PARTONS:

PARtonic **T**omography **O**n **N**ucleon **S**oftware

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(on behalf of PARTONS collaboration)

Meeting de lancement GDR QCD

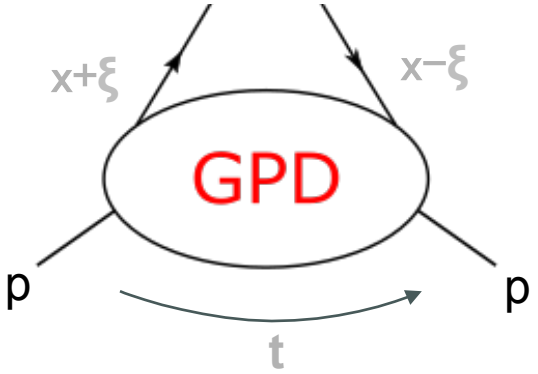
Outline

- Motivation
- Introduction to PARTONS
- Content and performance
- Summary

Motivations

General Partons Distributions

- GPDs are 3D functions describing partonic structure of nucleons
- Directly related to matrix elements of QCD energy-momentum tensor
- At twist-2 approximation there are four chiral-even functions for each parton, related to QCD operators by Fourier transform



$$H^{g,q}(x,\xi,t) \quad E^{g,q}(x,\xi,t)$$

$$\tilde{H}^{g,q}(x,\xi,t) \quad \tilde{E}^{g,q}(x,\xi,t)$$

Nucleon helicity conserved

Nucleon helicity changed

$$\frac{p^+}{4pi}\int dy^- \exp^{ixP^+y^-} < p'|\bar{\psi}_q(0)\gamma^+\psi_q(y)|p > |_{y^+=\vec{y}\perp=0} =$$

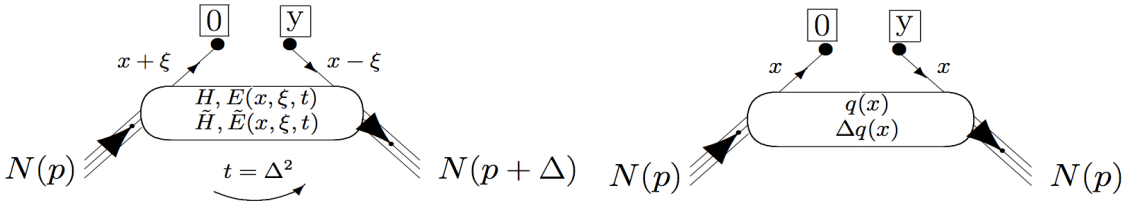
$$H^q(x,\xi,t)\bar{N}(p')\gamma^+N(p) + E^q(x,\xi,t)\bar{N}(p')i\sigma^{+\nu}\frac{\Delta_\nu}{2m_N}N(p)',$$

$$\frac{p^+}{4pi}\int dy^- \exp^{ixP^+y^-} < p'|\bar{\psi}_q(0)\gamma^+\gamma^5\psi_q(y)|p > |_{y^+=\vec{y}\perp=0} =$$

$$\tilde{H}^q(x,\xi,t)\bar{N}(p')\gamma^+\gamma^5N(p) + \tilde{E}^q(x,\xi,t)\bar{N}(p')\gamma^5\frac{\Delta^+}{2m_N}N(p)'$$

Motivations

They're related to known objects:



