^p = (1 - 4 \sin^2 \theta_W)$

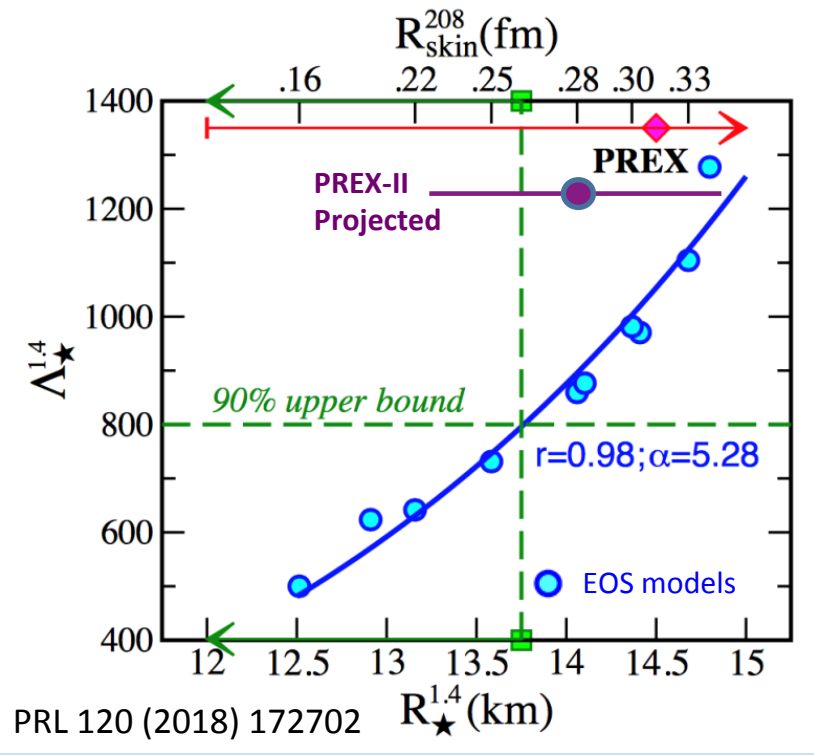
$Q_w^n = -1$

Parity Violating Electron Scattering sensitive to neutron distribution

Provides a **model-independent probe of neutron densities** free from most strong-interaction uncertainties

- **Precise determination of ^{208}Pb neutron radius:**
  - set basic constraints to nuclear dynamics (constrains the EOS of neutron matter)
  - has implications for the theory of neutron stars





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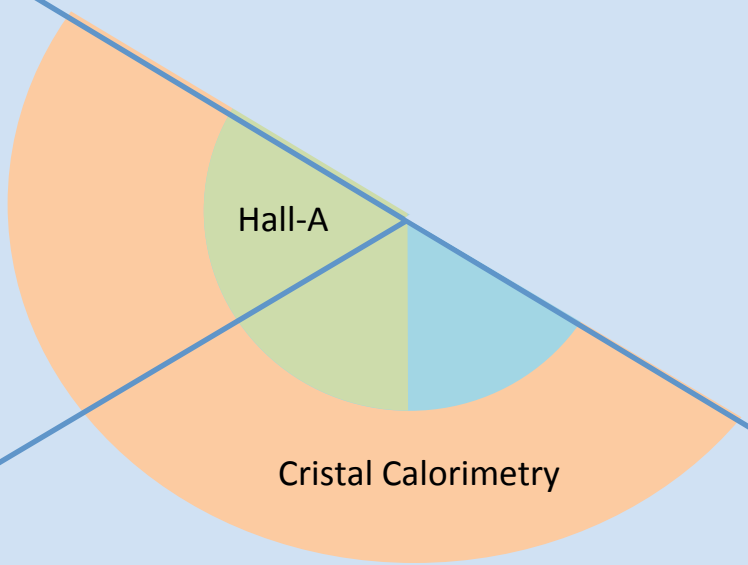


Dark Sector

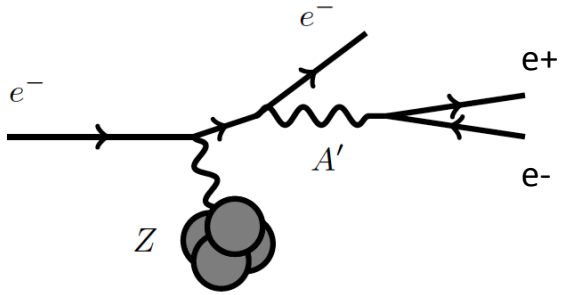
GE, CT, PV, LNS, RM2, TO, PD

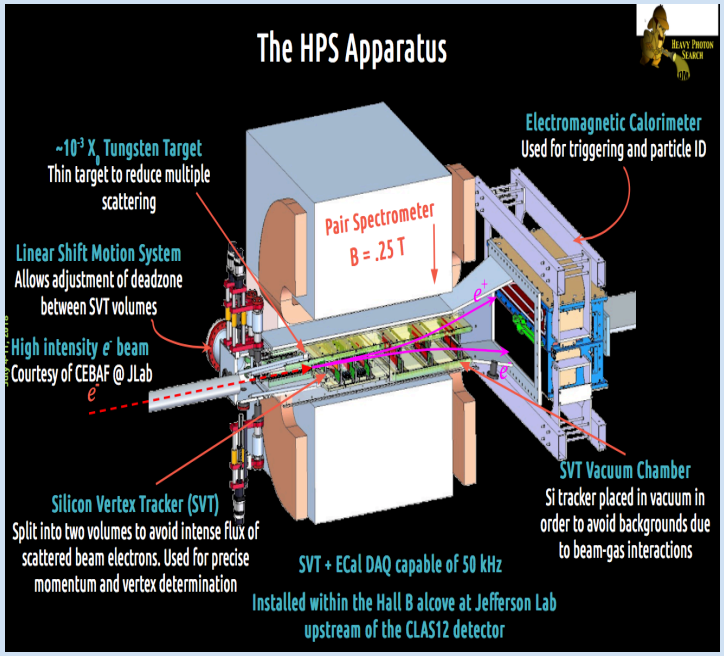
E11-006 HPS ‘17

E16-001 BDX ‘24

Heavy Photon Search

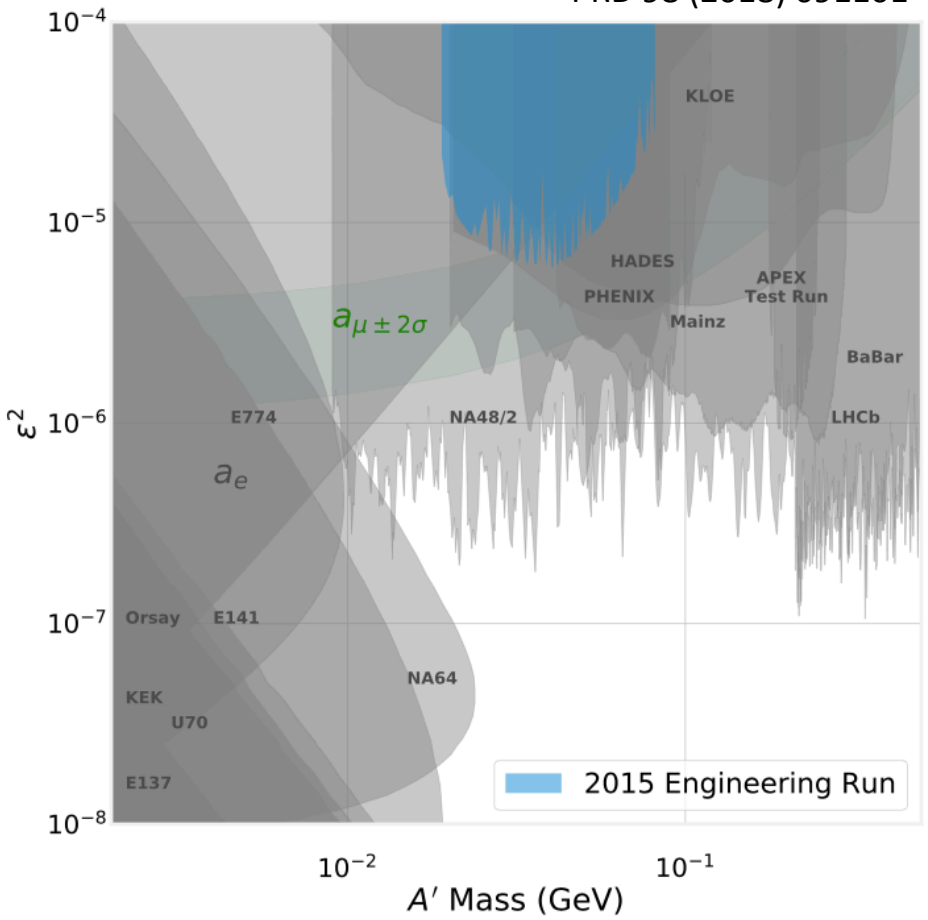
CEBAF intense high-energy electron beam allows to cover unexplored regions





Based on ~1 % approved data-taking

PRD 98 (2018) 091101

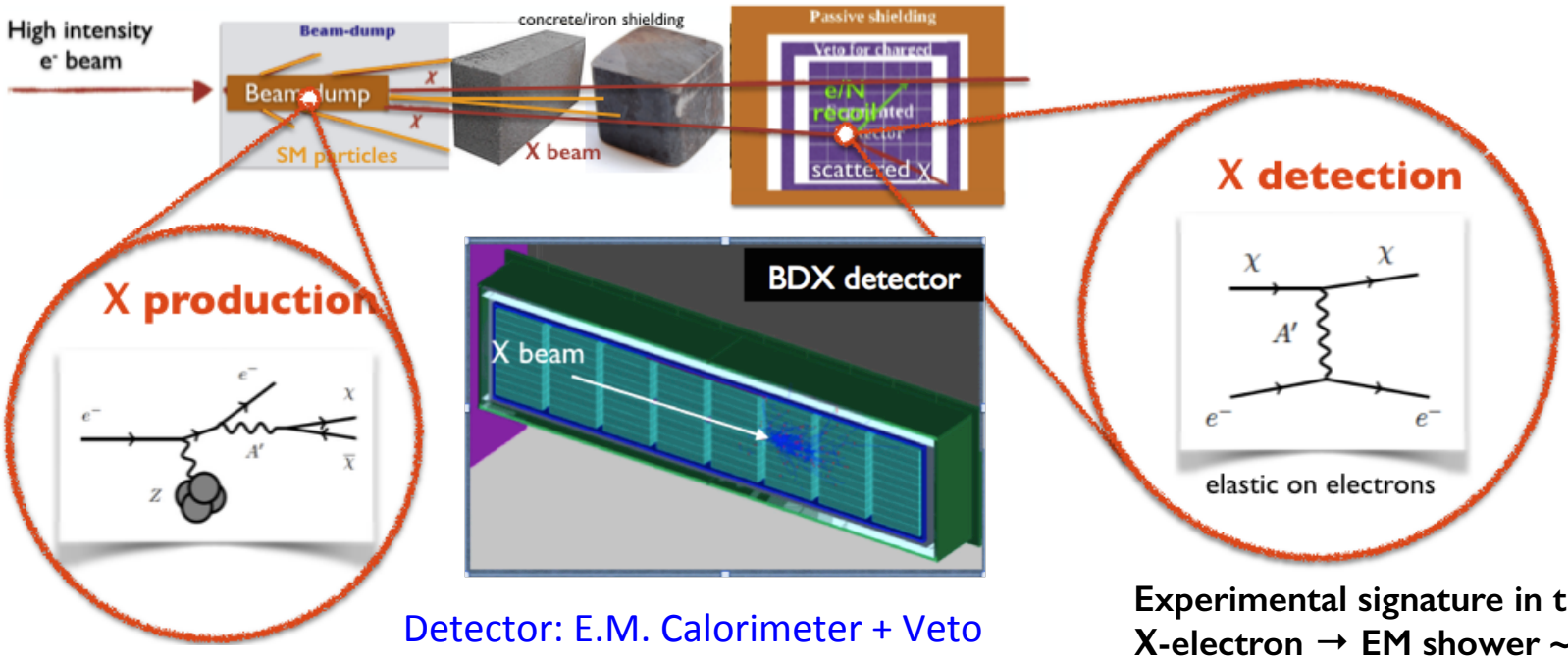


Beam Dump eXperiment

JLab beam dump (e-) experiments can provide unprecedented sensitivity to the light dark matter (< 1 GeV) suggested by many theoretical indications

