Charm and prompt photon production with EPOS

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Outline

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Universal approach for pp, pA and AA collisions

- Quantum mechanical multiple scattering approach based on pQCD and Gribov-Regge theory
- Saturation scale $Q_s \propto N_{part}\hat{s}^{\lambda}$ for non-linear effects
- Core-corona approach to separate fluid and jet hadrons
- 3+1 D viscous Hydrodynamical evolution done event by event
- True particle production (not only inclusive spectrum)

EPOS3 : arXiv:1312.1233, K. Werner, B. Guiot, Y. Karpenko, T. Pierog, M. Bleicher

EPOS : a "real" event generator

1 LHC event = 1 EPOS event

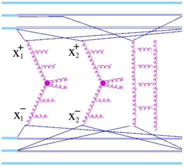
1. All kind of particles produced and registered in tables
2. We can (and have to) apply to these particles the same treatment as in experiments
   $\Rightarrow$ anti-kt for jets, background subtraction ...
   - Can reproduce exclusive observables

$\Rightarrow$ **Ideal for comparisons with experiments**

Multiple scattering in EPOS

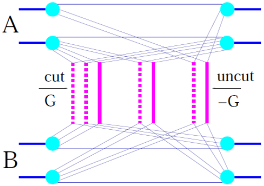
- Phenomenological treatment of multiple scattering based on Gribov-Regge theory

- Multiple pomerons exchange :



For pp, pA, AA:

$$\sigma^{tot} = \sum_{\text{cut P}} \int \sum_{\text{uncut P}} \int \underbrace{\qquad}_{d\sigma_{\text{exclusive}}}$$



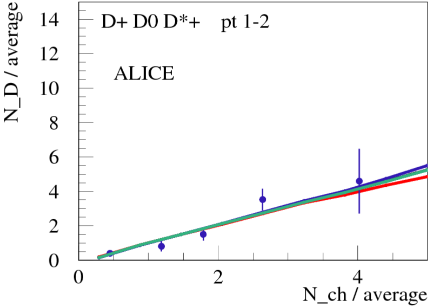
$d\sigma_{\text{exclusive}}$

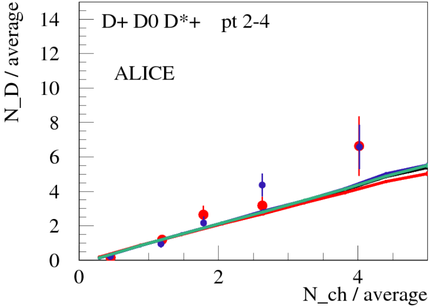
Cut pomerons important for hard probes...

Cut pomeron → particle production :

- Multiplicity ∝ # of cut pomerons
- # hard probes ∝ # of cut pomerons

⇒Linear rise of hard probes with multiplicity



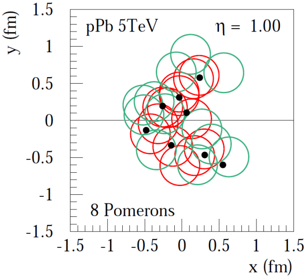


... and collective behavior

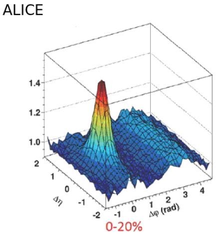
Cut pomerons provide initial conditions for hydro

- Cut pomeron ⇒ several color flux tubes
- Color flux tube : Mainly a longitudinal object

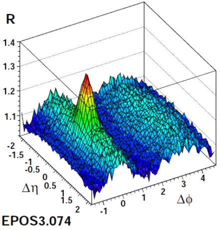
- High density of color flux tubes (in red) = **core** . Hydrodynamical evolution (hadronization : Cooper-Frye)
- Flux tubes in green = **corona** . Jet hadrons (hadronization : string fragmentation)

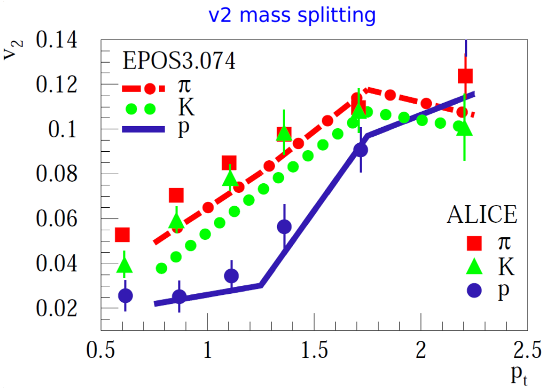


Ridge and v2 in pPb collisions



p_T^{assoc} 1.0-2.0 GeV/c p_T^{trigg} 2.0-4.0 GeV/c





arXiv:1307.4379v1; K.Werner, M.Bleicher, B.Guiot, Iu.Karpenko, T.Pierog; Jul 2013

