DE LA RECHERCHE À L'INDUSTRIE

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EIC activities in France

F. Sabatié – CEA Saclay - Irfu/DPhN

- Overview of french involvement
- EIC activities at IPNO (C. Munoz)
- EIC activities at CPHT (C. Marquet)
- EIC activities at CEA Saclay
- EIC activities in Europe : STRONG-2020

Involved parties, situation in France

37 registered members of EIC UG

Already part of the EIC UG:

- CNRS/IN2P3 – IPN Orsay (& Subatech)
- Ecole Polytechnique – CPhT & LLR
- CEA Saclay – DPhN & DEDIP

Soon to come:

- CNRS/IN2P3 – LPT
- CEA Saclay – IPhT

Officially:

- **EIC is on the CEA Saclay roadmap**: interest in physics, detectors and accelerators (potential production site)
- EIC was presented to the CNRS/IN2P3 Scientific Council in 2018
  But not yet an IN2P3 official project (considered too early)

Please register as early as possible !

Past involvements, new trends

- INT Workshop (many contributions from theorists, phenomenologists)
- EIC White Paper (part of the writing committee)
- EIC R&D – eRD1 (IPNO) and eRD3 (CEA Saclay)
- LDRD with JLab : Geometry tagging (IPNO)
- LDRD with BNL « Zigzag » (CEA Saclay)

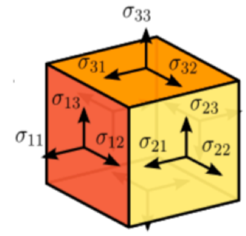
- NEWS on the french side:
    - Recent hiring of an EIC physicist at CEA Saclay
    - Soon: position on EIC/Jlab physics at IPNO
    - Soon: position on GPD theory/phenomenology at CEA Saclay

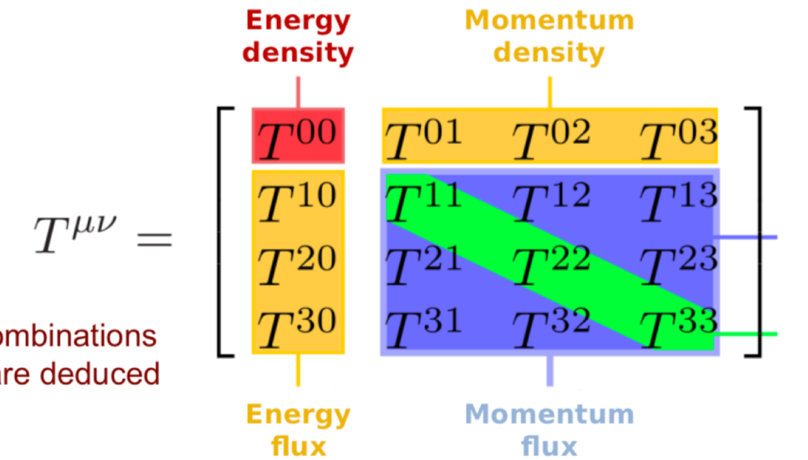
    - Involvement of CEA Saclay on sPHENIX
    - IN2P3/LPT and CEA/IPhT (theory labs) will soon join the EICUG

CPhT Contributions

QCD energy-momentum tensor for a bound system

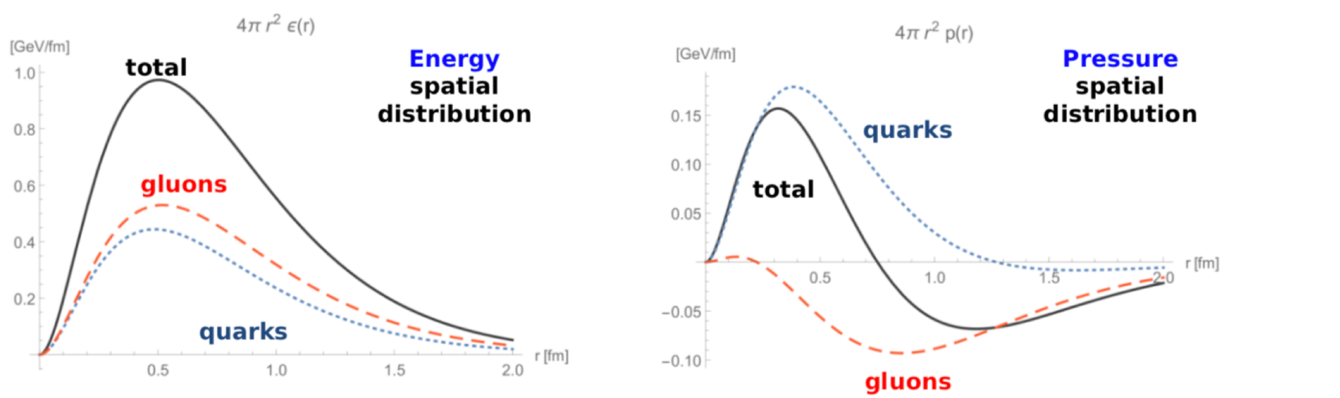
Encodes information about mass, spin and pressure forces





