Quark Gluon Plasma within QCD framework

Contributors (LPSC/LAPTH):

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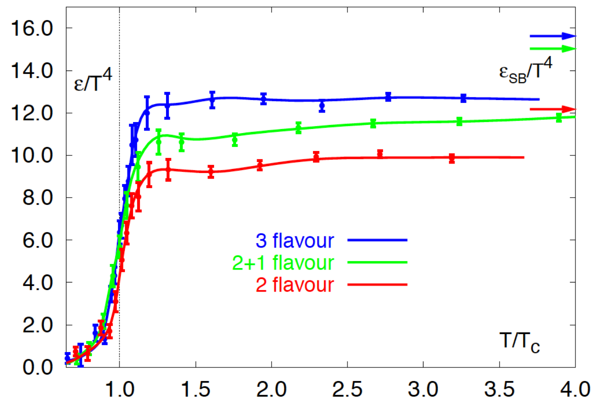
Quark-gluon Plasma is high density deconfined matter, which is produced in Pb-Pb collision at LHC. Its understanding requires:

- to apply particle physics to a system of finite size, complex (large number of constituents) and in dynamical evolution.
- To reconciliate the macroscopic and microscopic views of QGP in the QCD framework :
  - Soft probes (< 3-4 GeV) allow to access to macroscopic/collective properties: EOS, phase diagram, viscosity.
  - Hard probes (>10 GeV) allow to study energy loss within QGP and is sensitive to strong interaction at the partonic level.

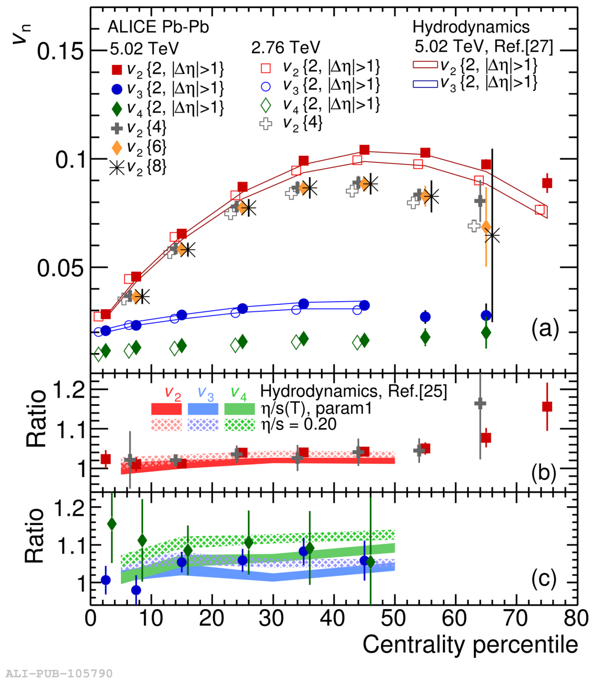
This can be done by:

- Precise measurements of various observables and experimental comparison of different systems like A-A and p-p (but also p-A) to quantify the effect of QGP.
- Theoretical understanding of the baseline systems (p-p and p-Pb) and a dynamical description of A-A collisions: precise QCD calculations and hydrodynamical models.

