Hard probes and the event generator EPOS

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High pT, 2013

Outline

1. Introduction
2. EPOS : general presentation
3. Charm
4. Photons

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Motivations

- pp collisions :
  1. Benchmark for Pb-Pb collisions
  2. Test for pQCD and our models
- Heavy quarks :
  1. Interaction with the dense medium : energy loss, heavy quarkonia
  2. shadowing/saturation
- Prompt photons :
  1. comparison with experiments on isolated photon
  2. γ/jet, γ/hadron correlation
  3. shadowing/saturation
  4. fragmentation photons could be affect by the medium

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EPOS philosophy

EPOS = event generator $\neq$ spectrum generator

- 1 experimental event = 1 EPOS event (we hope so)
  - slower than other generators like pythia (statistics)
  - Can reproduce complicated effects (like the ridge)

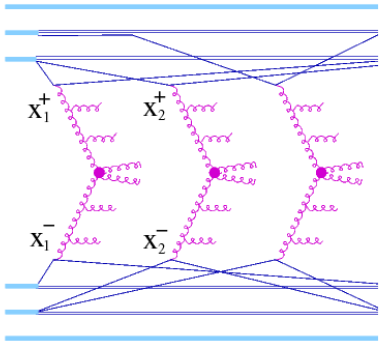
Unify formalism :

- The same treatment for pp, pA and AA

Multiple interactions

- At high energy : multiple interactions

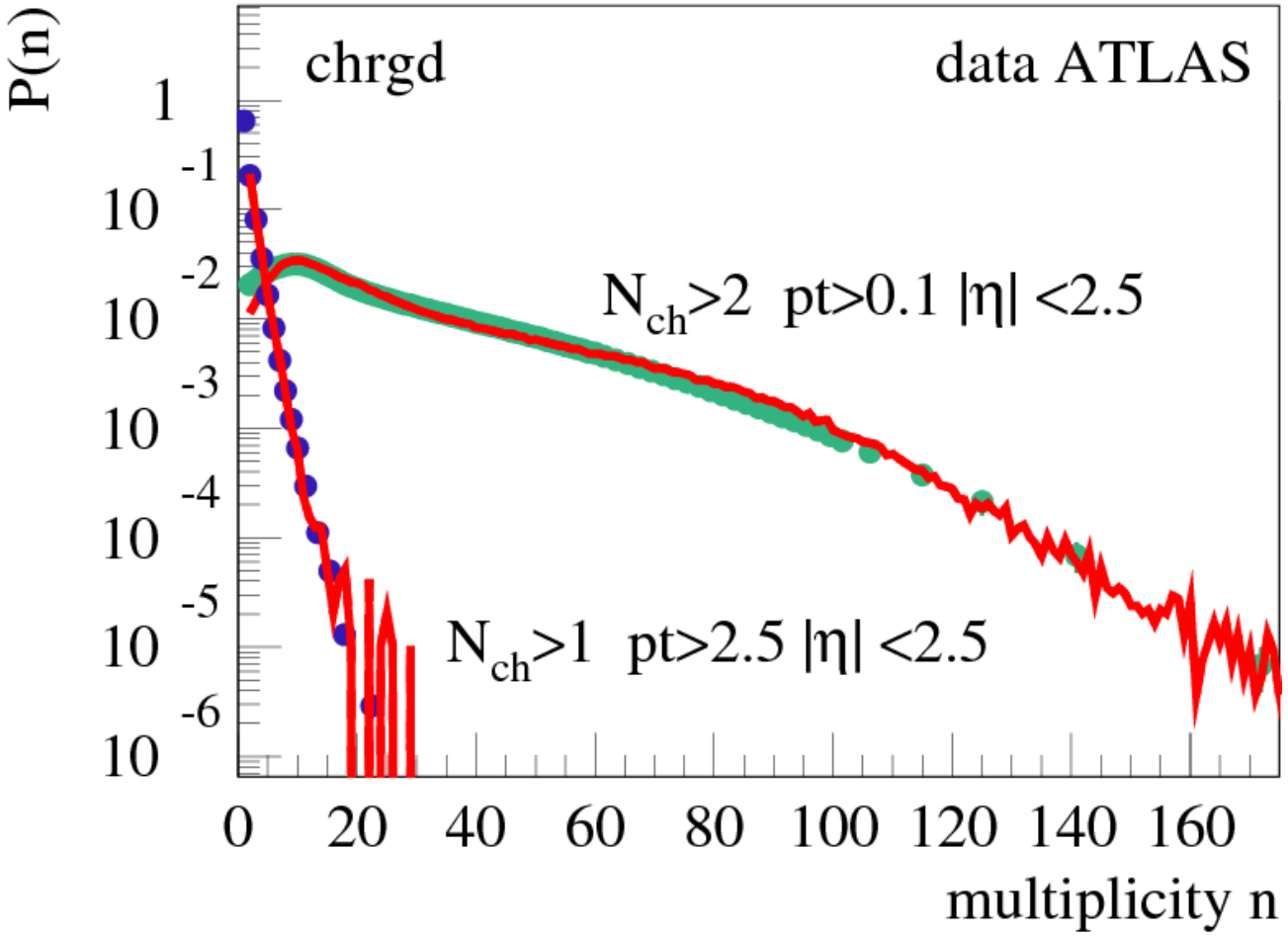
2001: H.J.Drescher, M.Hladik, S.Ostapchenko, T. Pierog, and K. Werner, Phys. Rept. 350, p93: Marriage pQCD + GRT, with energy sharing