Matrix elements are combinations of form factors which are deduced from GPDs

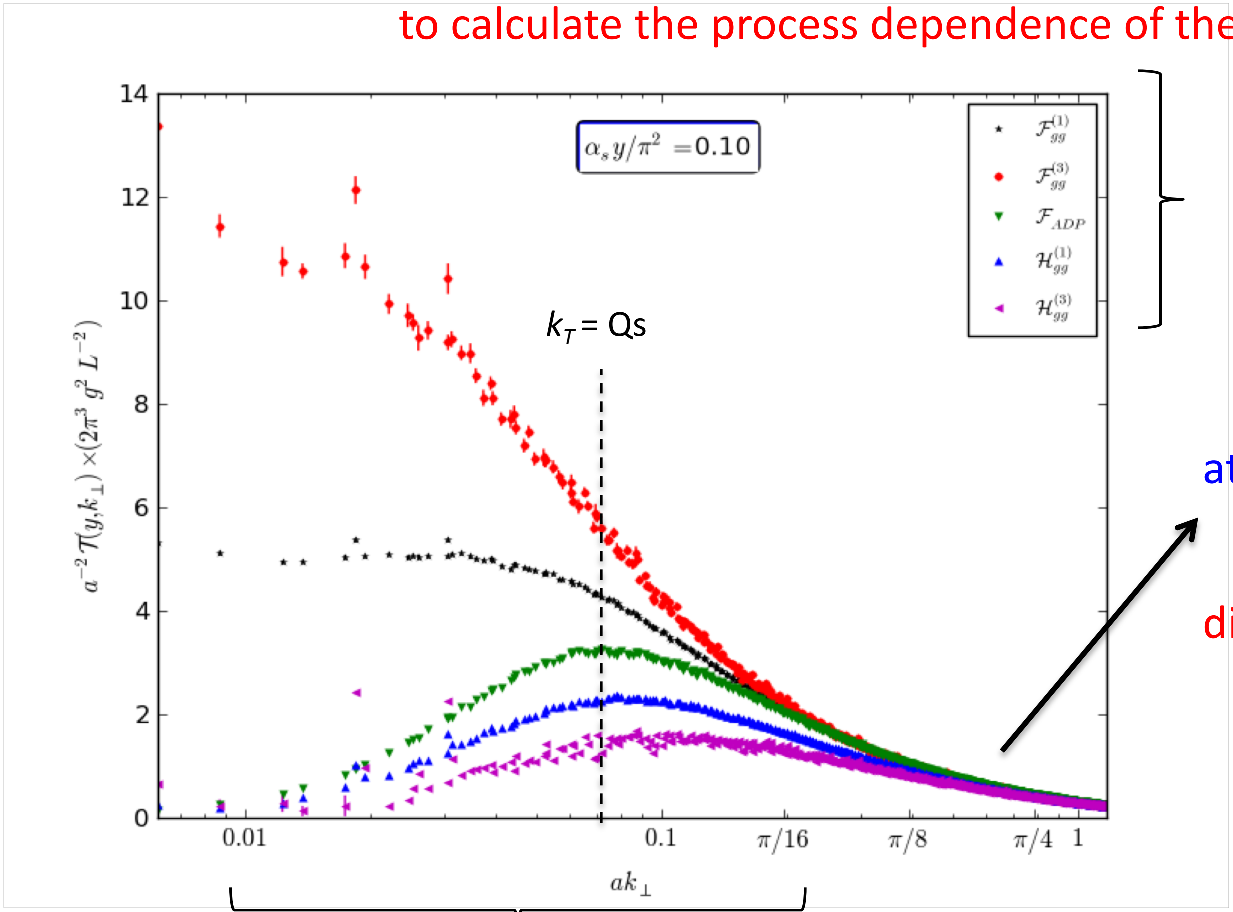
many aspects have been investigated, e.g:



[Lorcé, Moutarde, Trawinski, arXiv:1810.09837]

Gluon TMDs at small-x

in the small-x limit, the Color Glass Condensate can be utilized
to calculate the process dependence of the gluon TMDs



various gluon TMDs

Marquet, Petreska, Roiesnel (2016)