Outline

Interests and goals of hard probes implementation

Study of the QGP :

- Heavy quarks correlations
- Isolated photon/ charged particles correlations →modification of fragmentation functions by the medium
- γ jet

Small x study (includes cold matter effects):

- Multiple scattering
- Gluon distribution

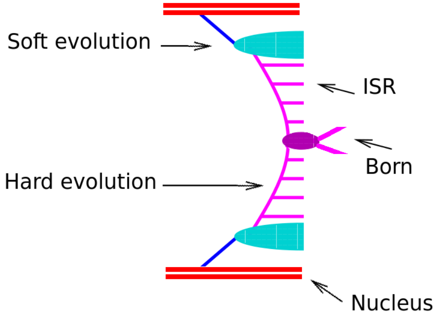
Test of "basic QCD" :

- partonic cascades
- QCD cross sections

First : comparison with data ⇒ test for hard probes implementation

Hard probes production

dissection of a cut pomeron :



Hard probes produced during :

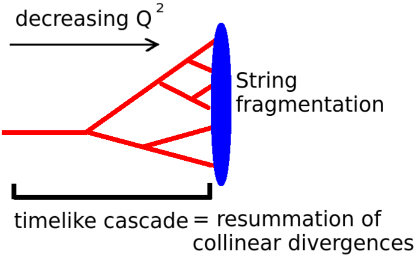
- Hard evolution
- Born process = σ_{QCD} at L.O

saturation scale :
$Q_s \propto N_{part} \hat{s}^{\lambda}$

- The same formalism (and parameters) for prompt photons and heavy quarks

... and timelike cascade $\otimes$ fragmentation

ISR and out born particles have $Q^2 \neq 0 \Rightarrow$ timelike cascade



Relevant splittings :

$g \to c\bar{c}$

$c \to cg$

$q \to q\gamma$

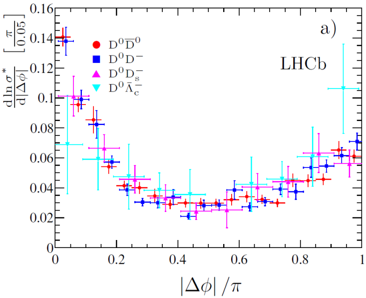
- Emissions at small angle $dP(z, Q^2) \propto \frac{\alpha}{2\pi} \frac{p(z)}{Q^2} \Delta(Q_0^2, Q^2)$ + **angular ordering**

String fragmentation (negligible)

Remarks on timelike cascade

- Particles produced in the timelike cascade have a small pt
- Small pt charms produced mainly in timelike cascade ⇒ precise test (light flavors can be produced in the medium or in string fragmention)

- Splittings done at small angle ⇒ peak at $\Delta\phi = 0$ for heavy quarks correlations



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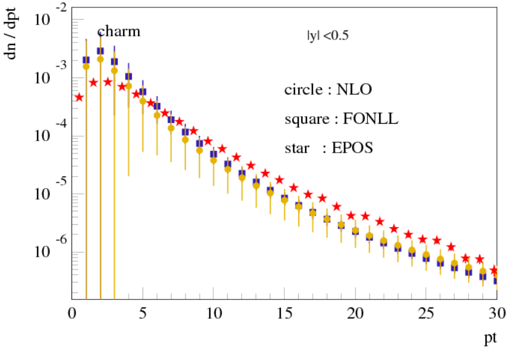
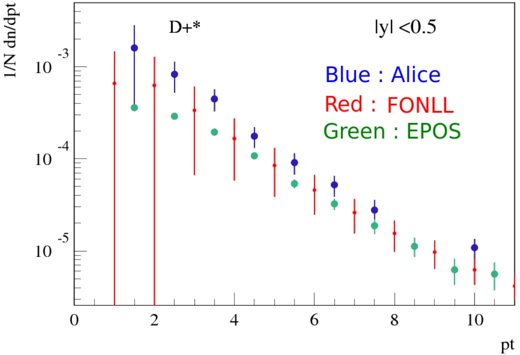
Basic test : charm distribution in EPOS vs NLO and FONLL

During all the work on charms and photons, no parameter has been changed or added



Satisfying result but not enough charms at low pt ⇒ timelike cascade (work in progress)