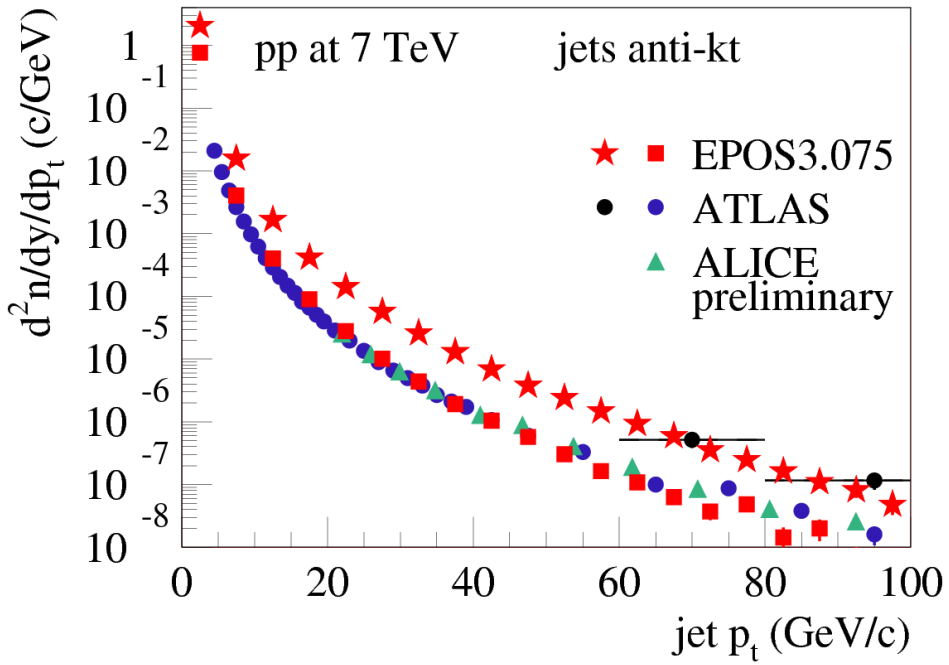
Multiple scatterings
(in parallel !!)
in pp, pA, or AA

- Multiple interaction treatment with the parton-based Gribov-Regge theory
- Gribov-Regge theory : exchange in parallel of "particles" called pomerons
- Gribov-Regge Pomeron $\neq$ Epos pomeron