Marquet, Roiesnel, Taels (2017)

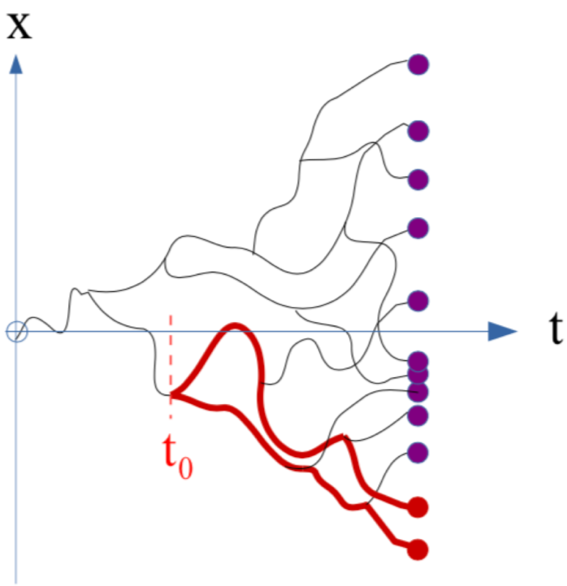
at large k_T :

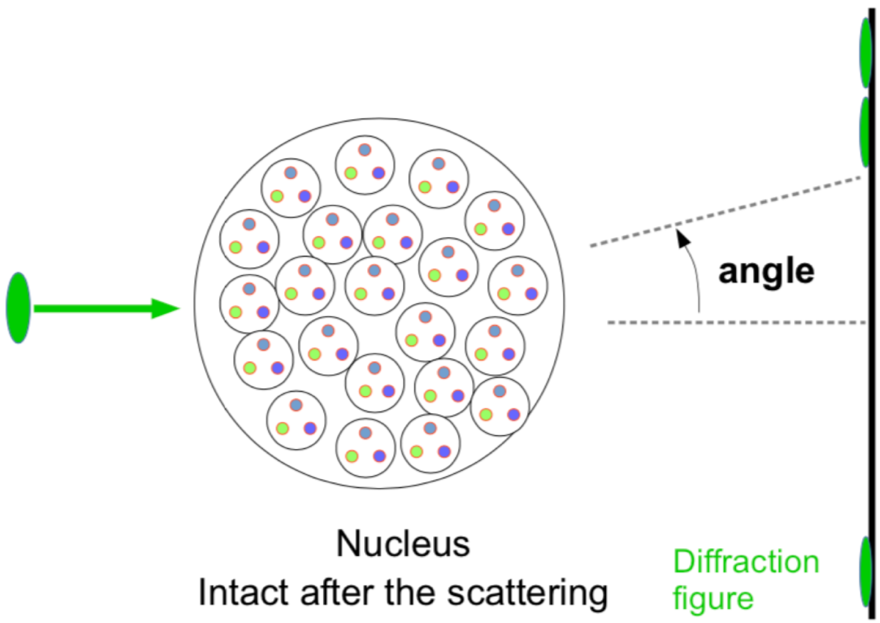
a universal distribution emerges

at small k_T : the process dependence is very relevant
saturation effects impact the various gluon TMDs in very different ways

Diffraction in e+A

the connections between parton evolution in QCD and statistical physics (branching random walks) can be exploited to predict the rapidity gap distribution





Distribution $p(t_0)$ of the coalescence times

~

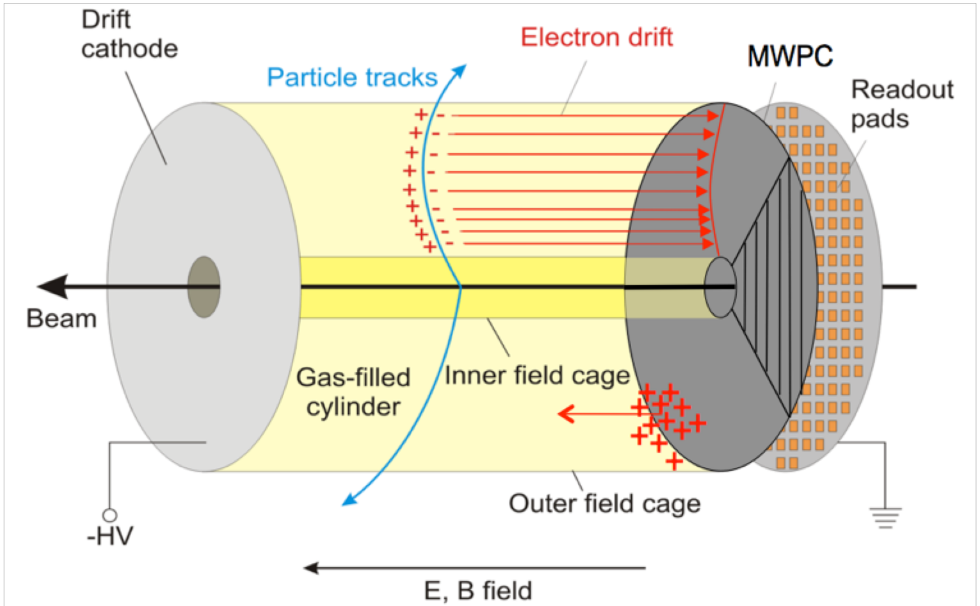
Distribution of the size of gaps void of particles in the final state of (e.g.) electron-nucleus scattering