Approved by JLab PAC in July '18 with maximum scientific rating (A)

PhysRevD.88.114015 E.Izaguirre,G.Krnjaic, P.Schuster, N.Toro



New experimental Hall
Extending after the Hall-A beam dump

Detector: E.M. Calorimeter + Veto
800 CsI(Tl) crystals (from Babar EMCal)
6x6 mm^2 SiPM readout

Experimental signature in the detector:
X-electron → EM shower ~GeV energy

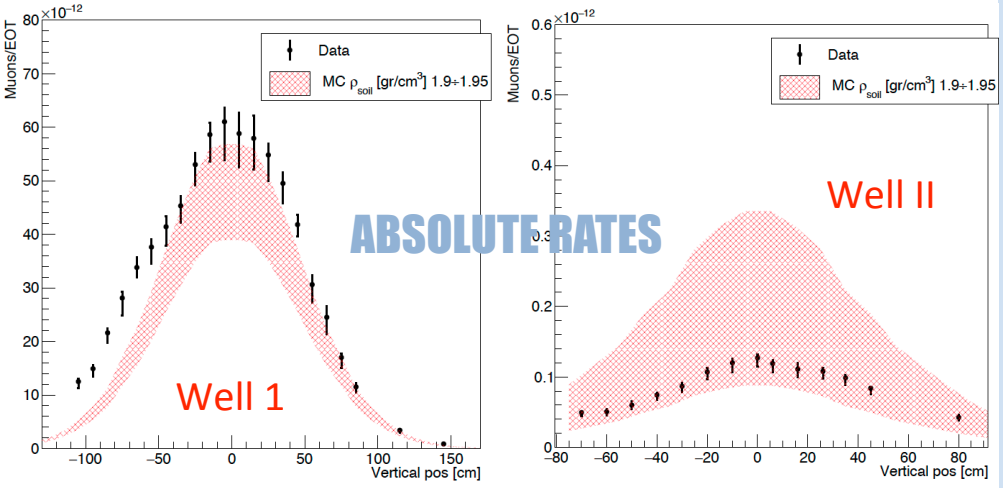
BDX Expected Reach

Present muon and neutron flux measurement

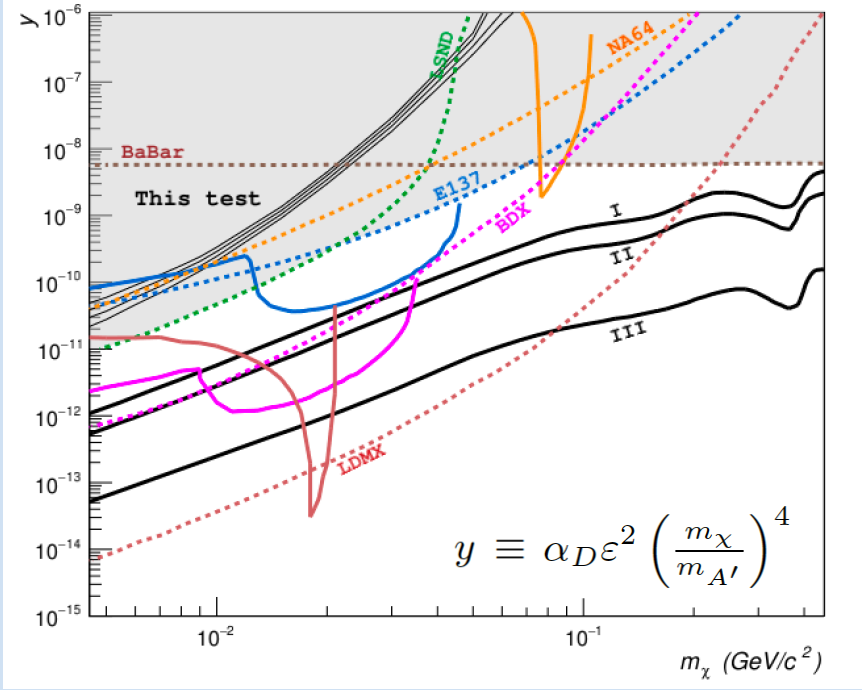
- High energy beam available: 11 GeV
- Highest available electron beam current: ~65 uA
- Highest integrated charge: 10^{22} EOT (41 weeks)

Accumulating 10^{22} EOT in ~1y BDX sensitivity is 10-100 times better than existing limits on LDM

Data vs simulation comparison



From validated detailed FLUKA simulation:
~5 ev irriducible background from ν_eCC



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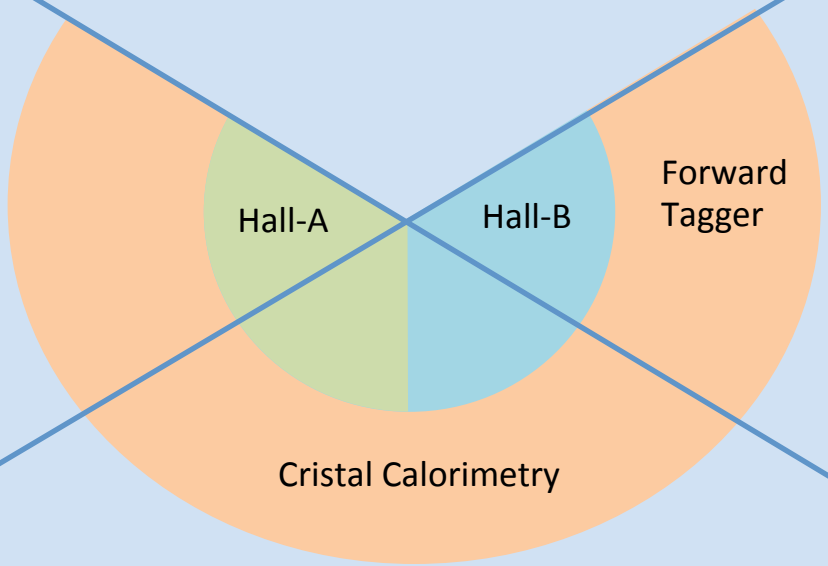

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Hybrid Baryons

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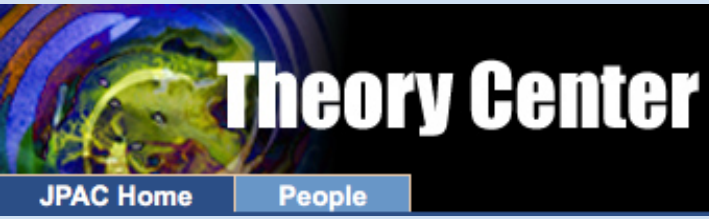
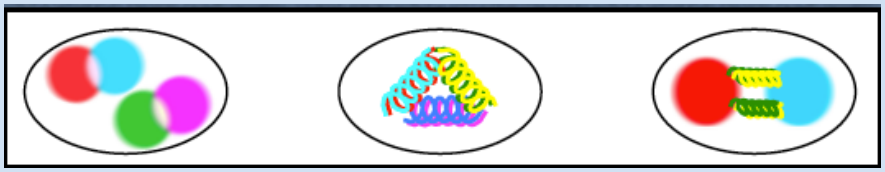
E16-001 BDX '24

Modern Spectroscopy

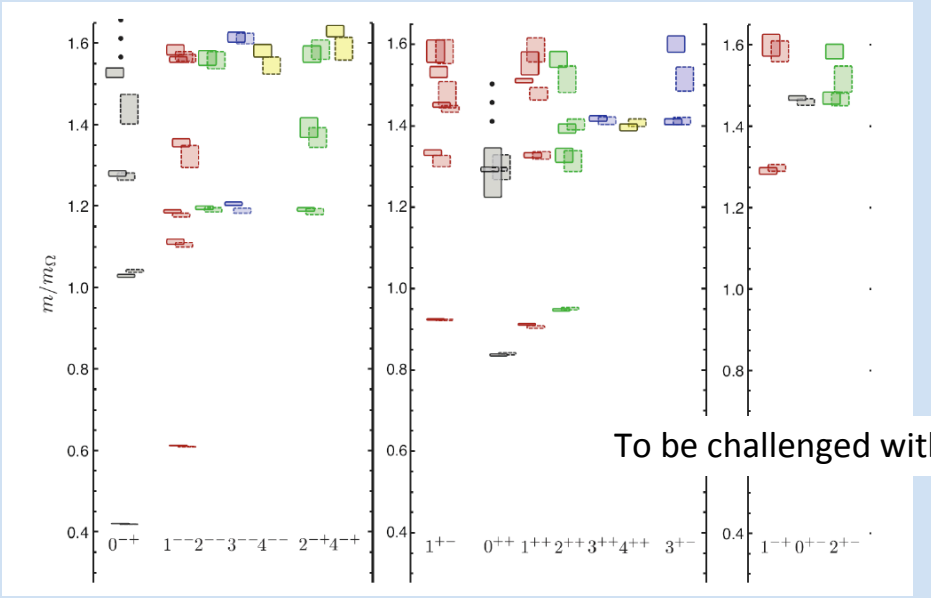
Unprecedented precision with electro-production at very low-Q^2 (photon tagging)