D^{+*}

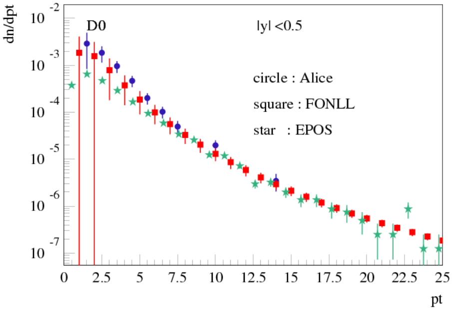


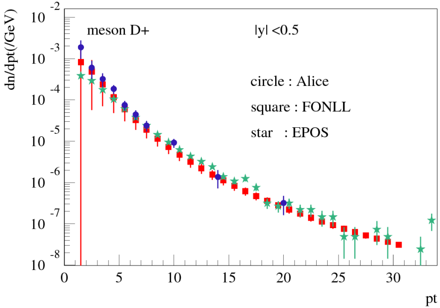
- In agreement with FONLL
- Not enough D^{+*} at low pt

Ref : Alice collaboration 2012, arXiv 1312.1233

D0 and D+ mesons

- Good agreement with FONLL
- Not enough D mesons at low pt





www.lpthe.jussieu.fr/~cacciari/fonll/fonllform.html
arXiv : 1111.1553v2, 2012

Outline

Photons and experiments

Some definitions (in pp collisions)

- Direct photon : produced during the born process
- Fragmentation photon : produced in spacelike/timelike cascade
- Prompt photon = fragmentation + direct photons

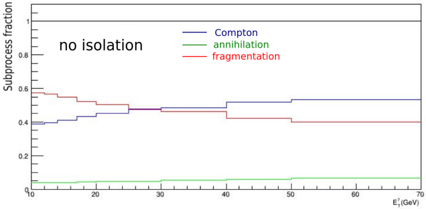
- Direct photon/charged particles correlations : provides an (approximate) measurement of quark fragmentation functions
  - Could be used for the study of the QGP

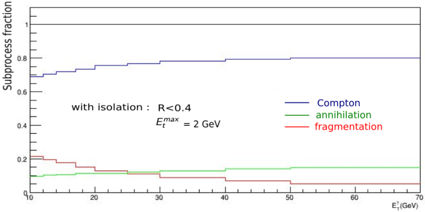
$\Rightarrow$ Need to separate contributions from direct and fragmentation photons

Isolated photons

1. Define a cone $R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$ around the photon
2. Isolated if $\sum p_t < E_t^{MAX}$, p_t : transverse momentum of particles in the cone (**or** $p_t < E_t^{MAX}$)

$\rightarrow$ Strong suppression of fragmentation photons (plot : Jetphox)





plot from Lucile Ronflette, subatech, during her Master2

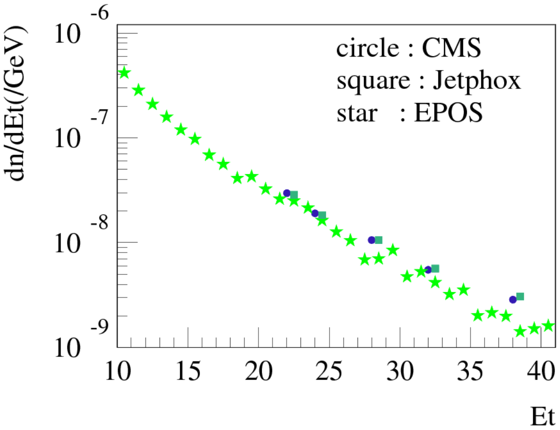
Implementation of isolated photons

- Isolation subroutine : like in experiments, we define a cone $R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$ around a triggered photon

Event generator with a true particle production :

$\Rightarrow$ realistic isolation
$\Rightarrow$ Able to reproduce sophisticated observables like isolated photon/charged particles correlations

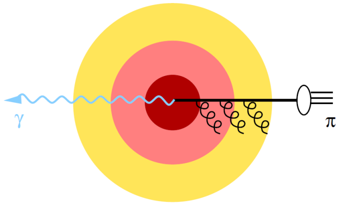
Isolated photons distribution



- Work in progress

For more clarity, Jetphox results have been shifted of 0.5 to the right

Isolated photon/charged particle correlation : ALICE



Aim :

- $x_E = -\frac{p_{t\,asso}}{p_t^{trig}} \cos(\Delta\phi)$. x_E distribution $\simeq$ quark fragmentation function
- Comparison of x_E distribution for pp and PbPb collisions

Measurement :