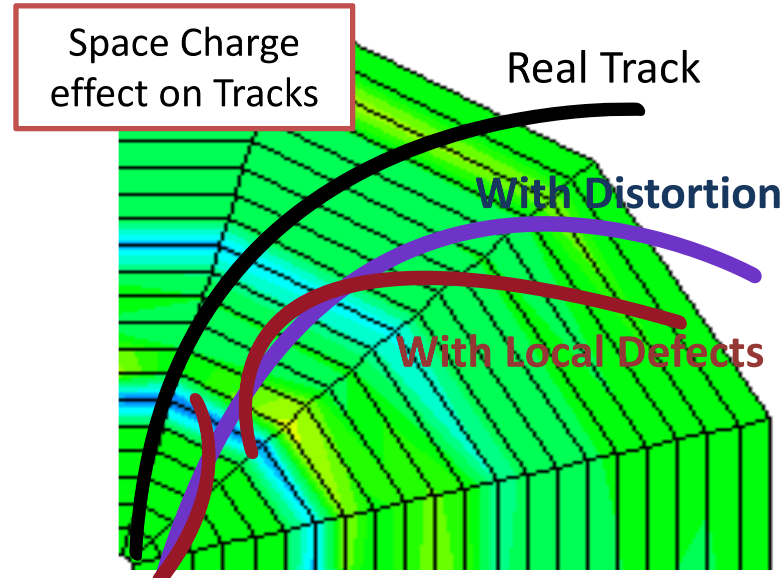
$$\frac{dp}{dt_0} = \frac{1}{\sqrt{4\pi}} \times \left[\frac{t}{t_0 (t - t_0)} \right]^{3/2}$$

Mueller, Munier, PRL (2018)

CEA Saclay Contributions

Distortions Within a Time Projection Chamber



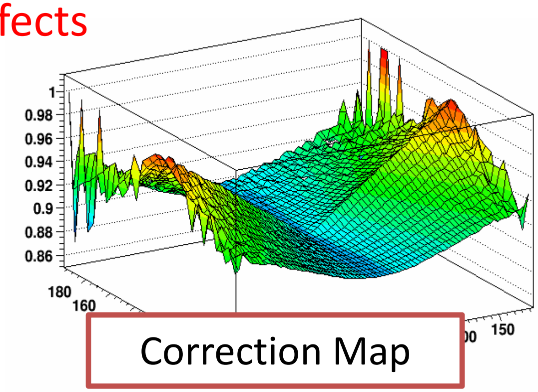


TPC readout plane (STAR)

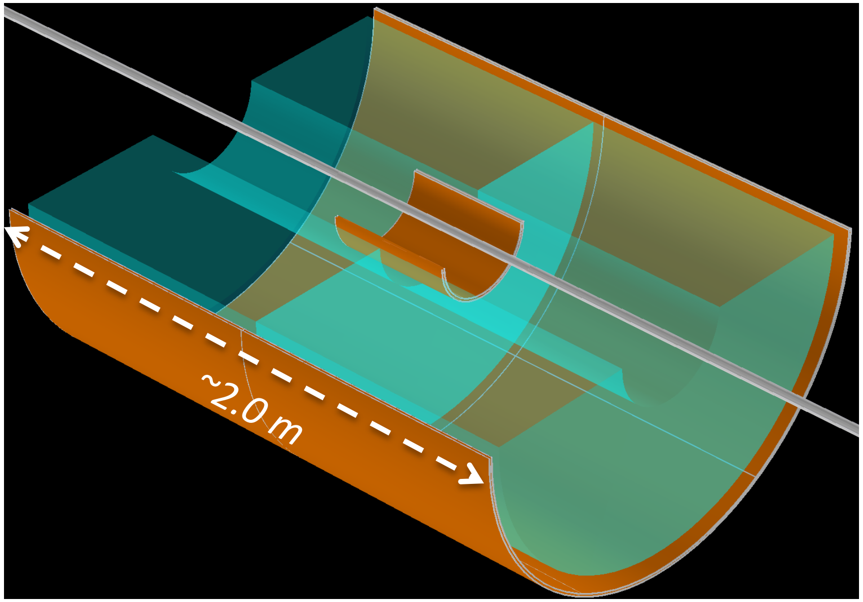
- The TPC active volume is *very* sensitive to several factors :
  - Temperature/Pressure/Gas => Drift velocity variations
  - Beam Type/Luminosity => Primary Ions
  - Gas Amplification => Ions Feedback