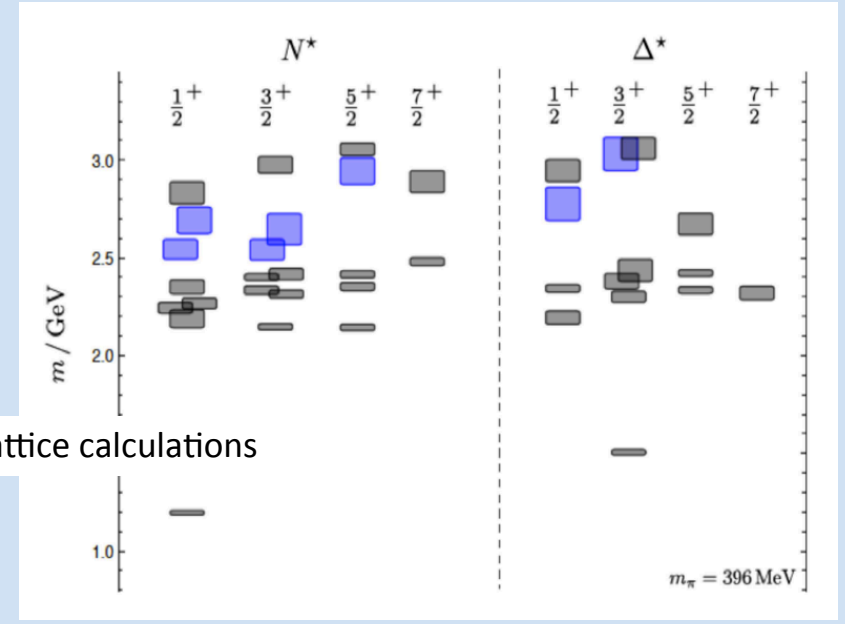
JPAC: JLab, Indiana U, GWU
Partial wave analysis framework
Strong collaboration with EU theory groups



Mesons

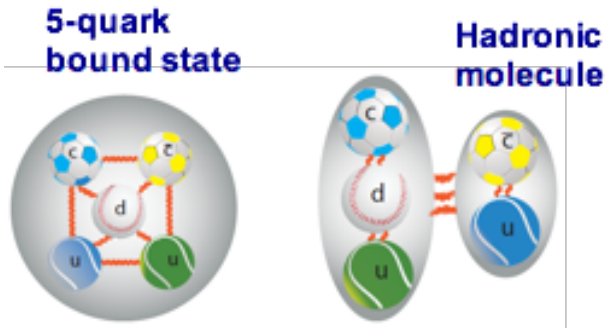


Baryons



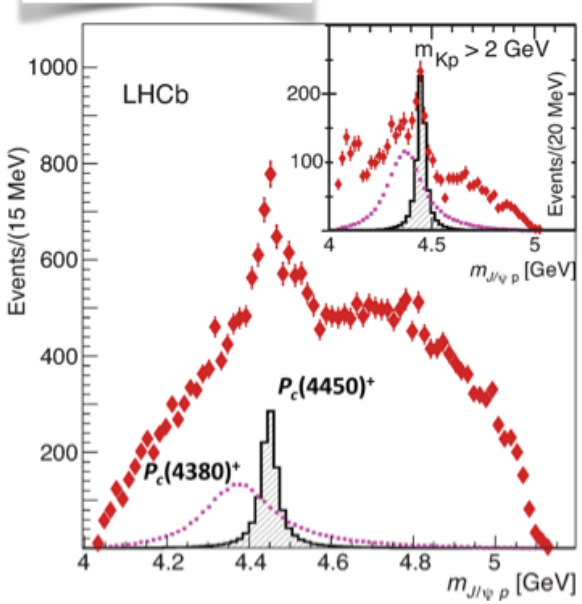
To be challenged with Lattice calculations

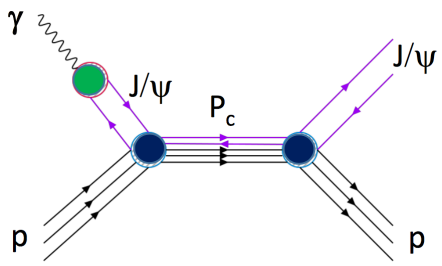
Pentaquark Search

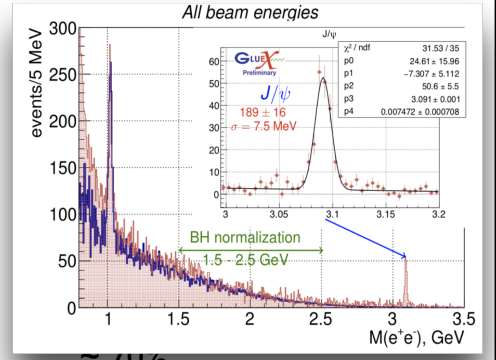


or cusp, triangle singularity, etc…

$\Lambda_b \to J/\psi p K^-$

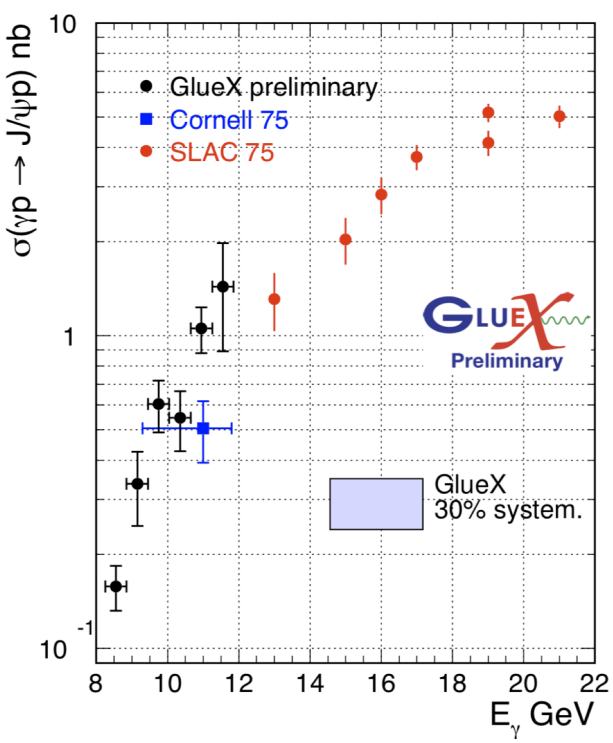






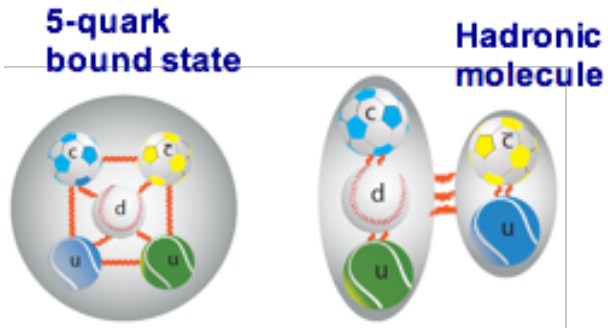
- J/ψ photoproduction at threshold
- Observation of charm at GLUEX
- Projections with CLAS12 shows a significant sensitivity

~ 70%
2016-2017statistics



From E. Chudakov talk @ SPIN 2018

Pentaquark Search



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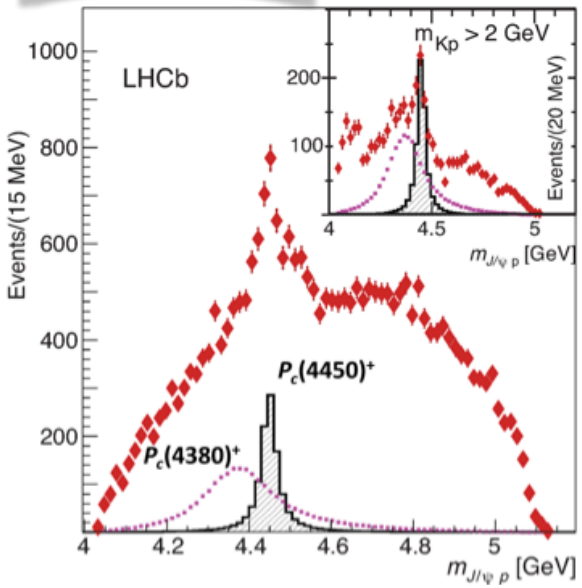

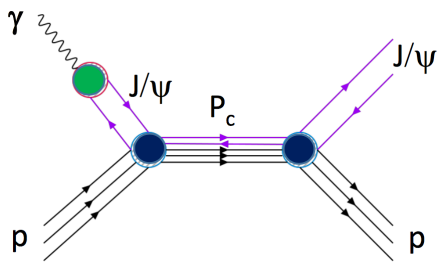

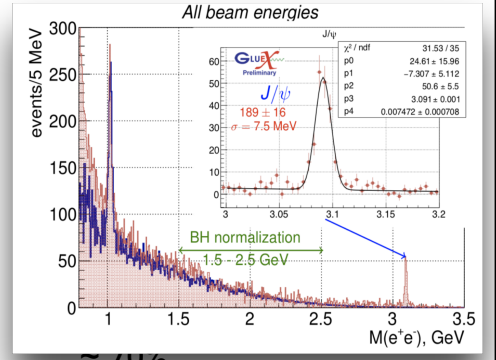

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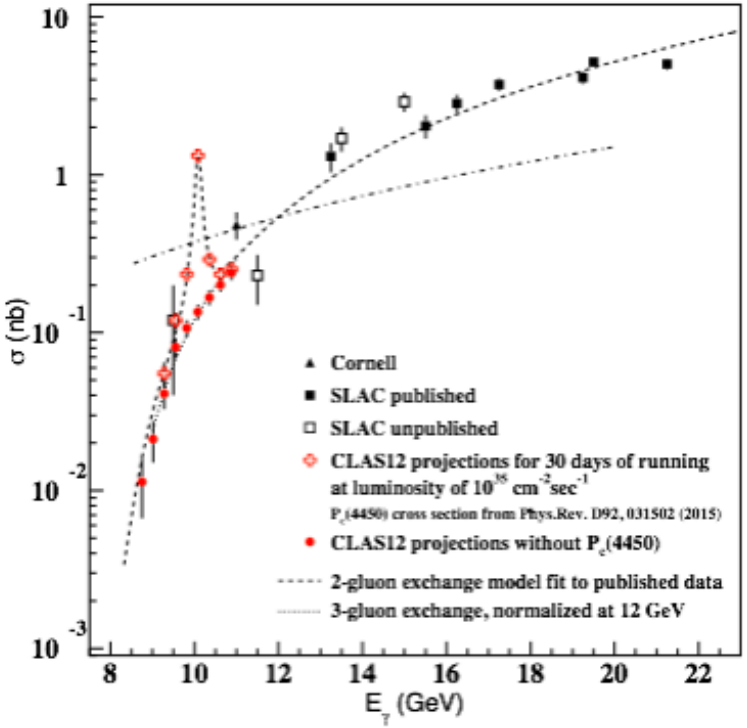
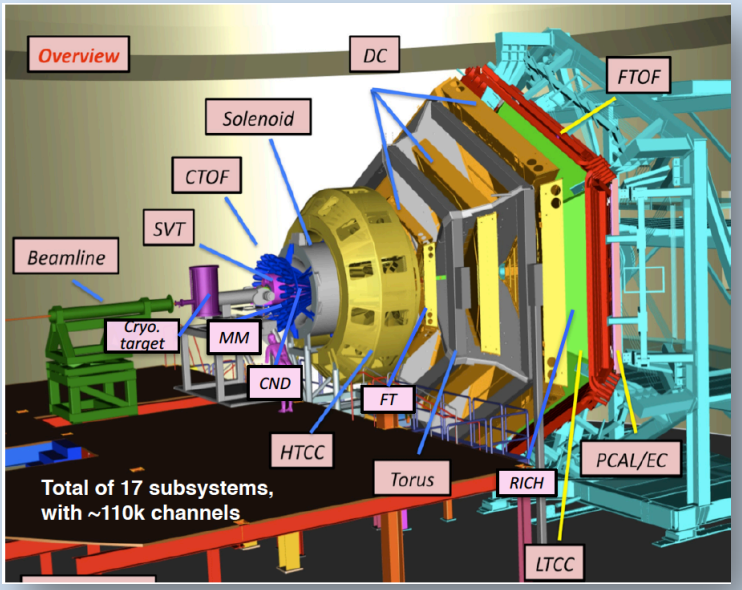