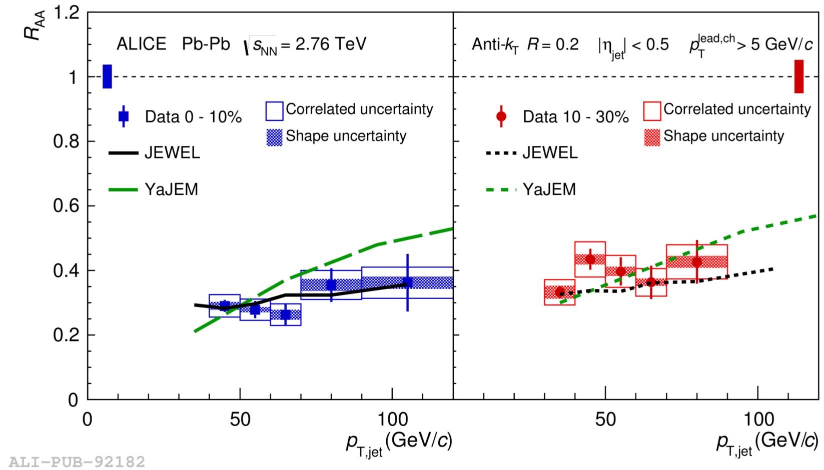
Exp. data versus theor. predictions



Hadrons-QGP phase transition as predicted by Lattice QCD

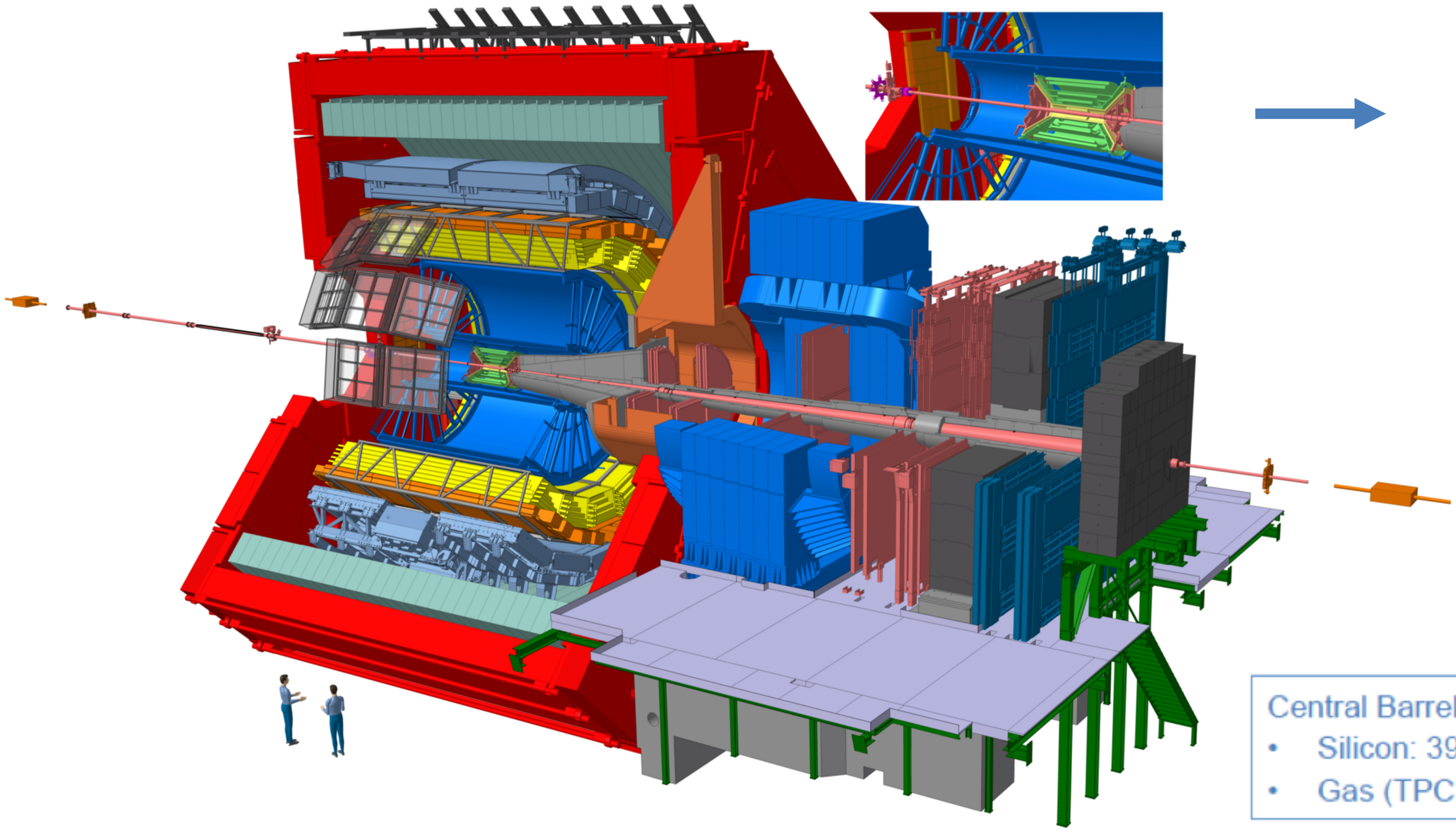


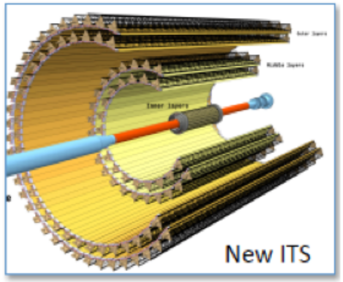
Exp. viscosity (η/s) compatible with a strong coupling (QFT calculations)



Jet quenching (R_AA) compared to pQCD based energy loss models

Upgrade d'ALICE run 3&4





Readout rate is currently limited by TPC and ITS (SDD)