Results for multiplicity



Hard events



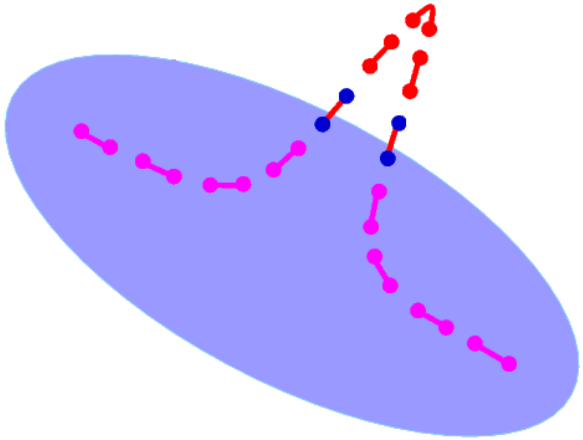
pQCD ingredients :

1. Partonic evolution done with DGLAP, ISR
2. Born scattering
3. FSR = timelike cascade

→ more details in few minutes

Collective behavior

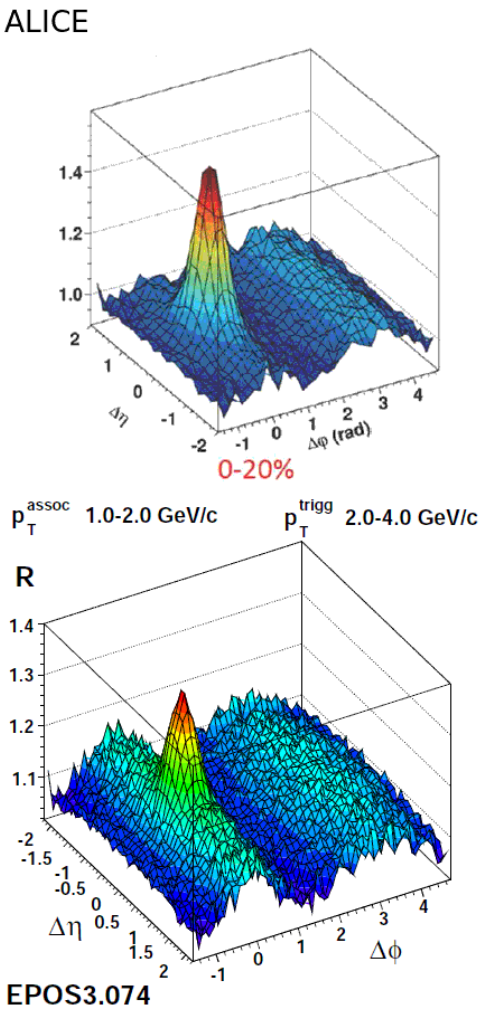
many scatterings (AA) => many color flux tubes