Forward Tagger

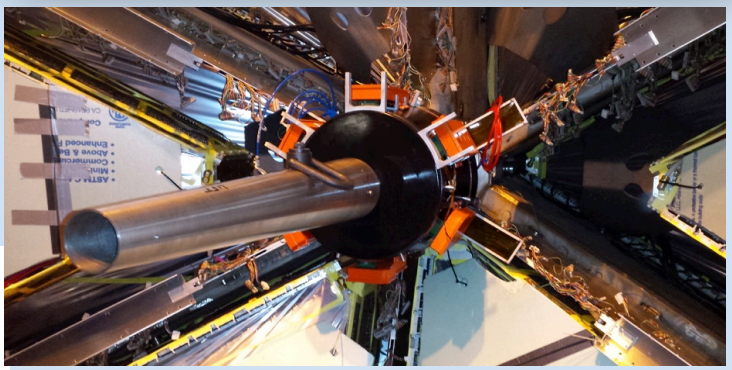
Small-angle complete spectrometer
(Gem tracking, pre-shower and ECAL)

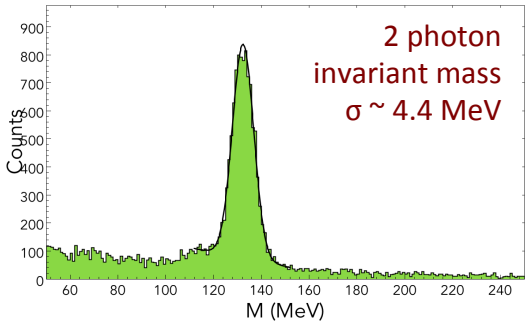
Coordination: INFN-Genova
Contributors: INFN-Genova, INFN-Roma2, CEA, U. Edinburg, U. Glasgow, JLab, James Madison U., Norfolk State U., Ohio U.

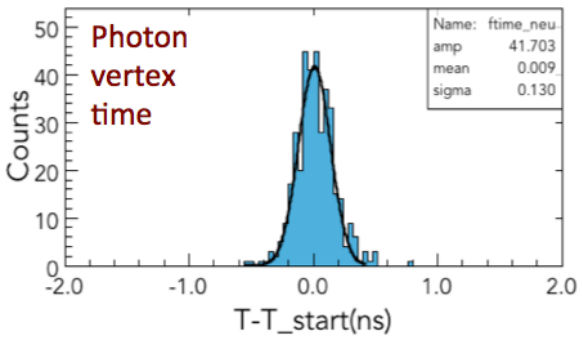


Quasi-real photon physics (low Q^2)
Spectroscopy with photon kinematics and polarization control on event-by-event basis

Hard-exclusive channels
Enhanced phase-space coverage for benchmark reactions







Full Forward Tagger installed in July 2017
Performance in line with specifications

INFN 12 GeV Projects

RM1, CT, BA

Nucleon 3D

FE, LNF,GE

E07-109 Proton form factor '22
E17-004 Neutron form factor '22
E09-018 SIDIS off neutron (^{3}He) '23

E06-112A, B Quark dynamics '18
E07-107, E09-009 TMDs '18
E09-007, E09-008 TMDs '21
C11-111 TMDs '22
C12-009 Di-hadron probes '22

Nuclear Potentials

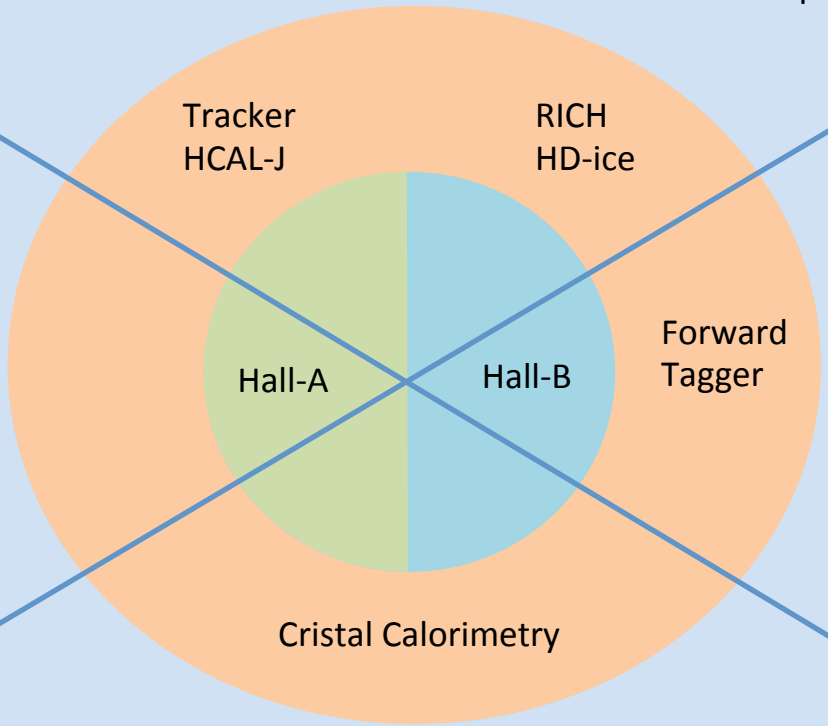
RM1

E17-003 '18
Lambda-nn off trithium (^{3}H)

E11-101 '19
PREX-II: neutron skin

E15-008 '24
Lambda hypernuclei

E14-012 '24
^{40}Ar cross-section for ν



Spectroscopy

GE, RM2, TO, PV

E11-005 '18
MESONX

E12-001A '18
J/psi and penta-quark

E16-010 '18
Hybrid Baryons

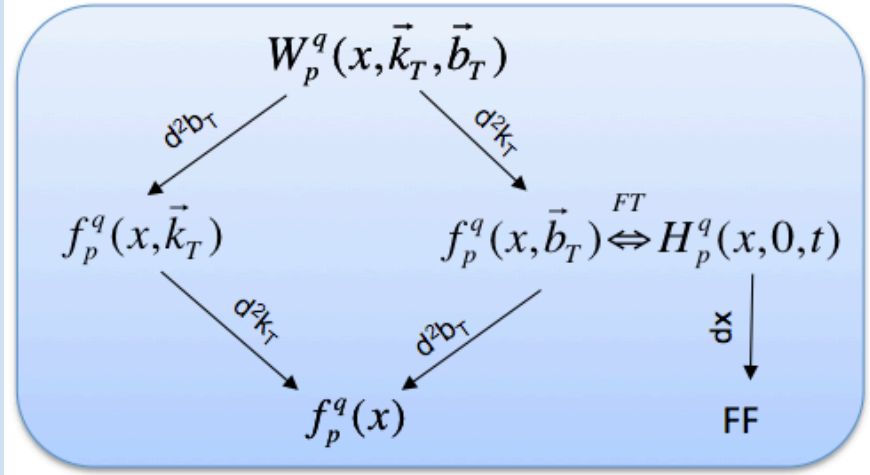
Dark Sector

GE, CT, PV, LNS, RM2, TO, PD

E11-006 HPS '17

E16-001 BDX '24

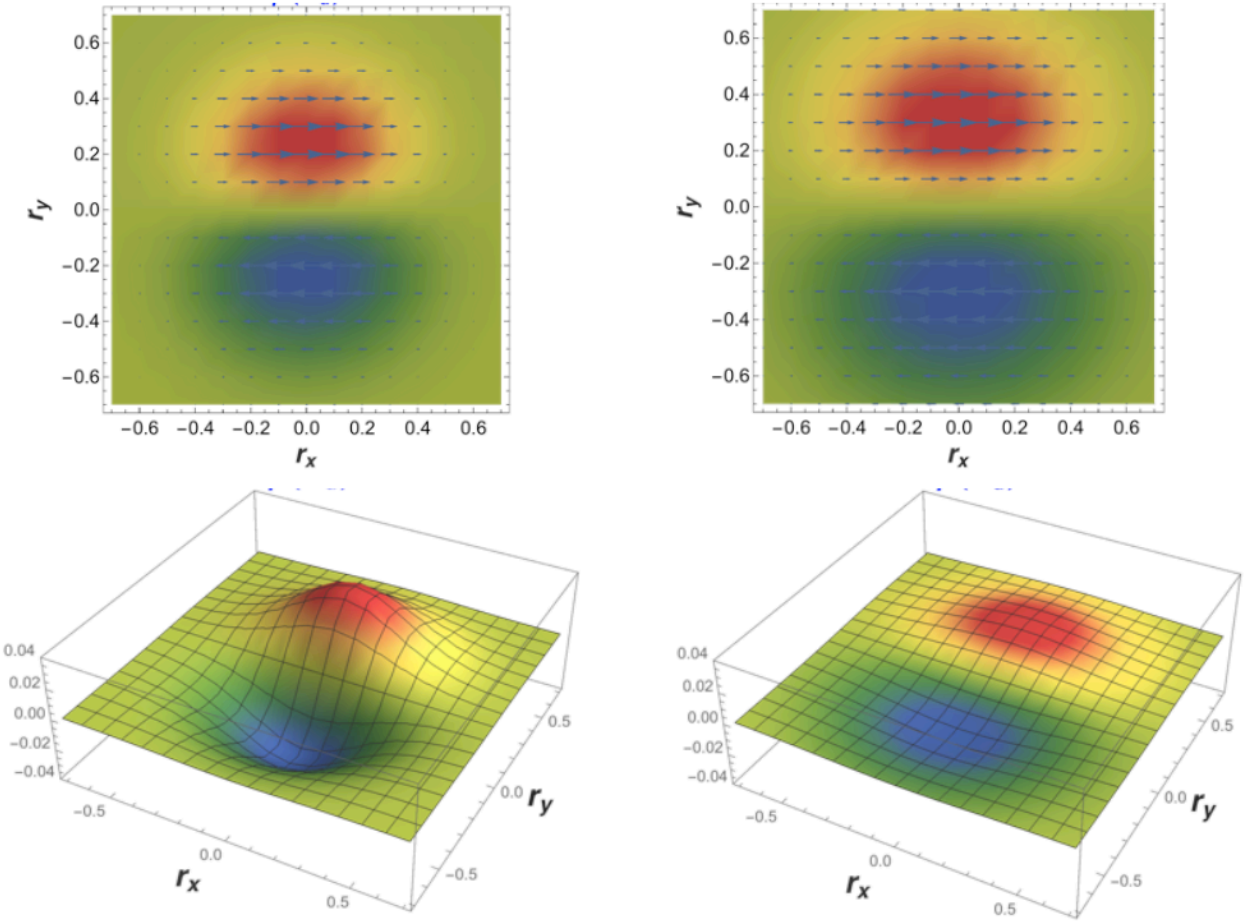
JLab12 able to provide x 1000 luminosity (vs HERMES) at large x