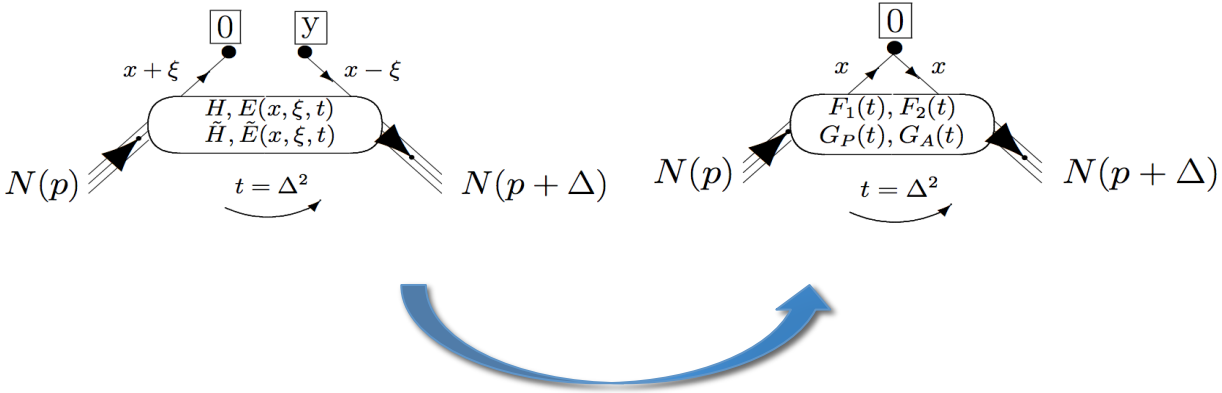
$$H^q(x,0,0) = \begin{cases} q(x), & x > 0, \\ -\bar{q}(-x), & x < 0. \end{cases}$$

$$\tilde{H}^q(x,0,0) = \begin{cases} \Delta q(x), & x > 0, \\ \Delta\bar{q}(-x), & x < 0. \end{cases}$$

Forward Limit

GPDs "contain" the Parton Distribution Functions probed in DIS experiments

Motivations



$$\int_{-1}^{+1} dx H^q(x,\xi,t) = F_1^q(t)\,, \qquad \int_{-1}^{+1} dx E^q(x,\xi,t) = F_2^q(t)\,,$$

$$\int_{-1}^{+1} dx \tilde{H}^q(x,\xi,t) = G_A^q(t)\,, \qquad \int_{-1}^{+1} dx \tilde{E}^q(x,\xi,t) = G_P^q(t)$$

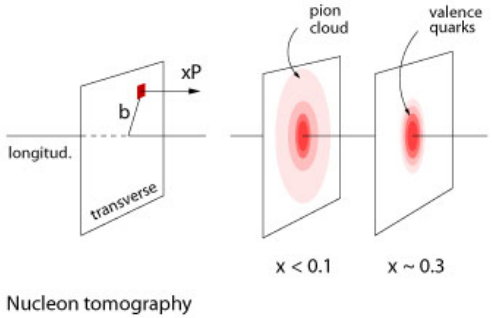
Model independent Sum Rules relate GPDs to Elastic Form Factors

Motivations

GPDs hold other precious information…

- NUCLEON TOMOGRAPHY

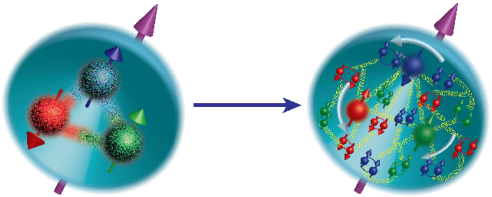
$$H^q(x, \mathbf{b}_\perp) = \int \frac{d^2\boldsymbol{\Delta}_\perp}{(2\pi)^2} e^{-i\mathbf{b}_\perp \cdot \boldsymbol{\Delta}_\perp} H^q(x, 0, -\boldsymbol{\Delta}_\perp{}^2)$$



Nucleon tomography

- TOTAL ANGULAR MOMENTUM

$$J_q = \frac{1}{2} \int_{-1}^{+1} dx\, x\, [H^q(x, \xi, t = 0) + E^q(x, \xi, t = 0)]$$

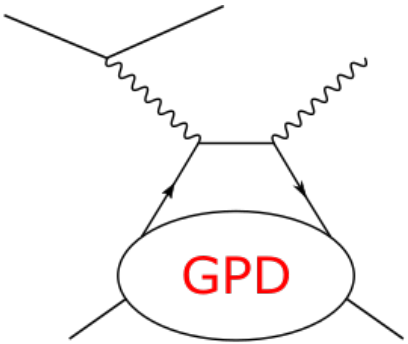


They can help to solve the proton spin crysis

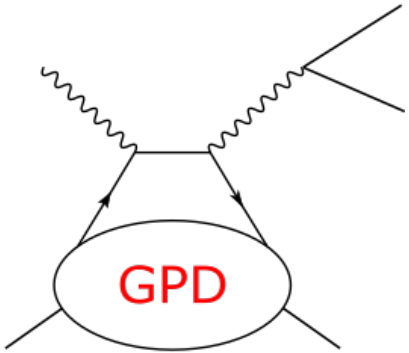
Motivations

GPDs describe (and are studied in) various experimental channels:

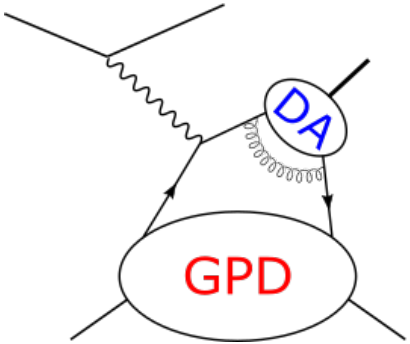
DVCS



TCS



HEMP

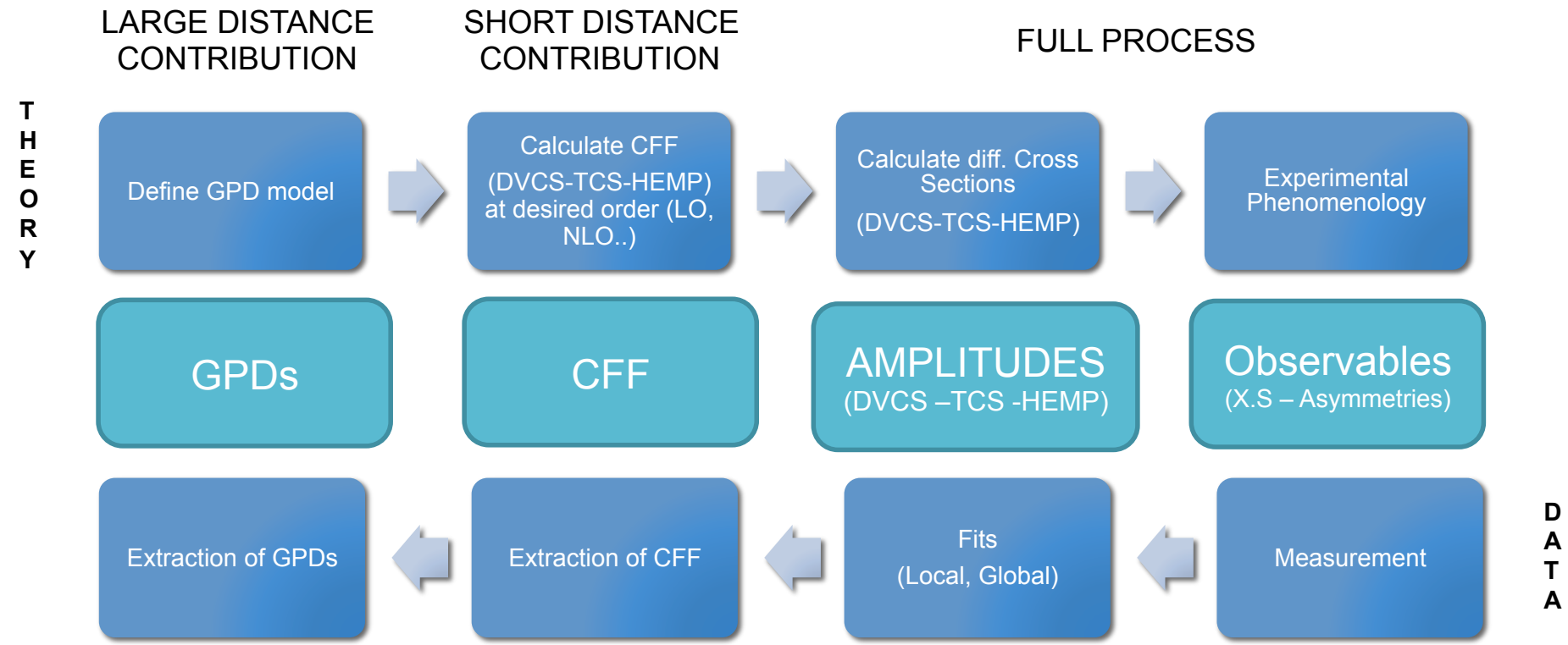


Motivations

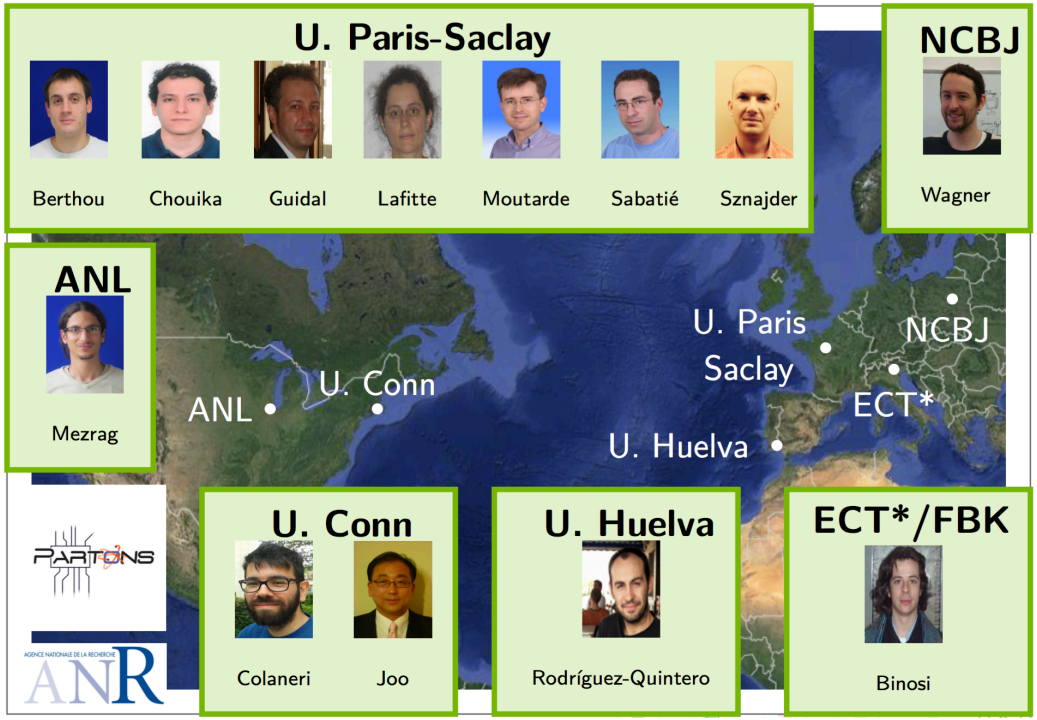
Studied in many experiments

- Available data
  - Jlab: HallA , CLAS
  - HERMES
  - HERA
  - COMPASS
- Future experiments
  - JLab12
  - EIC