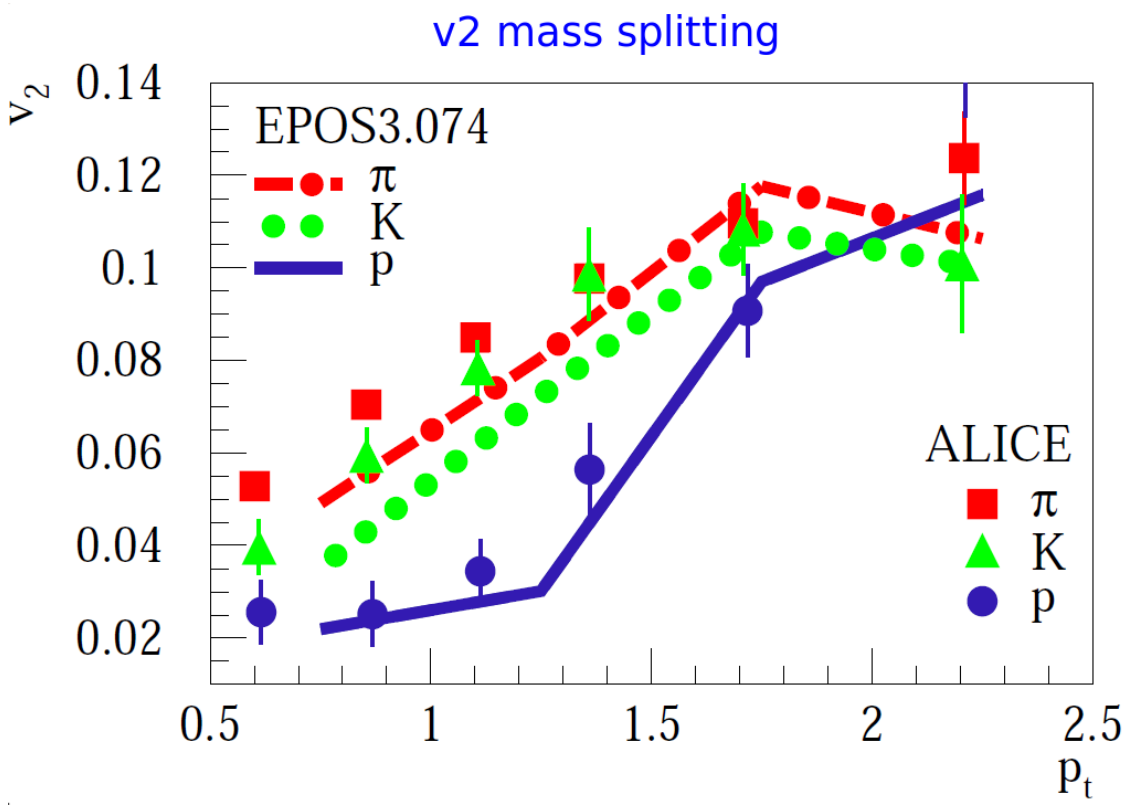


- Hydro event-by-event
- Flux tubes form jet **and** bulk matter
- Interaction between jet and bulk matter

arXiv:1203.5704v2; K.Werner, Iu.Karpenko, M.Bleicher, T.Pierog, S. Porteboeuf-Houssais; Jun 2012

Ridge and v2 in pPb collisions





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

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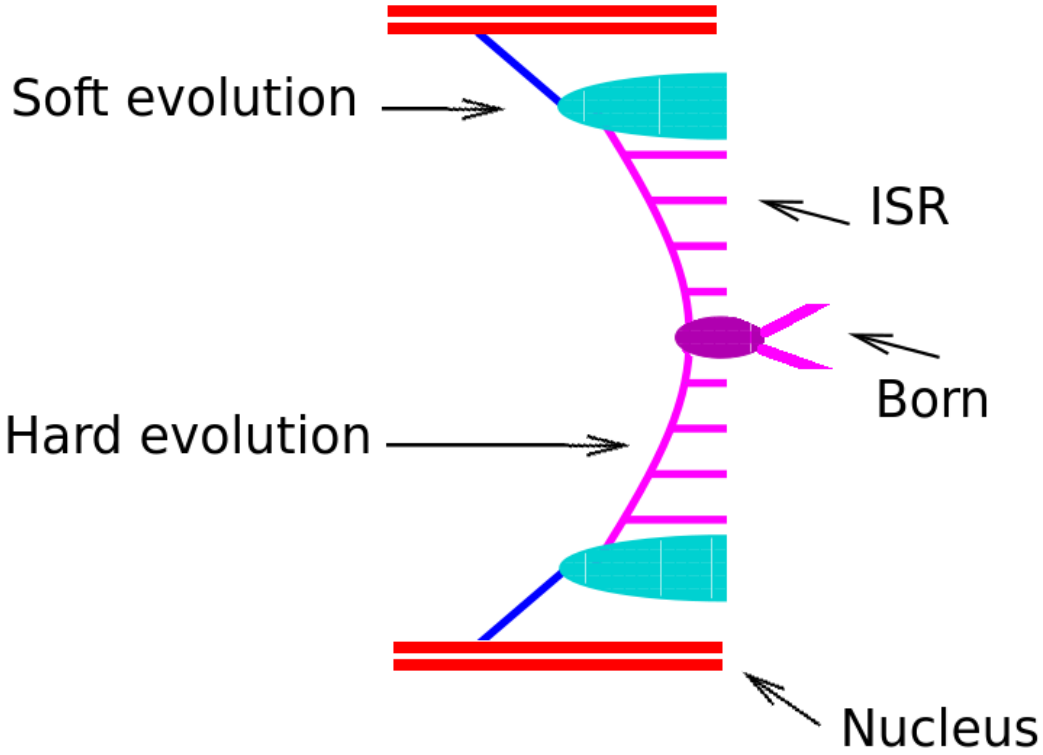
Work on charm production