~ 1kHz for Pb-Pb

Central Barrel Tracking
- Silicon: 39 – 430 mm
- Gas (TPC, TRD): 88 – 368 cm

- **HL-LHC runs 3+4: > 10 nb^{-1} (x10 luminosity compared to runs 1+2)**
- New electronics (TPC, TOF, TRD, Muon spectro…) + New DAQ & HLT (**50 kHz Pb-Pb**, O2 project)
- New detectors: ITS (Internal Tracking System) and MFT (Muon Forward tracking)

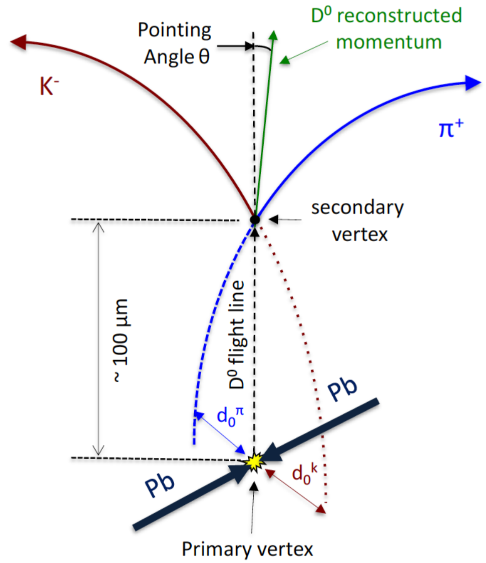
LPSC involvement (past and future):

- Electromagnetic calorimeter (assembly, energy calibration, Level 1 trigger, reconstruction+analysis); ITS upgrade (mechanical tools); DAQ and Trigger upgrade (**O2 project**)

LPSC strategy for run3 & 4

General ALICE upgrade:

- Strategy:
  - High tracking efficiency and high resolution at low pT
  - High statistics (x10) using minimum-bias data sample
  - Preserve excellent particle ID capabilities
- Physics topics:
  - Heavy flavour and quarkonia at very low pT
  - Vector mesons and low mass di-leptons
  - Jets measurements to lower pT
  - High precision measurement of light nuclei and hypernuclei

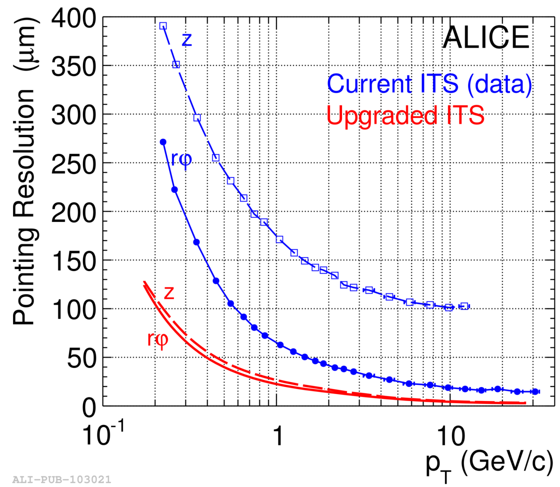


LPSC/ ALICE project:

- Inclusive jets, jet-jet and photon-hadron/jet correlation measurements using combined information of EM calorimetry and ITS

  → parton fragmentation related observables and allow to study in-medium modification of parton energy loss and energy redistribution at relatively low pT
- Development of new b-tagging methods for heavy flavour identification in jets:

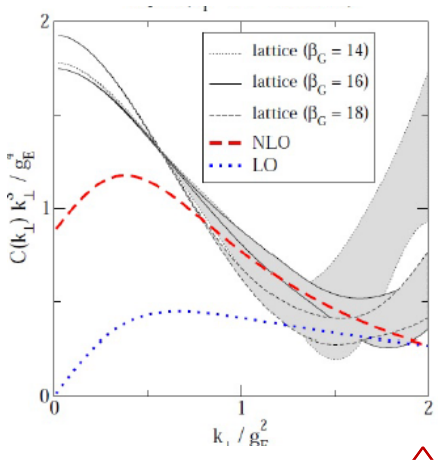
  → allow to study quark flavor dependence of energy loss in QGP: test dead cone effect prediction



Item 1: Jets physics

Physics motivations:

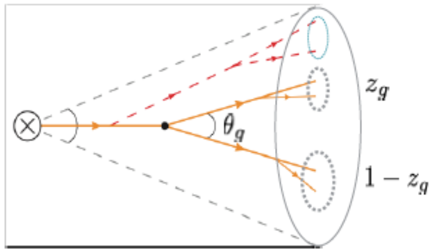
- Explore jet-medium interaction at the partonic level.
- Study the modification of the jet structure due to medium induced radiation (energy redistribution)
- Understand the fundamental QCD dynamics and showering in vacuum and in medium (Jet-medium interaction is expressed in terms of $\hat{q}$, which is the transferred momentum per length)