} Space charge effects

- A TPC monitor composed on cylindrical MM layers inside and outside of the TPC will help correct for :
  - Internal Distortions (Drift velocity + Space Charge)
  - Event pileup in the case Drift time>Time between Events



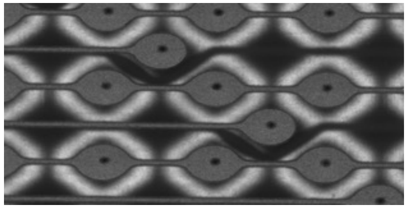
- 4 layers; technology-driven azimuthal and longitudinal segmentation
- 2D readout with ~100 μm spatial resolution

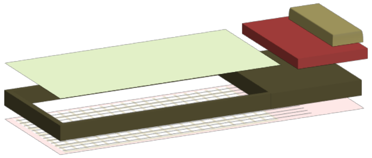


- Internal structure modeled according to the real-life prototypes
- ~0.5% X/X_0 per layer
- Potential early application in sPHENIX TPC

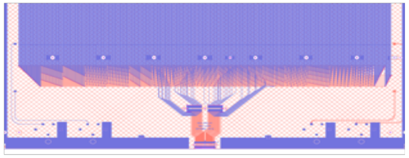
Orientation of CEA Saclay MPGD R&D towards an EIC

- Reduce material budget
  - → 2D detectors
  - → Lightweight detectors

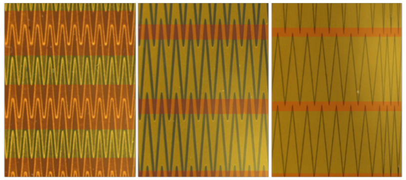




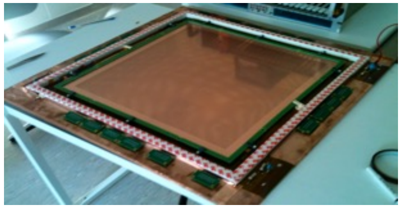
- Reduce number of electronics channels
  - → Genetic Multiplexing



- …while keeping high position resolution
  - → Zigzag R&D

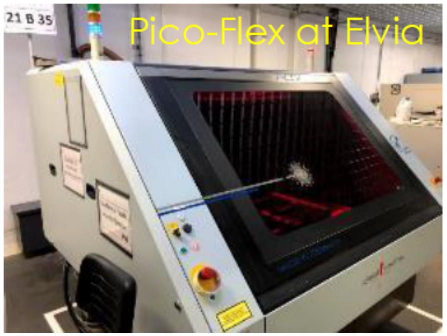


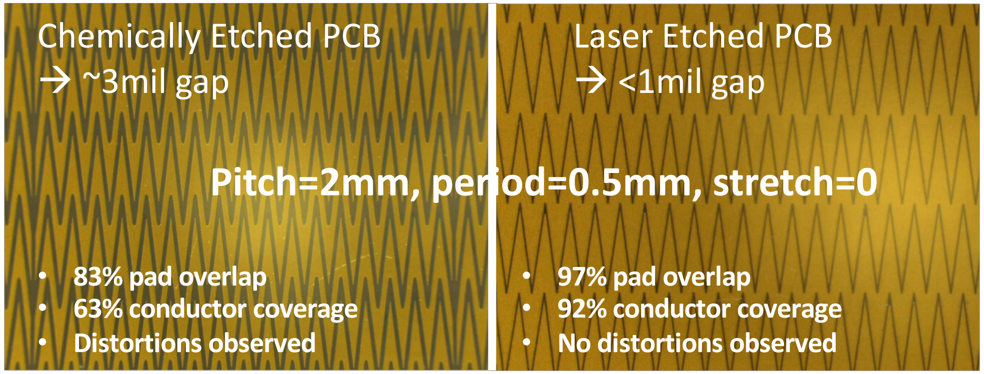
- Reduce ion backflow (for TPC readout mostly)
  - → Hybrid or double-mesh Micromegas