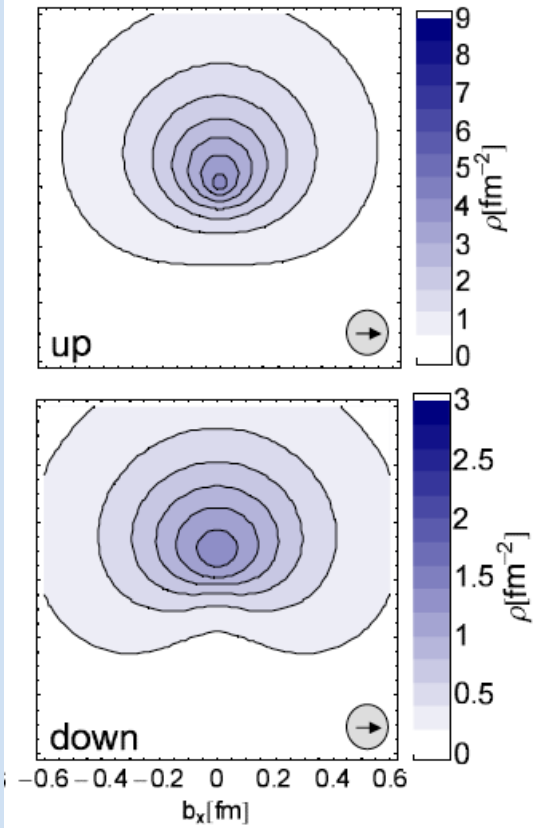
Polarized Quark Imaging

$$q_T(x,b^x) \equiv \frac{1}{2} b^y \frac{1}{m} \frac{\partial}{\partial b^2} \bar{\mathcal{E}}_T$$

$q\left(\bar{\mathcal{E}}_T\, u\right)$ $q\left(\bar{\mathcal{E}}_T\, d\right)$



Lattice Calculations
arXiv: hep-lat/0612032



3D Phenomenology

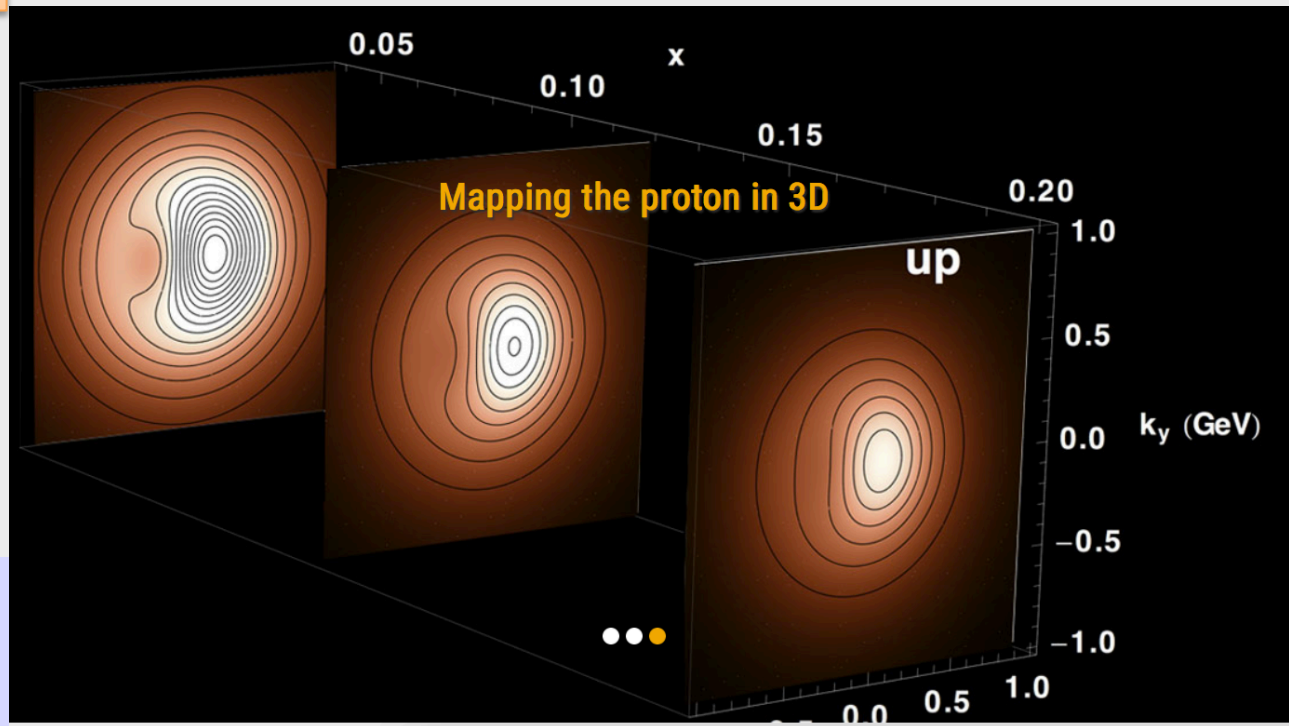
HadQCD HADRONICS STRUCTURE AND QCD

HOME TEAM 3D SPIN WORKS NEWS CONTACTS

http://www.hadronicphysics.it/hasqcd/index.php/3d-spin/

A. Bacchetta
ERC Consolidator Grant

Devoted to the study of the properties of transverse momentum distributions and their extraction from experimental data



3DSPIN MAPPING THE PROTON IN 3D

The Italian side of

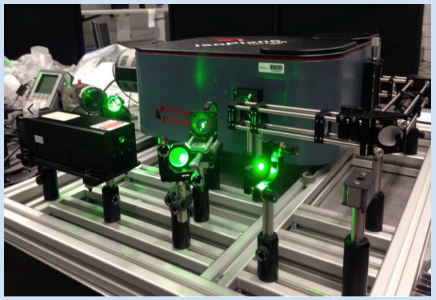
Topical Collaboration for the Coordinated Theoretical Approach to Transverse Momentum Dependent (TMD) Hadron Structure in QCD

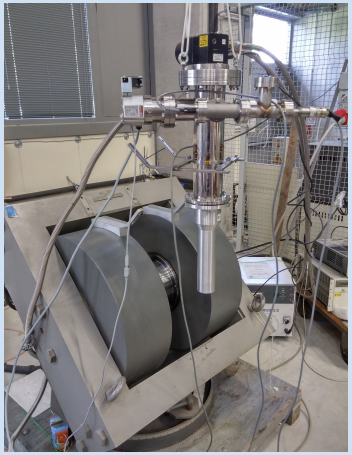
TMD Collaboration

HD-ice Frozen Spin Target

Solid HD in frozen spin mode
polarization up to 60% H or 35% D

- Minimize nuclear background





HD gas distillation

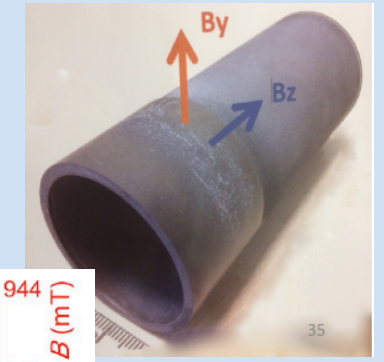
Very pure HD gas is needed to produce polarized targets.

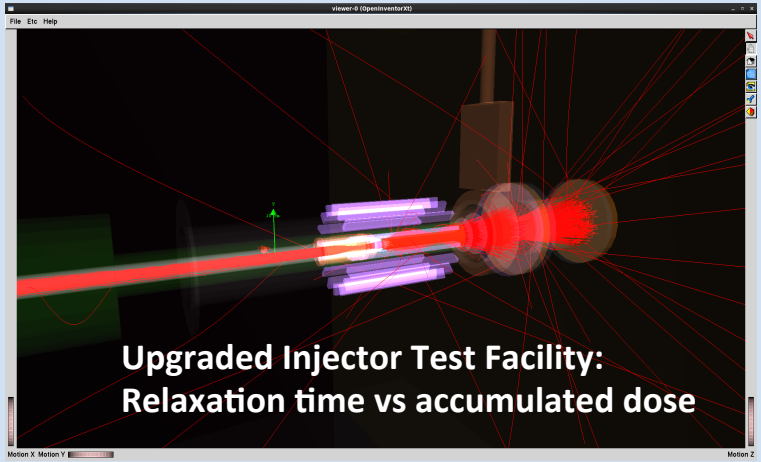
Raman spectroscopy

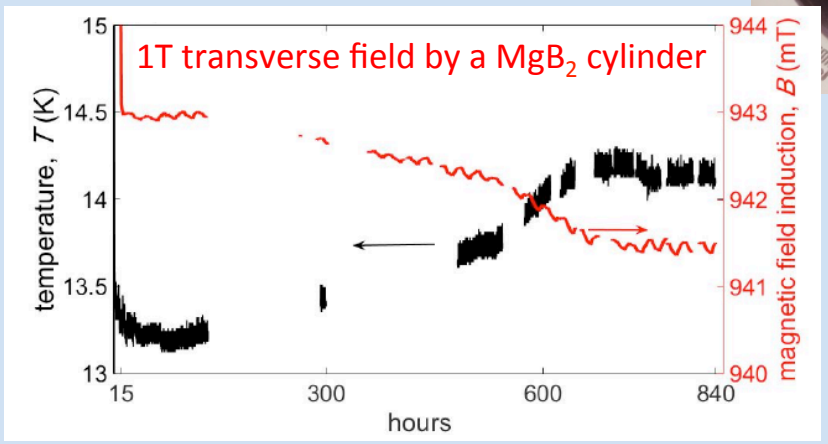
Analyze the content of H_2 and D_2 contaminants in the HD gas.