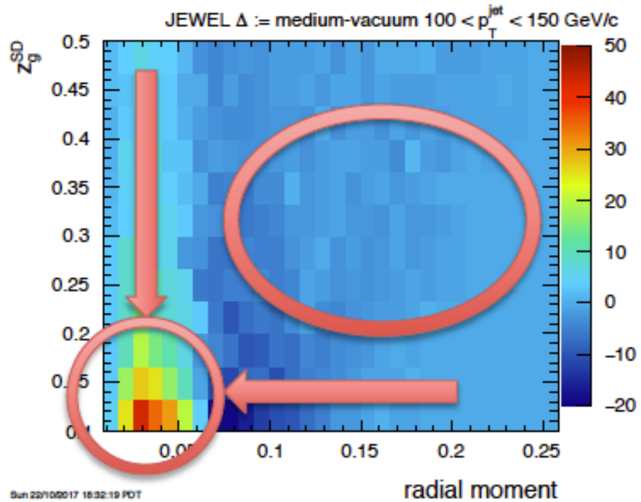
Collision kernel for $\hat{q}$ calculation

Experimental observables:

- Jet inclusive RAA, photon/hadron+Jet coincidences (Jet pT distribution), profile distribution
- Jet Fragmentation functions for inclusive and photon-hadron/jet correlations
- Jet sub-structure (N-subjettiness, Delta_R, Z_g, radial moment)
- Need more accurate modeling of jet observables



Jet substructure

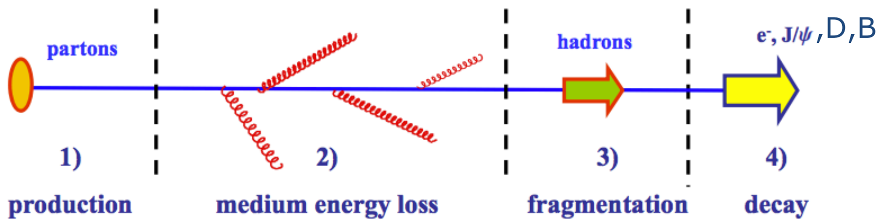


Z_g versus radial moment

Item 2: Heavy flavour

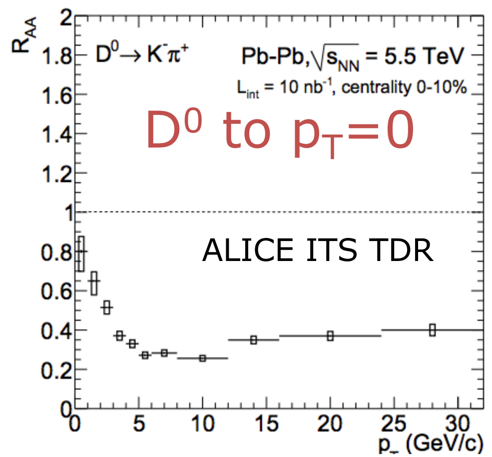
Heavy quarks are excellent probes of QGP

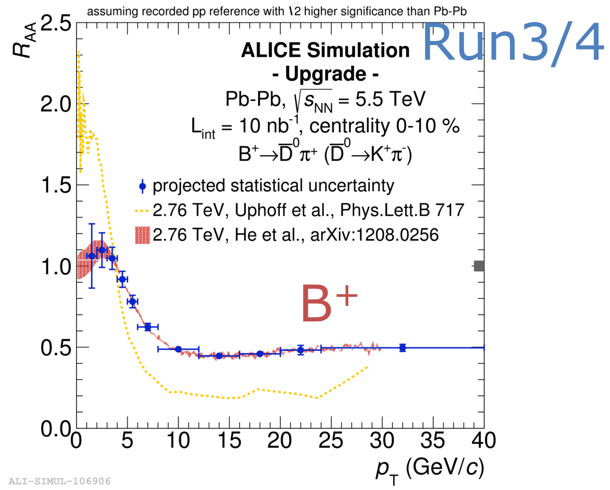
- Act as ‘calibrated’ probe of the QGP
    - Production can be calculated from pQCD
    - Experience full space-time evolution of the system
    - Quark number conserved
- Measure heavy-quark transport properties
- Allow to study collisional vs radiative energy loss and quark flavor dependence of energy loss in QGP



Physics observables for runs 3+4 :