Focus on Zigzag LDRD with BNL

In October 2017: LDRD "MPGD-4-IEC" selected at BNL
1.2 M$ is obtain on 3 years
- 500 k$ for BNL
- **300 k$ for CEA Saclay <- Laser ablation R&D**
- 200 k$ for SBU



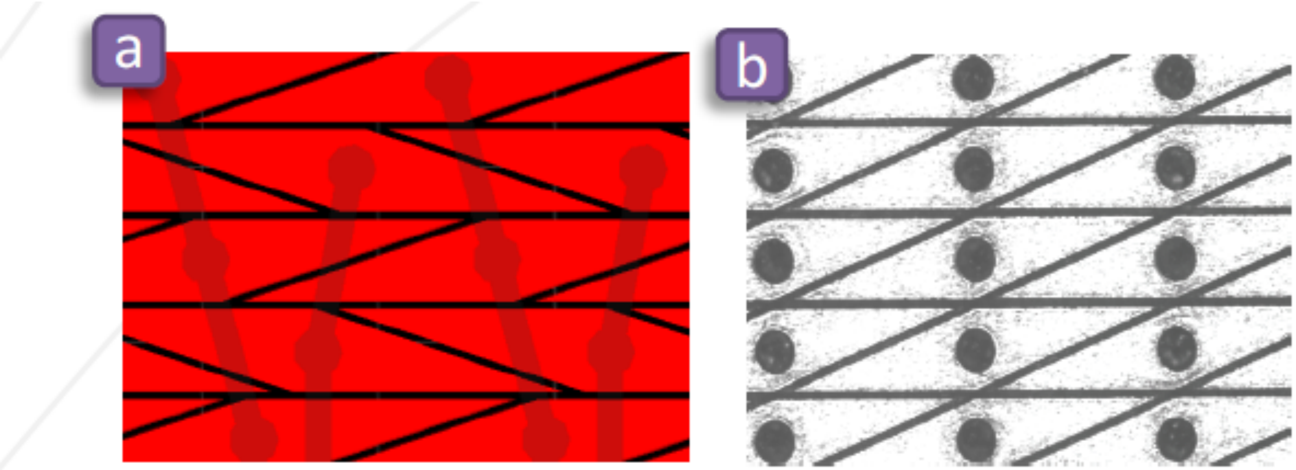


- **Clear trend in improved performance**
- Reduced the gap width, increased pad overlap, and increased the level of conductor

Beam tests at FNAL:

- Exposed several 4-GEM detectors equipped to ~1cm x 1cm 120GeV proton beam
- Studied multiple zigzag
- Also tested Micromegas(MM)+multi-ZZ, and GEM+MM+multi-ZZ
- ***ZZ design parameters have very significant impact on performance!***

ZZ pattern	1. Chemical Etch (un-optimized)	2. Chemical Etch (optimized)	3. Laser Etch (optimized, low gain)
pitch/period	2mm/0.5mm	2mm/0.56mm	2mm/0.5mm
Strip Overlap / Conductor coverage	40% / 66%	83% / 63%	87% / 90%
Gap width	82µm	84µm	22µm
Position Resolution / Efficiency due to removal of single pad hits	93µm (56% eff.)	70µm (99% eff.)	63µm (100% eff.)

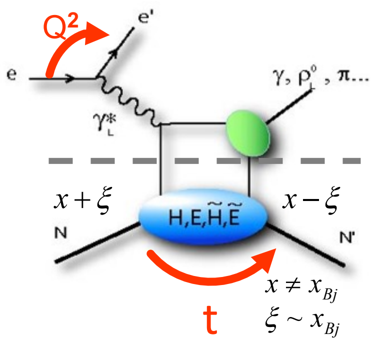


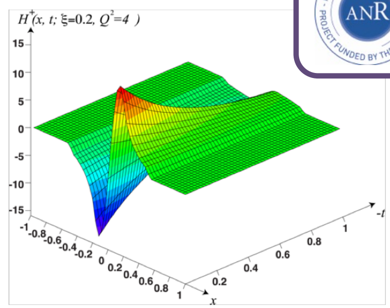
2D Zigzag strips : *Diamond design with Gerber view (a) and prototype board (b)*

For FNAL beam test plans for 2019:

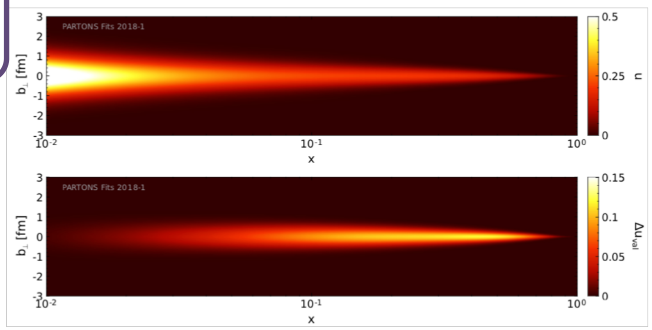
- Mechanics to hold 8 detectors on moving XY table (BNL)
- Readout + cables for 4096 channels with DREAM (Saclay)
- The board is the same for Micromegas and GEM !
  - 4 micromegas bulk with
    - 2D zigzag
    - Pillar study (how to remove pillars shadows on residual)
    - 1D zigzag with plain resistive layer !
  - 4 GEM

- Absolutely needed for analysis of Deep Exclusive Experiments (DVCS, DVMP, etc.)





Eur.Phys.J. C78 (2018) no.11, 890



- Project to extend it to TMD analysis as well (within European project)

- Co-organization of recent workshop in Warsaw :
  Prospects for extraction of GPDs from global fits of current and future data

IPN Orsay Contributions

(Slides from C. Munoz)

Ongoing R&D at IPNO on crystal calorimetry

IPNO joined the calorimetry consortium in 2014

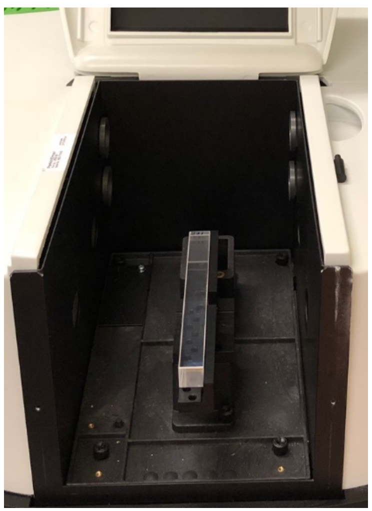
- Sci-fiber EM calorimeter (SPACAL)
- Crystal EMCal at small angle: high resolution and PID needed
- Shashlyk EMCal
- HCal
- Sensors
- Simulations

IPNO Contribution

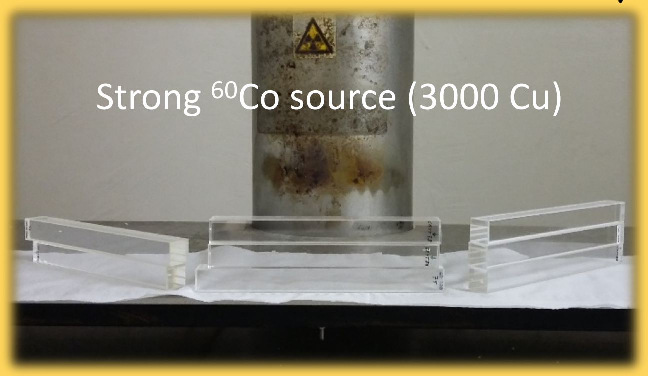
Possible future IPNO contribution

IPNO expertise in calorimetry: CLAS EC, HPS, PANDA…

$PbWO_4$ crystal caracterization at IPNO:



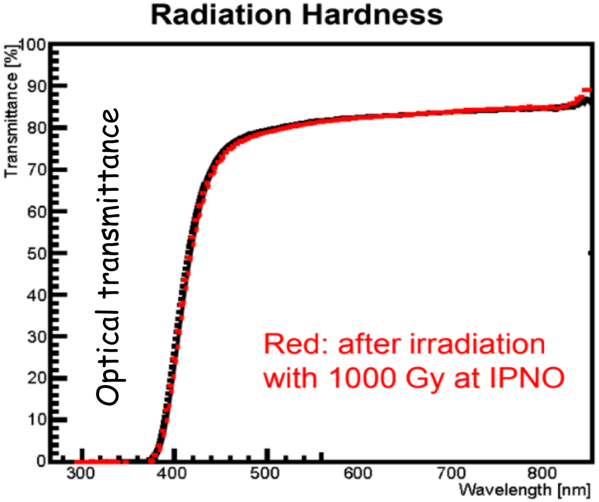
Radiation hardness measurements (in collaboration with LCP-Orsay)