Bulk MgB_2 magnet solution

Transverse target inside CLAS12 requires to screen a 2T solenoid and generate ~1T transverse holding field







RICH Project

Ring-Imaging Cherenkov Detector

Coordination: INFN-FE
Contributors: INFN-FE,LNF,RM1,BA,GE, JLab, ANL, GWU, Duquesne U., UCONN, Glasgow U, UTFSM (Chile), KNU (Korea)

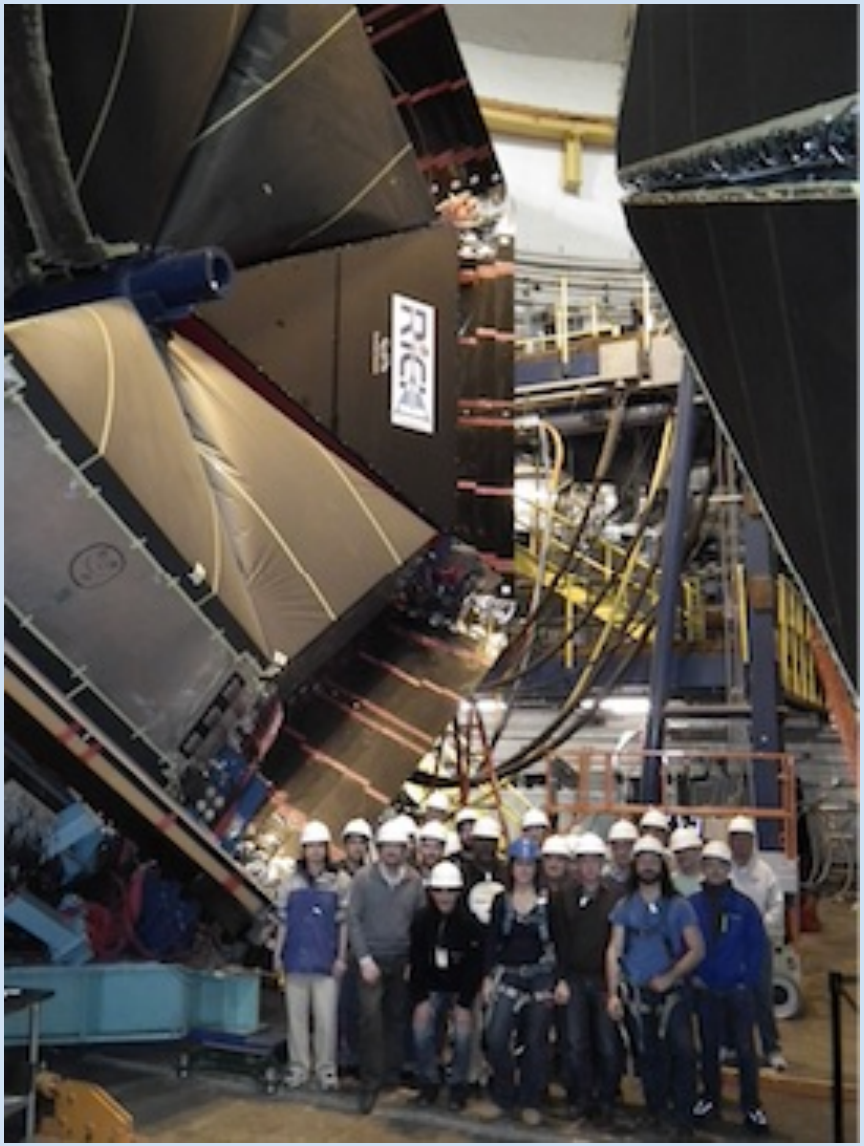
Supported by MIUR priority project CLASMED

3D Structure and Fragmentation
Access to parton dynamics with flavor sensitivity

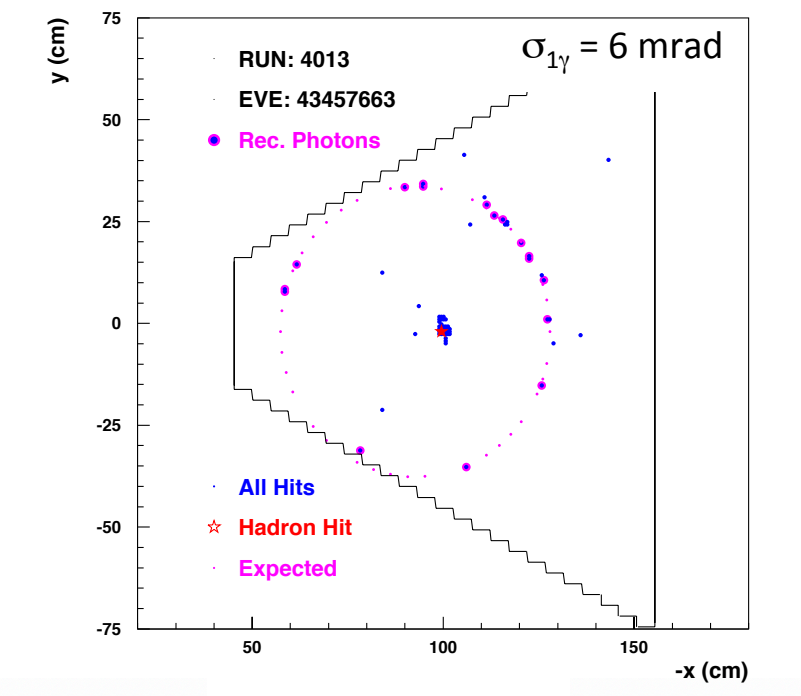
Rare channels
Background suppression

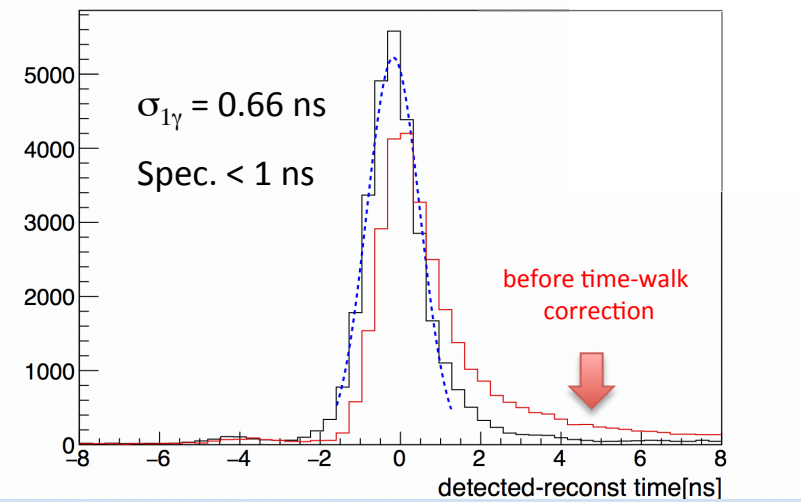
RICH 1st Module Installed in January 18

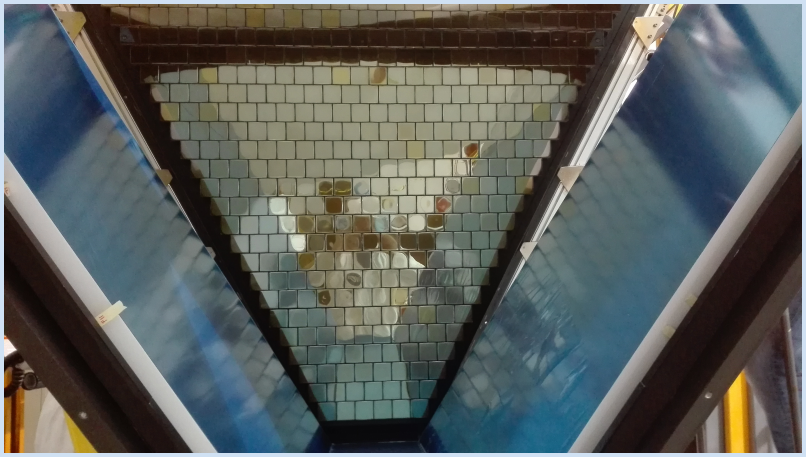
RICH 2nd Construction ongoing
Module expected to be ready in 2021

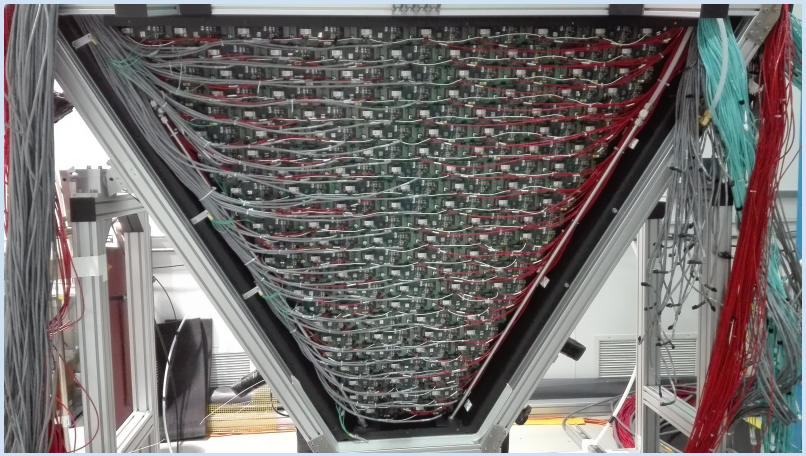


RICH Readout Electronics









Readout Electronics: INFN-JLab joint venture

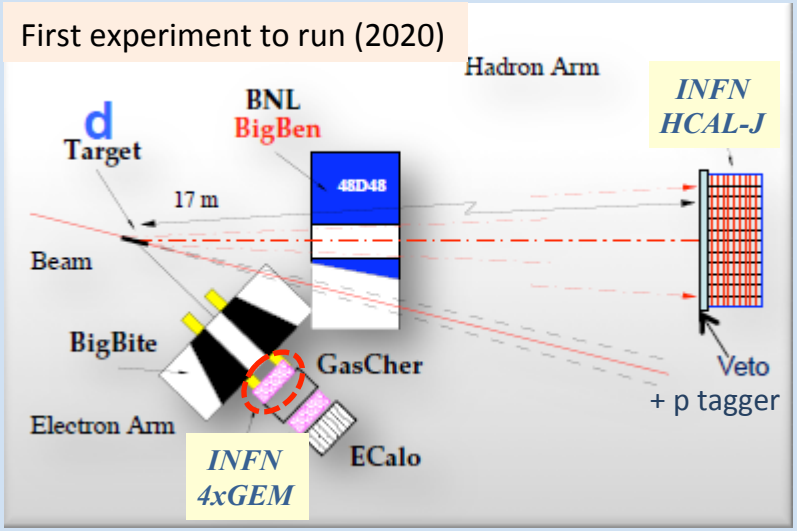
Applications:

- Gluex DIRC
- EIC R&D
- SOLID
- Medical Imaging
- Homeland Security

SBS in Hall-A

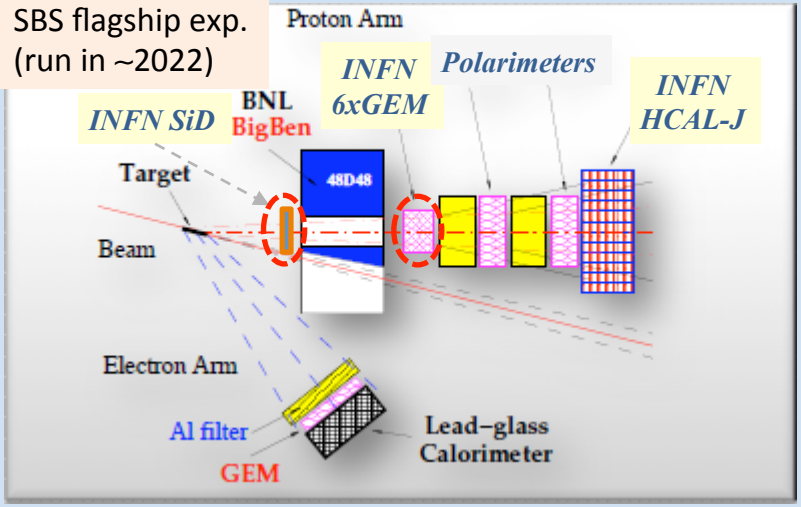
E-12-09-019: GMn - Cross section ratio

First experiment to run (2020)



E-12-07-109: GEp - Polarization transfer

SBS flagship exp. (run in ~2022)



Configurable detector facility

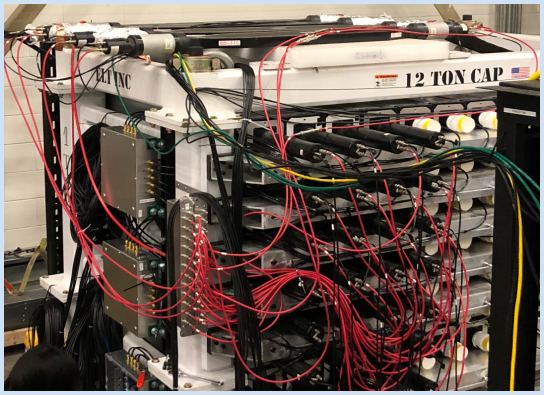
Designed to work at the **luminosity frontier (>10^{38}/cm^2/s)**

Expected to start data-taking in 2020

Hadron Calorimeter HCAL-J

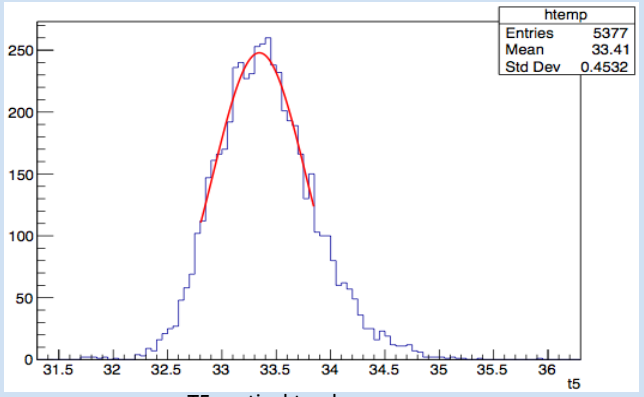
Modules ready for assembling

Cosmic stand



Cosmic Test:

Estimated time resolution 1.4 ns (Spec < 1ns)



T5 vertical track

Tracker Status and Plan

GEM:

4 chambers under cosmic test @ JLab since Jul '18

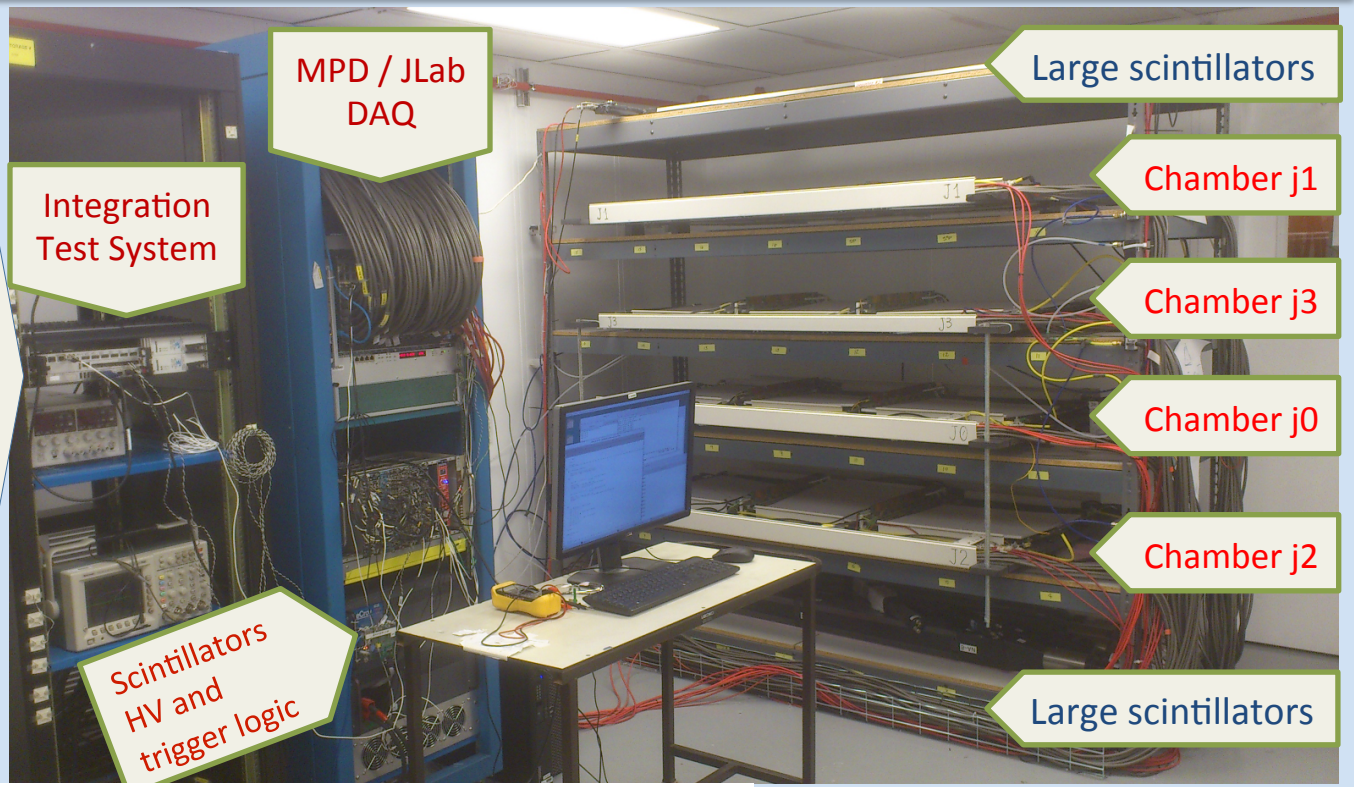
Installation in BigBite planned for summer '19

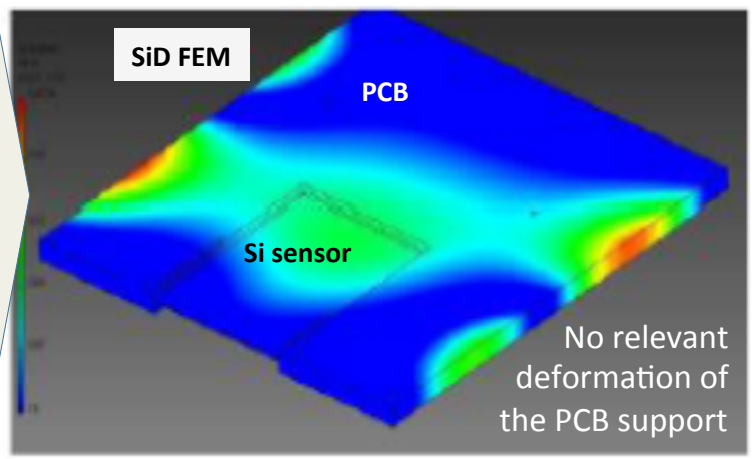
SiD:

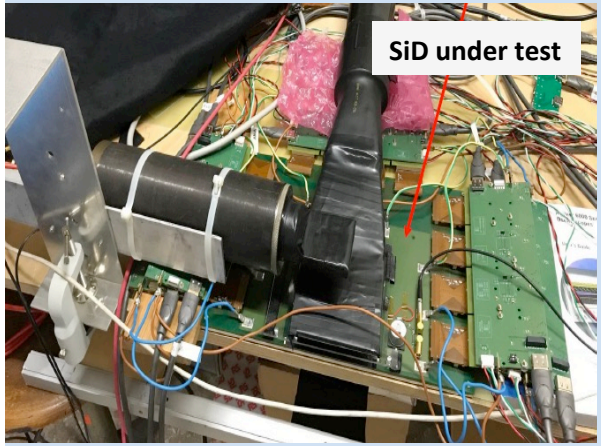
Production started at BA using automatic bonding machine

Laser and cosmic test stand in Rome

Integration into GEM cosmic stand @ Jlab in 2019







EIC R&D as Synergic Activity

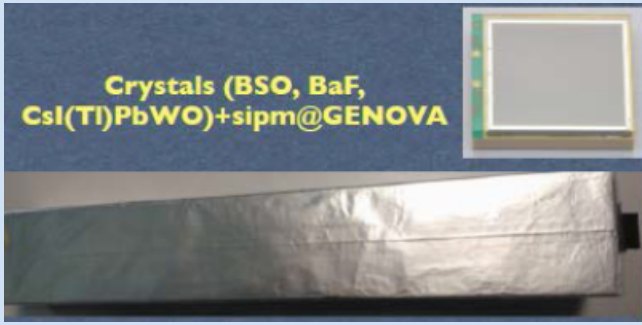
INFN users pursuing a synergic R&D activity

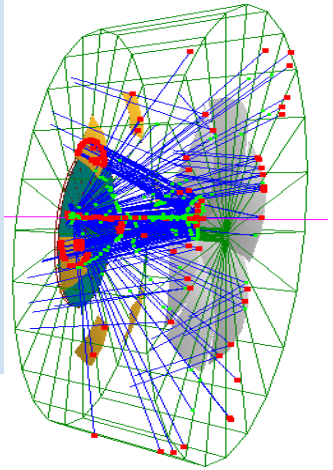
Promote a spectroscopy program (GE, RM2)

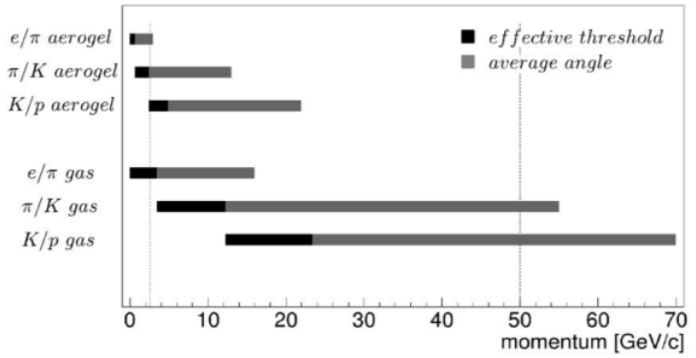
Electromagnetic Calorimeter with doped glass (GE, RM2)