- Transport properties of the medium: HF elliptic flow, R_{AA}
- Hadronization mechanisms :
    - baryon-to-meson ratios (Λ_C/D, Λ_b/B), strange mesons (D_S)
- Total cross sections w.r.t pp collisions R_{AA} down to p_T=0
- Redistribution of energy, modified fragmentation
    - HF jets (b-jets, c-jets) and correlations (D-hadron, B-hadron..)
- ..Plus smaller systems
    - Heavy-flavour production as a function of multiplicity

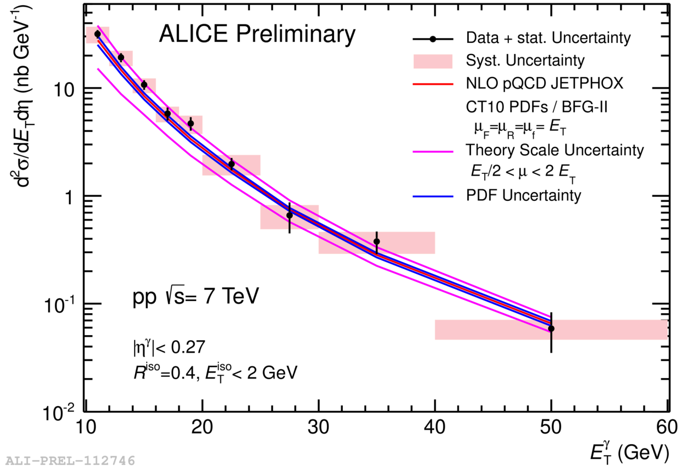




QCD related framework

p-p collisions:

- Accurate predictions for charged particle, photon, photon/hadron-jet and heavy quark production
- Constraints on non perturbative fragmentation functions
- Several QCD calculations availables: DIPHOX/JETPHOX and GM-VFNS



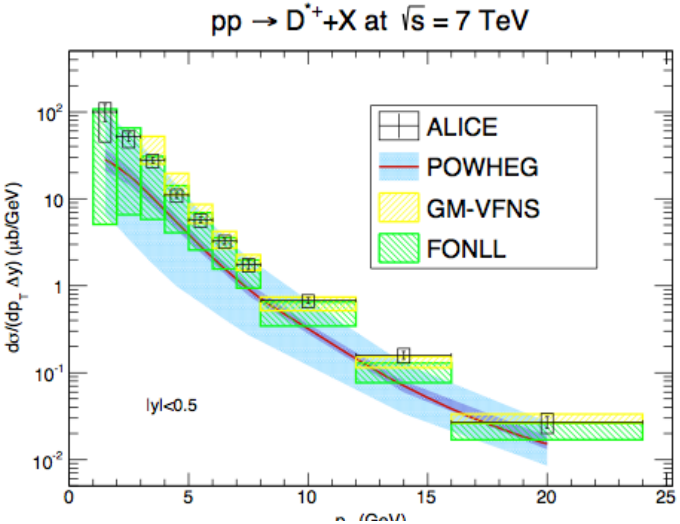
Isolated photon production (comparison with JETPHOX)

p-Pb collisions:

- Constraints of non perturbative nuclear PDFs (nCTEQ) using LHC data. Explore small x gluon nPDF. Use HF and charmonium data.
- Predictions for di-jets production and RpA attenuation factor.

Pb-Pb collisions:

- New QDC based energy loss models can provide some insights on jet quenching: energy dependence, size effect, flavour dependence, etc …
- Several approaches to be compared: pQCD, Mcarlo, etc …



Comparison of inclusive D-meson production with GM-VFNS

…

QCD related framework

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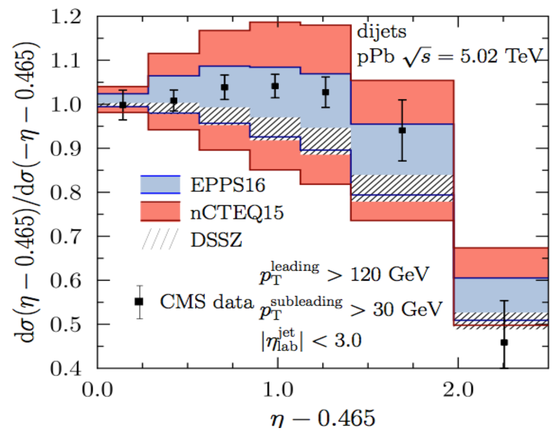
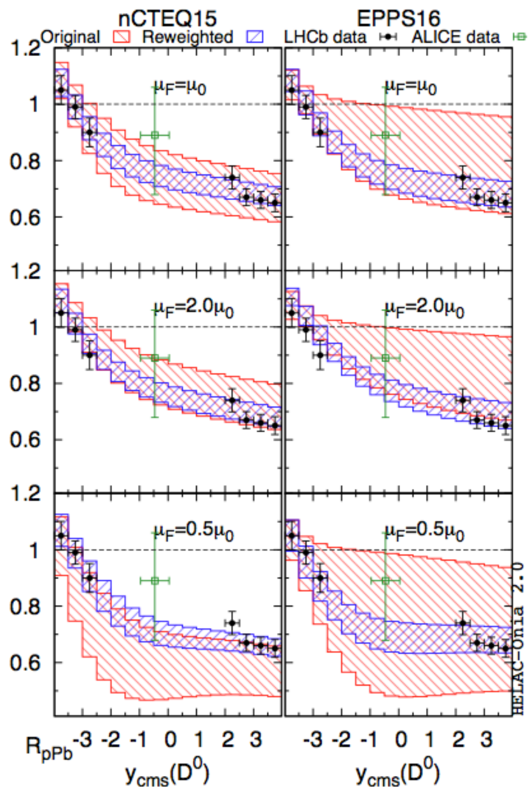