Motivations



PARTONS Collaboration



- Automation
- Accuracy
- Modularity
- Speed
- User friendly
- Fits

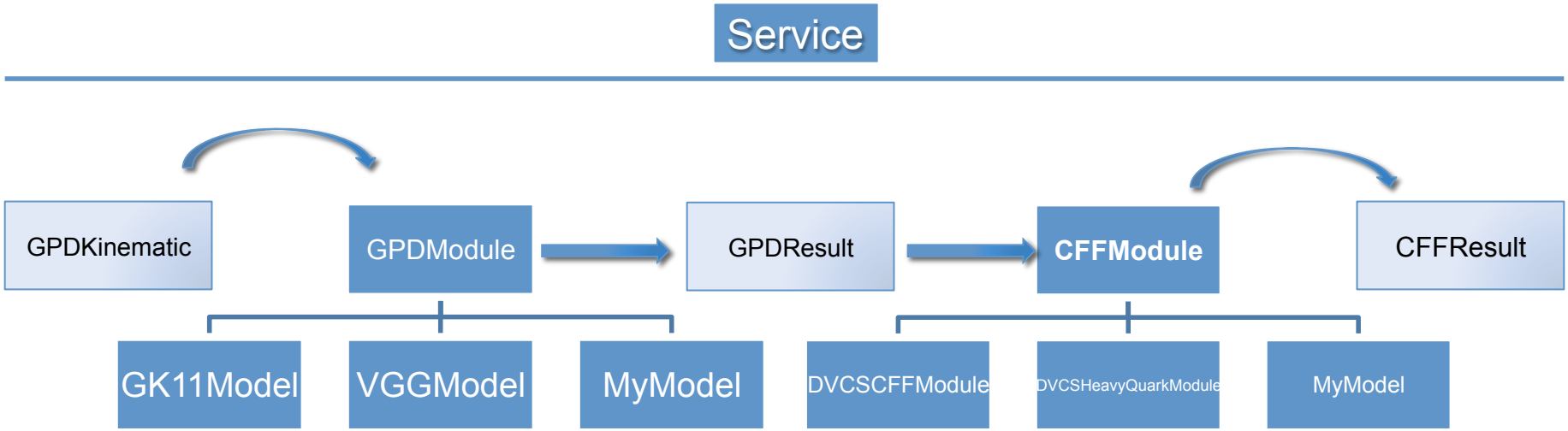
PARTONS Project

Layered structure

- Each layer is a collection of objects (modules) with the same purpose
- Each module contains one physical development
- Operation on modules and between layers performed by Services

```
GPDResult computeGPDModel
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule) const;
GPDResult computeGPDModelRestrictedByGPDType
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule,
        GPDType::Type gpdType) const;
GPDResult computeGPDModelWithEvolution
        (const GPDKinematic& gpdKinematic, GPDModule* pGPDModule,
        GPDEvolutionModule* pEvolQCDModule) const;
...
```

PARTONS Project



- Each module has standardized input and output
- C++ objects, inheritance, polymorphism..
- Easy to “plug in” new module
- Easy to study new phenomenology!!

PARTONS Project

It can be used via the C++ interface…

```
// Retrieve GPD service
GPDService* pGPDService =
                Partons::getInstance()->getServiceObjectRegistry()->getGPDService();
// Load GPD module with the BaseModuleFactory
GPDModule* pGPDModel =
        Partons::getInstance()->getModuleObjectFactory()->newGPDModule(GK11Model::classId);
// Create a GPDKinematic(x, xi, t, MuF, MuR) to compute
GPDKinematic gpdKinematic(0.1, 0.00050025, -0.3, 8., 8.);
// Compute data and store results
GPDResult gpdResult = pGPDService->computeGPDModel(gpdKinematic, pGPDModel, List<GPDType>());
// Print results
std::cout << gpdResult.toString() << std::endl;
```

PARTONS Project

…or XML interface (doesn't even require compilation!)

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>
<scenario date="2016-03-25" description="Example : computation of one GPD model (GK11) without evolution">
  <task service="GPDService" method="computeGPDModel" storeInDB="0">
      <kinematics type="GPDKinematic">
         <param name="x" value="0.1" />
         <param name="xi" value="0.00050025" />
         <param name="t" value="-0.3" />
         <param name="MuF2" value="8" />
         <param name="MuR2" value="8" />
      </kinematics>
      <computation_configuration>
         <module type="GPDModule">
            <param name="className" value="GK11Model" />
         </module>
     </computation_configuration>
   </task></scenario>
```

PARTONS Project

DATABASE

- Result computed by each layer can be stored/retrieved from database

```
// Retrieve GPD DAO service
GPDResultDaoService gpdResultDaoService;

// Insert
int computationId = gpdResultDaoService.insert(gpdResult);