Also: light yield measurements & uniformity using a ^{137}Cs source

Optical bleaching with blue LED

Also testing new glass scintillators developed at VSL/CUA

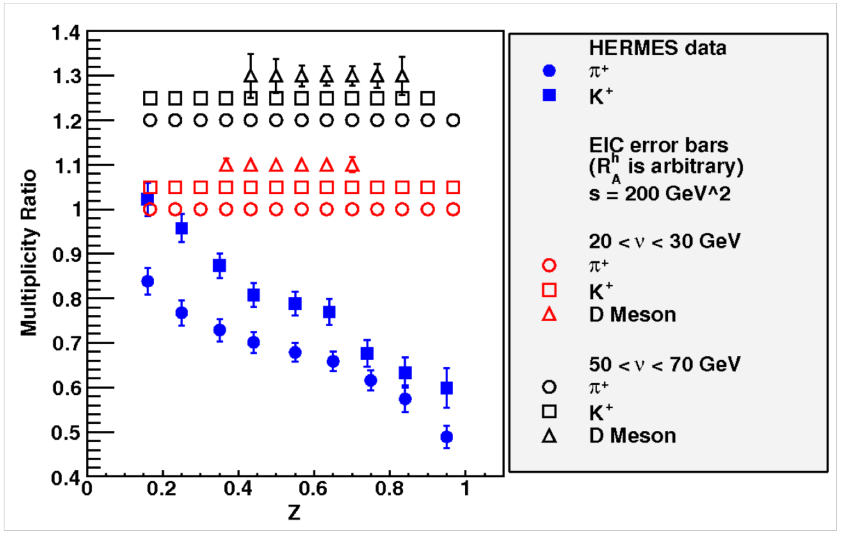


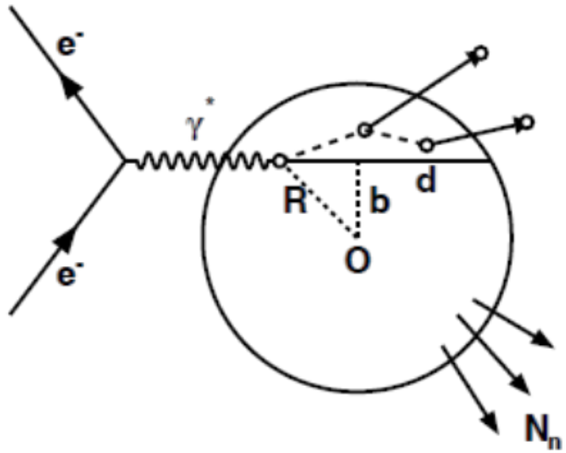
Hadronization at EIC: simulations

- Simulations & phenomenology
- Motivations for EIC:
  - First measurements of charmonia hadronization
  - Indirect access to saturation (interaction with nuclear matter is dominated by low energy gluons)
- Challenges:
  - High energy reduces the signal
  - High luminosity is key for quarkonia measurements
- Results published in 2 White Papers:

(ArXiv:1108.1713 and Eur.Phys.J. A52 (2016) no.9, 268)

Multiplicity ratio in Pb vs proton





Geometrical tagging:

- Impact parameter measurement
- Participation to a new working group at JLab (LDRD Geometry tagging)
- Motivations beyond hadronization (centrality dependence of nuclear effects, shadowing…)
- In synergy with developments for JLab CLAS12

European STRONG-2020 project

STRONG-2020 overview

10 M€ project for 4 years, starting on June 1st 2019

- 32 Work Packages
  - Management and Coordination
  - Dissemination and Communication
  - 7 Transnational Infrastructures (COSY, MAMI, ELSA, GSI, LNF, CERN, ECT*)
  - 2 Virtual Infrastructures
  - Experimental / Theoretical / Instrumentation Activities
    - 7 Networking Activities (NA)
    - 14 Joint Research Activities (JRA)

- 44 participating institutions
  - 16 countries: Austria, Belgium, Switzerland, Germany, Spain, Finland, France, Croatia, Ireland, Italy, Montenegro, The Netherlands, Poland, Portugal, Sweden and United Kingdom

STRONG-2020 content

List of STRONG2020 WP with direct relationship to EIC:

- VA1- A Virtual Access on Nucleon Structure (= PARTONS)

- NA2- Small-x Physics at the Large Hadron Collider and in new DIS experiments
- NA4- Proton Radius European Network

- JRA4- 3D structure of the nucleon in momentum space: opening the next stage
- JRA5- Generalized Parton Distributions
- JRA6- Challenges for Next-generation DIS facilities (PI: CEA Saclay & U Glasgow)
- JRA9- Tracking and Ions Identifications with Minimal Material budget
- JRA13- Polarized Electrons, Positrons and Polarimetry
- JRA14- Micro Pattern Gaseous Detectors for Hadron Physics

A lot of progress towards EIC science and detectors should be expected