Predictions for di-jet production



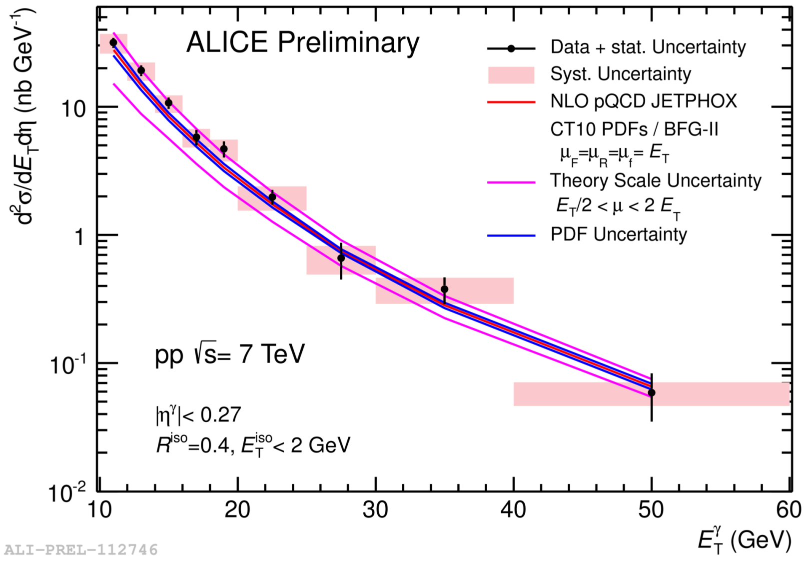
Predictions for RpA(D0) vs rapidity

Running schedule

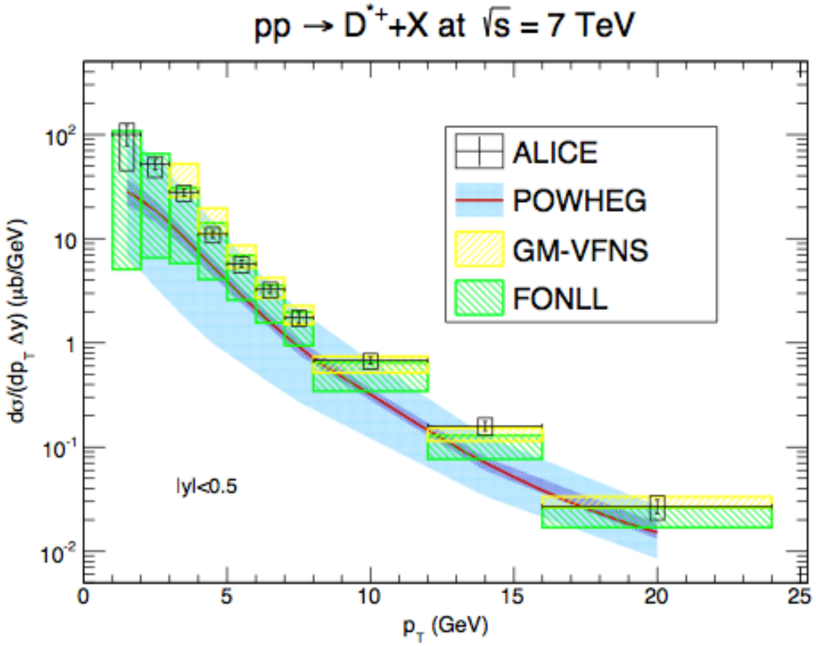
- Requirements (LOI):
  - Pb-Pb: 10/nb @0.5T + 3/nb @0.2T
  - pp 5.5 TeV: 6/pb (4e11 MB)
  - p-Pb: 50/nb
    - x150 pPb5 2016
- LOI: programme organised in 3+3 years in Runs 3 and 4 assuming:
  - Pb-Pb @ 50 kHz
  - p-Pb @ 200 kHz
  - pp @ 200 kHz
- pp 14 TeV introduced in O^2 TDR
  - Few weeks per year
  - ~2.5/pb min bias (~1.5e11 events)
  - Main limit by computing capacity