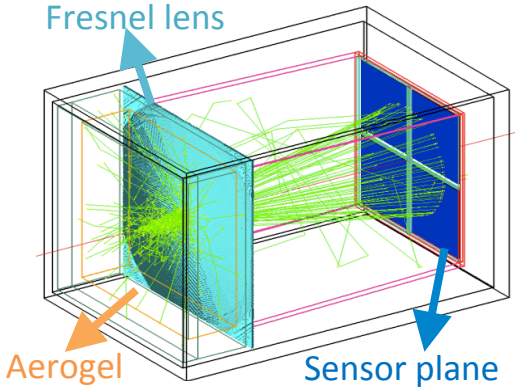
Streaming Readout (GE)

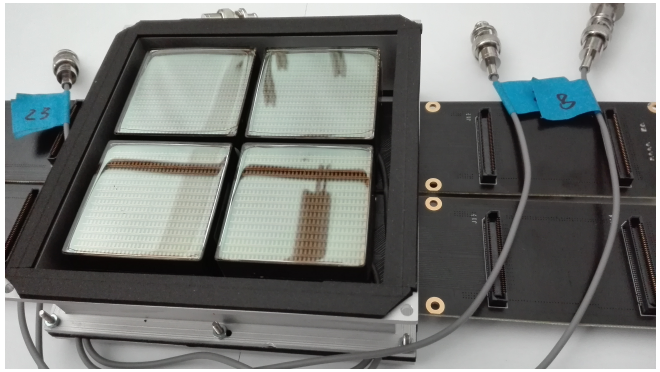
Imaging Cherenkov (FE, RM1, LNS, CT)
h-endcap: Dual radiator RICH
e-endcap: Modular RICH



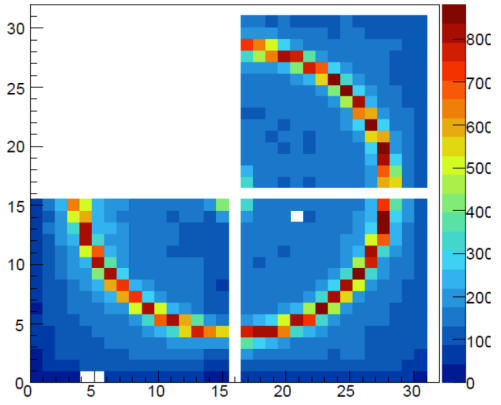








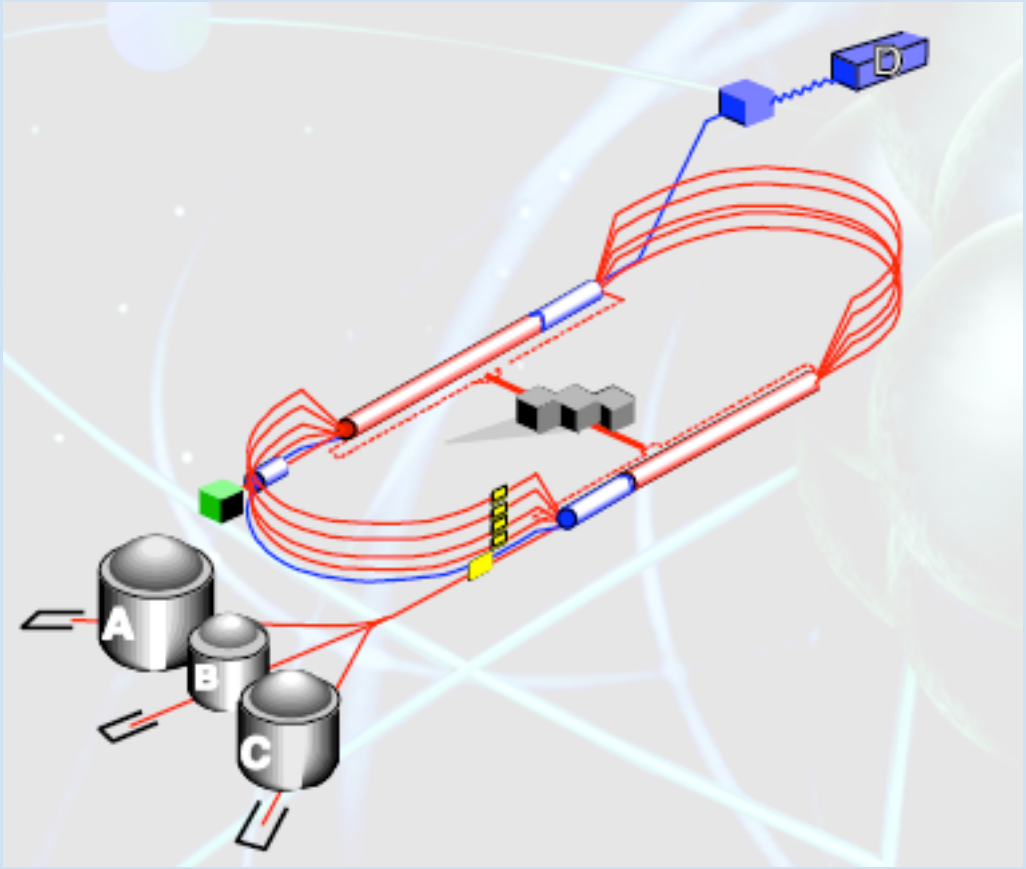
SiPM with CLAS12 electronics



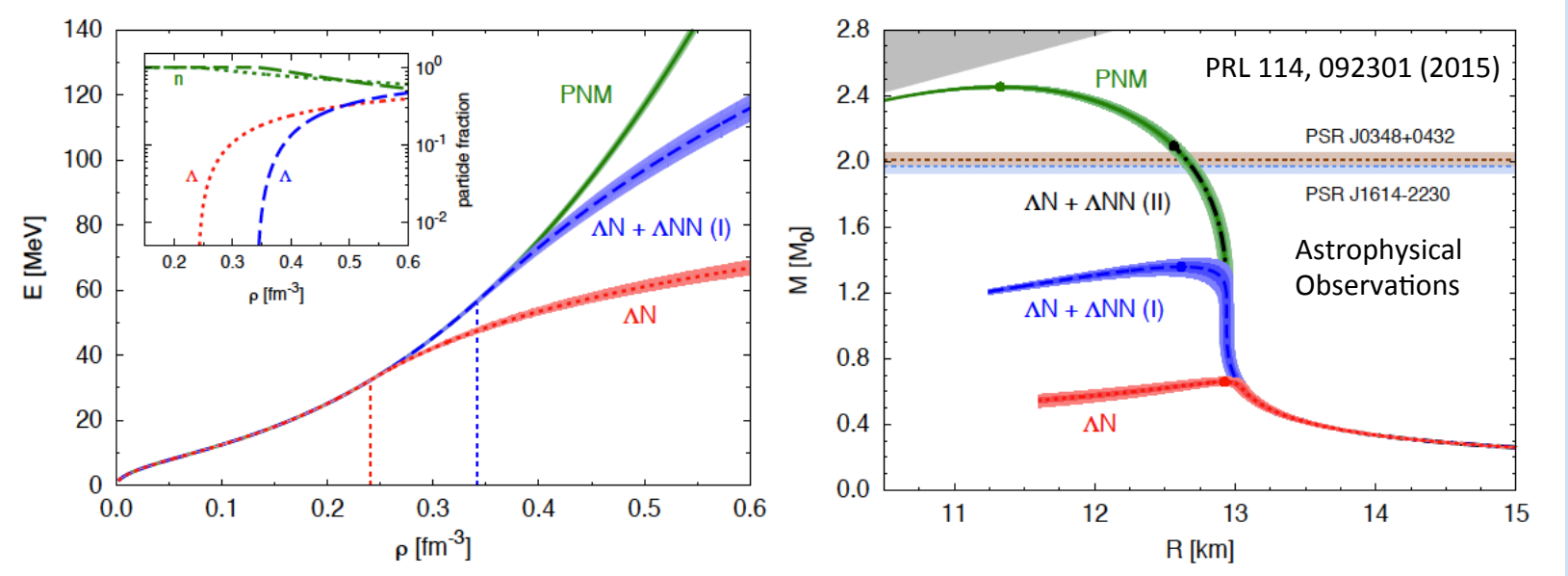
Conclusions

JLab 12 GeV era is now a reality with all experimental Halls operative

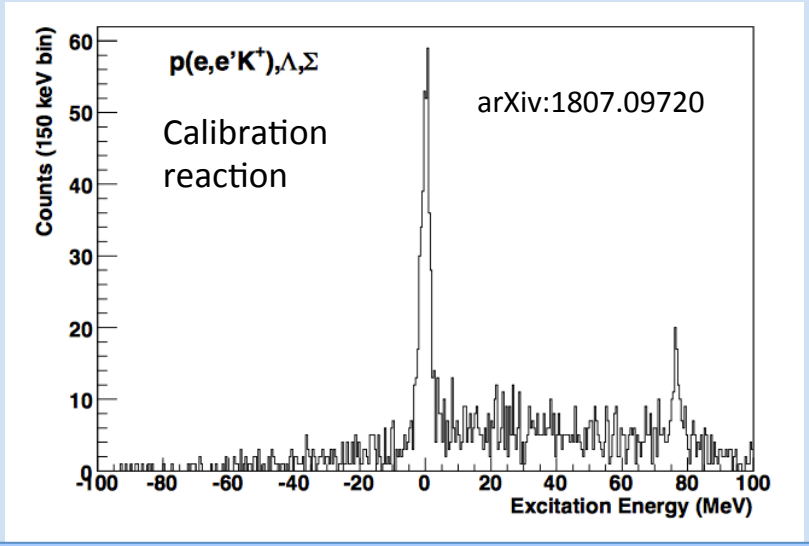
INFN committed to contribute to the broad approved physics program



Ultra-dense Matter EOS



At JLab: Excellent linearity and resolution verified on control reactions (Hydrogen target). Study symmetric and asymmetric hypernuclei with different sensitivity on the Λnn e Λpp contributions



$^{3}H\ (e,e'K^{+})\ ^{3}_{\Lambda}H$

$^{4}He\ (e,e'K^{+})\ ^{4}_{\Lambda}He$

$^{40}Ca\ (e,e'K^{+})\ ^{40}_{\Lambda}K$

$^{48}Ca\ (e,e'K^{+})\ ^{48}_{\Lambda}K$

Prototype: Small PAD-Size Micromegas

The development of the resistive MICROMEGAS prototype with miniaturized pad-size

- Design & construction completed
- Pad size: 3 x 3 mm^2, pitch 3.5 mm
- Modularity for extendibility: for each group of 128 pads, read-out and services make use of an area as large as the pad group itself

- Read-out via SRS by the original DAQ system Raven
  - LabView based, developed for larger band width (up to the saturation rate of the Gigabit Ethernet when the UPD protocol with Jumbo Frame format)
  - it takes care of APV25 setting (FE chips), data collection and visualization, including pedestal subtraction and zero suppression
  - user friendly graphical interface
- Preliminary test of the prototype

(MICROMEGAS stable up to large gain!)