dissection of a pomeron :



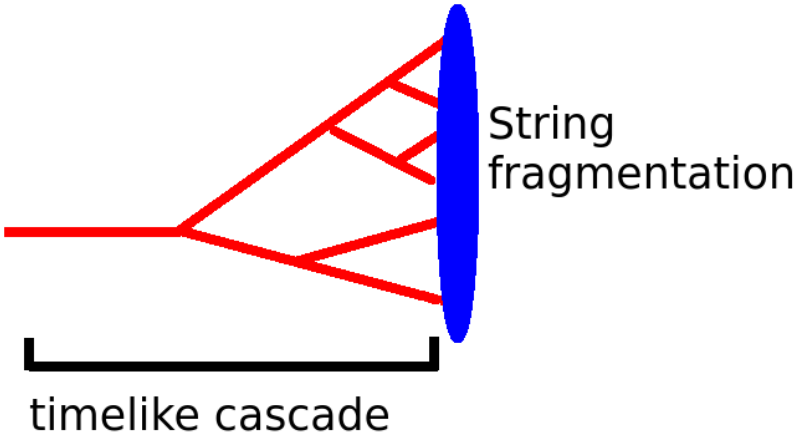
charm produced in :

- Initial State Radiation
- born

- Done by Monte-Carlo techniques

... and timelike cascade ⊗ fragmentation

For ISR and out born particles



Processes implying a charm :

$g \rightarrow c\bar{c}$

$c \rightarrow cg$

- Timelike cascade $\sim$ inverse of hard evolution
- Q^2 decreases from $m_t^2 = p_t^2 + m^2$ to $Q^2_{min} \sim MeV + m^2$

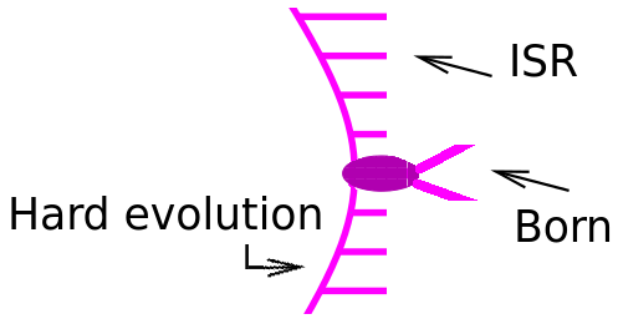
String fragmentation

Hard evolution and ISR

- Hard evolution done with DGLAP : increasing virtuality, Q^2, of spacelike parton
- ISR = initial state radiation : production of small p_t particles

emission probability :

$$dp(x, Q^2) \propto \frac{\alpha_s}{2\pi} \frac{dQ^2}{Q^2} p_{i \to jk}(x)$$



- Threshold for Heavy quarks : $x_{max} = \frac{Q^2}{Q^2+m^2}$.