Year	System	$\sqrt{s_{NN}}$ (TeV)	L_{int} pp: (pb^{-1}) p–Pb: (nb^{-1}) Pb–Pb: (nb^{-1})	$N_{collisions}$
2021	pp	14	0.4	$2.7 \cdot 10^{10}$
	Pb–Pb	5.5	2.85	$2.3 \cdot 10^{10}$
2022	pp	14	0.4	$2.7 \cdot 10^{10}$
	Pb–Pb	5.5	2.85	$2.3 \cdot 10^{10}$
2023	pp	14	0.4	$2.7 \cdot 10^{10}$
	pp	5.5	6	$4 \cdot 10^{11}$
2027	pp	14	0.4	$2.7 \cdot 10^{10}$
	Pb–Pb	5.5	2.85	$2.3 \cdot 10^{10}$
2028	pp	14	0.4	$2.7 \cdot 10^{10}$
	Pb–Pb	5.5	1.4	$1.1 \cdot 10^{10}$
	p–Pb	8.8	50	10^{11}
2029	pp	14	0.4	$2.7 \cdot 10^{10}$
	Pb–Pb	5.5	2.85	$2.3 \cdot 10^{10}$

Predictions from JETPHOX and GM-VFNS



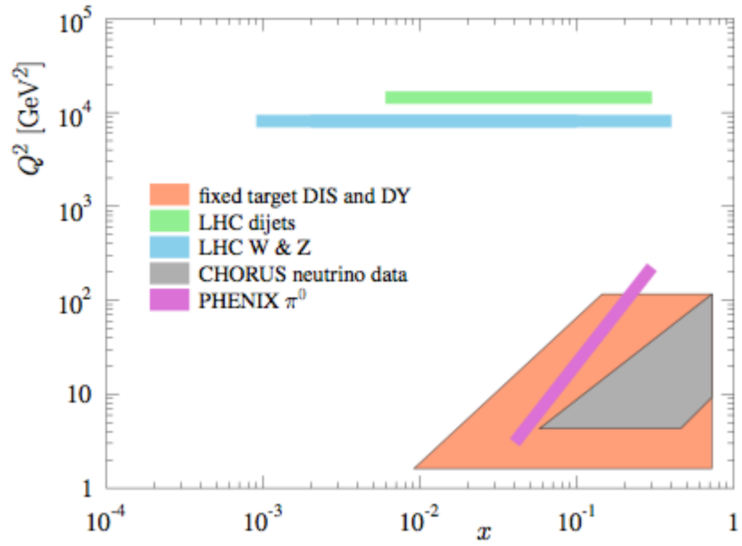
Isolated photon (comparison with JETPHOX)



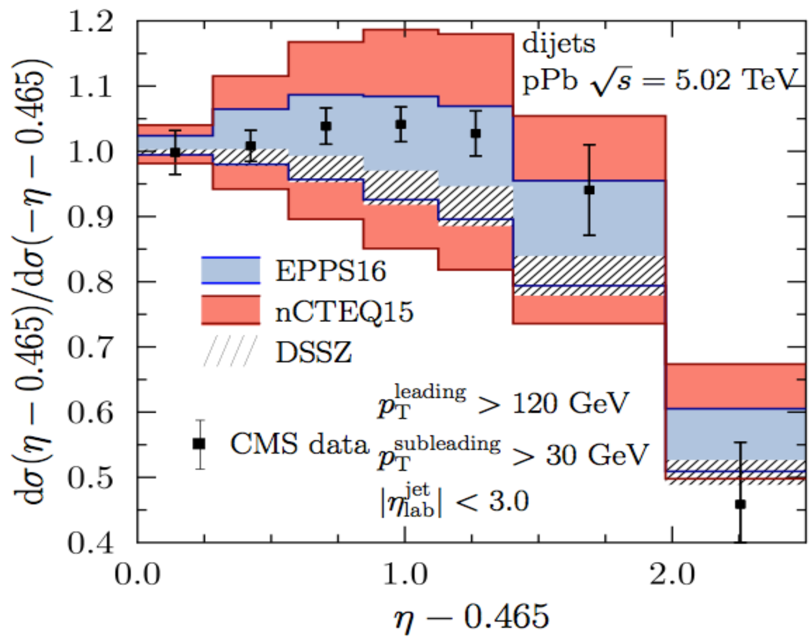
Inclusive D-meson production at ALICE (1405.3083)
Comparison with GM-VFNS and other codes