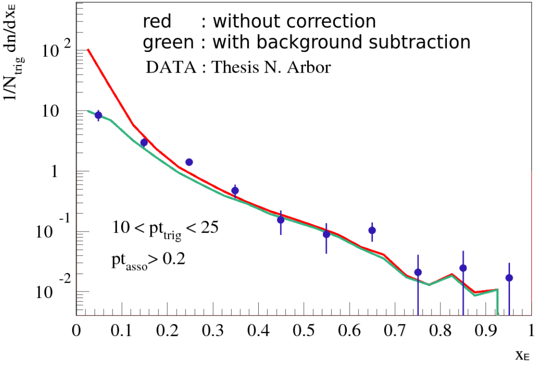
Isolation :

$R = 0.4$
No particle with $p_t > 0.5$ GeV

Additional criteria :

$p_t^{trig} \in [10, 25]$ + highest p_t of the event
$p_t^{asso} > 0.2$ GeV

x_E Alice

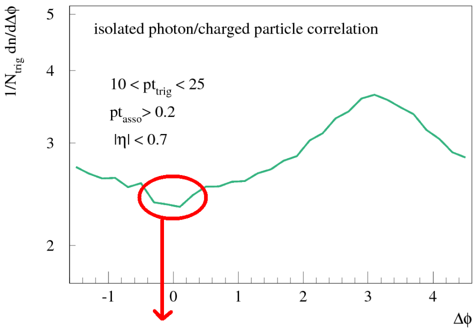


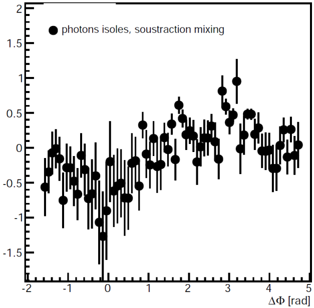
$$x_E = -\frac{p_{t}{asso}}{p_t^{trig}} \cos(\Delta\phi)$$

$$\Delta\phi \in [2\pi/3, 4\pi/3]$$

- Underlying event regions : $\Delta\phi \in [\pi/3, 2\pi/3]$ and $\Delta\phi \in [4\pi/3, 5\pi/3]$

Azimuthal correlations

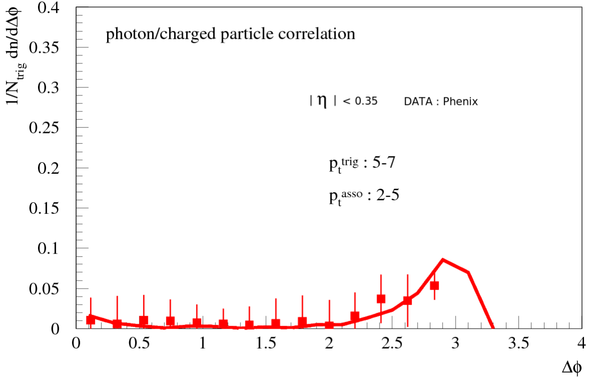




- "Anti-correlation" reproduced : less particles around the **isolated** photon
- The two plots are comparable

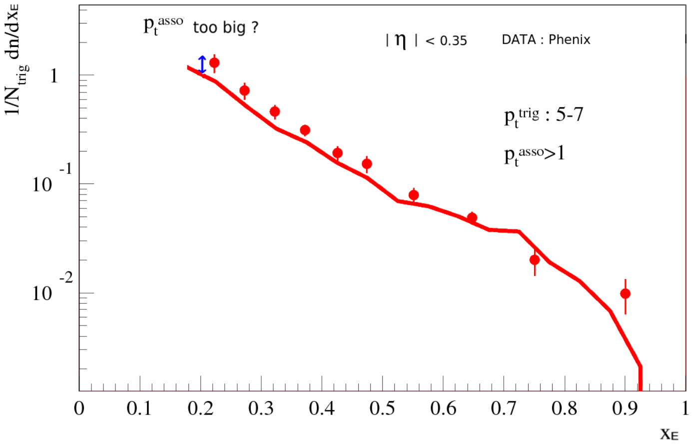
(*ref : thesis, N. Arbor, 2013*)

Photon/charged particles correlations : Phenix



- Done for p_t^{trig} = [7,9] , [9,12] and [12, 15] ⇒ good agreement

Xe Phenix



ref : Phys. Rev. D.82.072001

Summary

- In EPOS, multiple scattering is a central mechanism
- Good results for D mesons, except at low pt
  $\Rightarrow$ The partonic cascade need to be improved
- Good results for isolated photons : More detailed studies could be done
- **Outlook :**
  - Implementation of new particles : bottom, (J/ψ ?)
  - Heavy quarks correlations (work in progress)
  - Precise comparison with Jetphox (for fragmentation photons)

acknowledgment : projet together, Region des pays de la Loire