// Retrieve
List<GPDResult> gpdList = resultService.getGPDResultListByComputationId(computationId);
```

- MySQL support
- Optimized for large transactions
- Database also to store experimental data → Fits

PARTONS Project

Validation..

- We put a lot of effort in the *validation* of every module
  - All existing modules have been tested reproducing published results or results obtained with Mathematica
  - Benchmark results stored in Database
- ..Non-Regression…
  - After every manipulation of the code, all module are re-tested and results compared with validated ones in database
- ..Debug

PARTONS Project

Existing modules

- GPDs
  - GK
  - VGG
  - MPSSW13
  - MMS13
  - Vinnikov
- Evolution
  - Vinnikov code
- CFFs (DVCS only)
  - LO
    - Light Quaks
  - NLO
    - Light Quarks and gluons
    - Light Quarks, Heavy Quarks and gluons
- Cross Section (DVCS only)
  - VGG
  - BMJ
  - GV
- Observables
  - Alu
  - Aul
  - Ac
  - All
  - Fourier moments
  - …
- Running coupling
  - 4-loop PDG expression
  - Constant value

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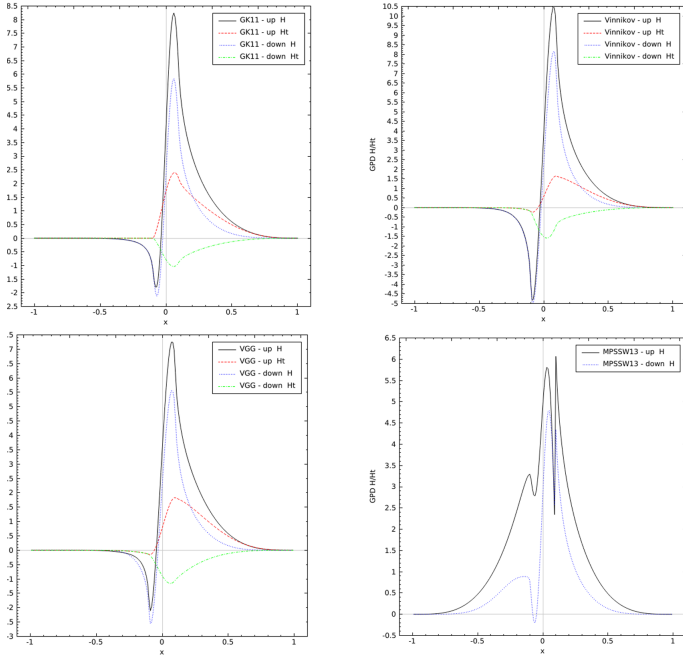
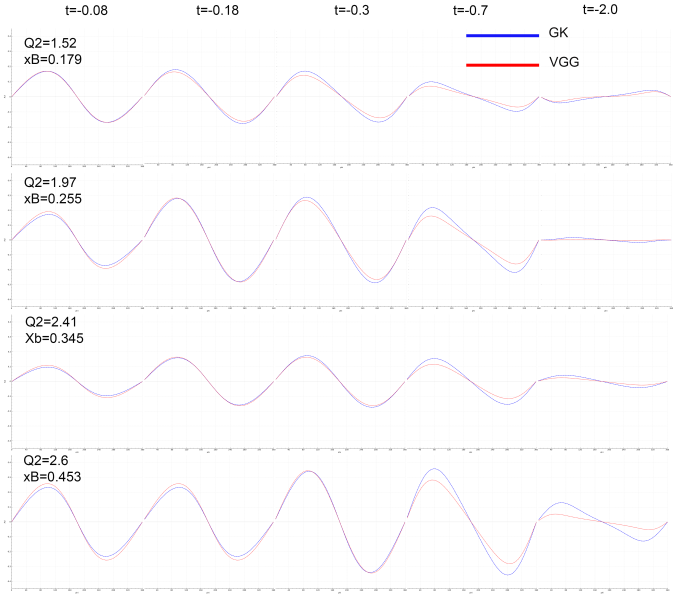


GPDs comparison



Target-spin asymmetry

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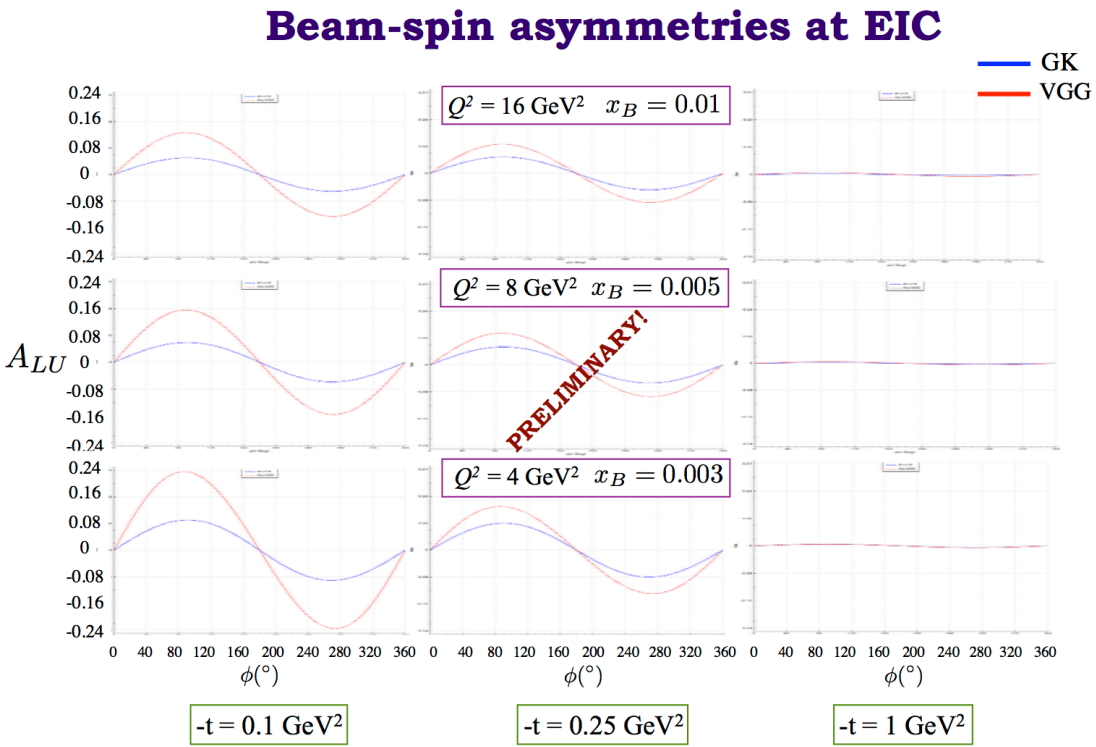
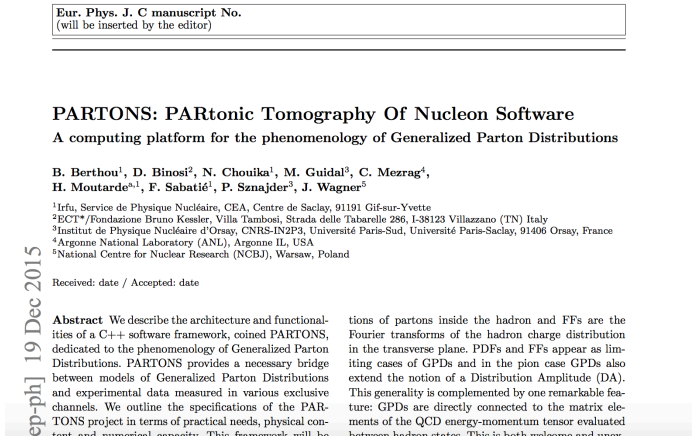


PARTONS Project

Future developments

- FITS
  - Local and Global fits of CFF
- Phenomenology of DVCS at EIC
  - Higher-order effects in α_S
  - Contribution of heavy flavors.
- Modeling of GPDs
  - Gap and Bethe-Salpeter equations.
  - Light Front Wave Functions.



Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

PARTONS: PARtonic Tomography Of Nucleon Software