State-of-the-art nuclear PDFs needed

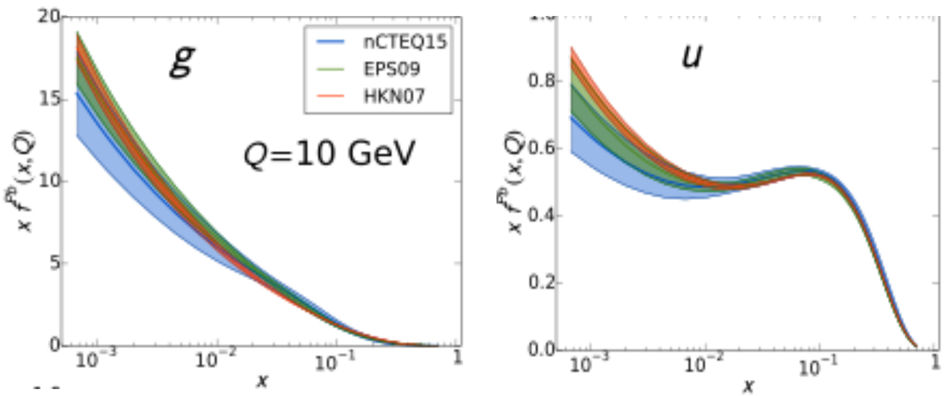
Data used in global analyses of nPDFs



Predictions for di-jet production
(Note that EPPS16 has been fitted to these data.)

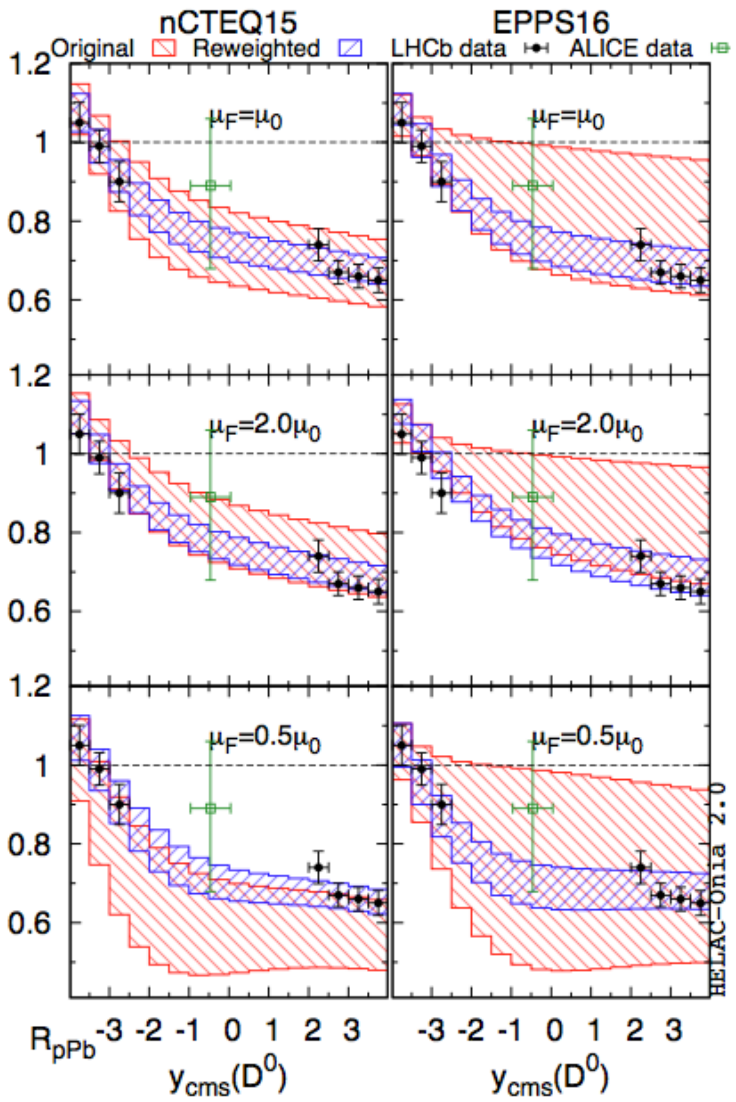


NCTEQ15 nuclear PDFs with uncertainties



Impact of LHC heavy flavour data on NPDFs

Predictions for RpA(D0) vs rapidity



Impact on small-x nuclear gluon PDF