A computing platform for the phenomenology of Generalized Parton Distributions

B. Berthou[1], D. Binosi[2], N. Chouika[1], M. Guidal[3], C. Mezrag[4], H. Moutarde[a,1], F. Sabatié[1], P. Sznajder[3], J. Wagner[5]

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Received: date / Accepted: date

Abstract We describe the architecture and functionalities of a C++ software framework, coined PARTONS, dedicated to the phenomenology of Generalized Parton Distributions. PARTONS provides a necessary bridge between models of Generalized Parton Distributions and experimental data measured in various exclusive channels. We outline the specifications of the PARTONS project in terms of practical needs, physical content and numerical capacity. This framework will be

tions of partons inside the hadron and FFs are the Fourier transforms of the hadron charge distribution in the transverse plane. PDFs and FFs appear as limiting cases of GPDs and in the pion case GPDs also extend the notion of a Distribution Amplitude (DA). This generality is complemented by one remarkable feature: GPDs are directly connected to the matrix elements of the QCD energy-momentum tensor evaluated between hadron states. This is both welcome and unex-

arXiv:1512.06174v1

PARTONS Project

Summary

- GPDs hold keys to proton structure and they are explored in many experiments

- PARTONS is software for GPDs phenomenoly about to be released (DVCS channel only)
  - Designed to be as automated as possible
  - Modular
  - To allow systematic and differential studies

- Expected in 2016
  - Study of DVCS Observables at EIC kinematics
  - Local and global fits of CFFs
  - Release of the code