Born scattering

- L.O QCD cross sections $\Rightarrow$ High p_t particles
- Strong and electromagnetic processes

Monte-Carlo

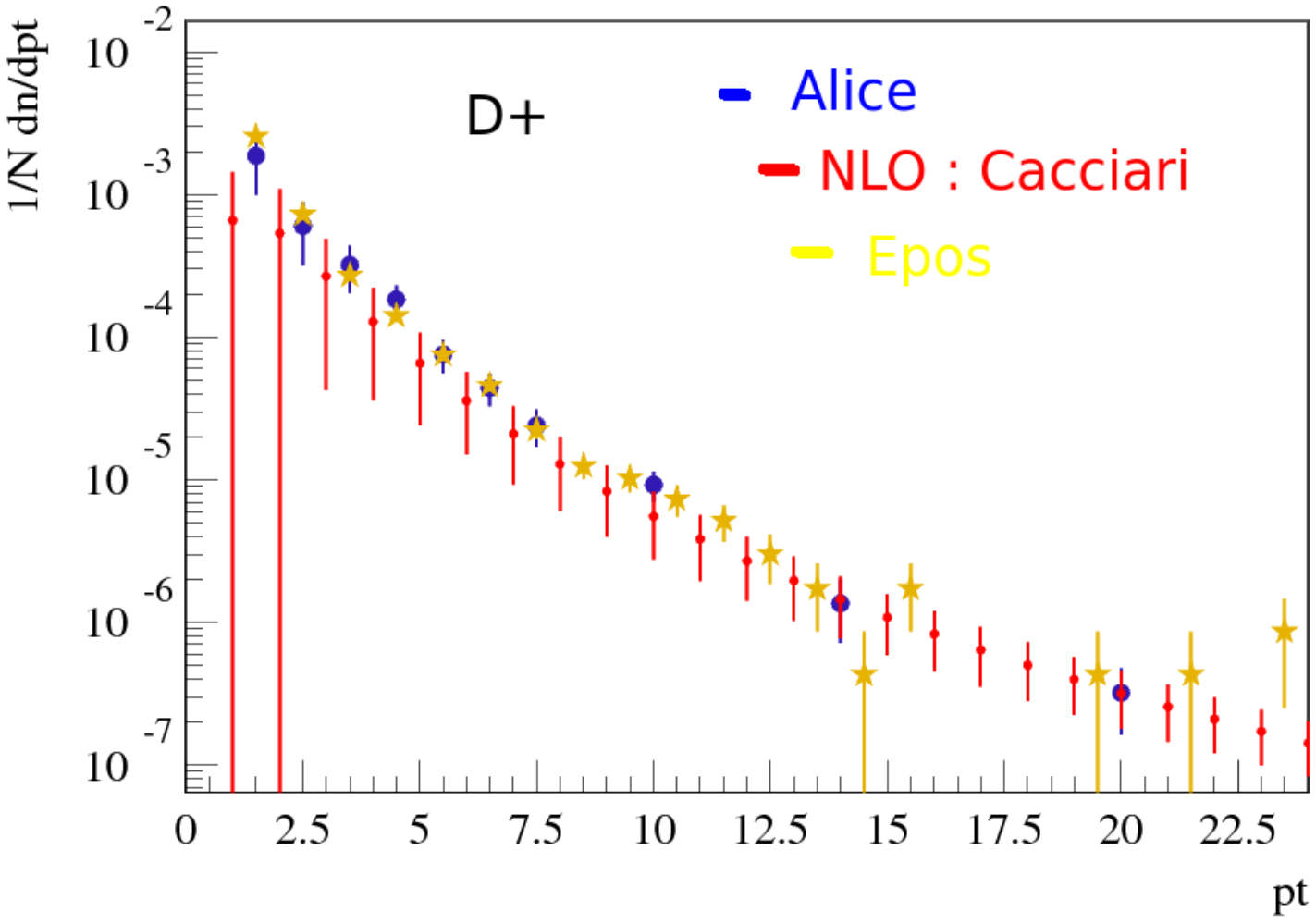
- t probability distribution : $\sum_i \sigma_i(s,t)/N$, s fixed
- Proba for the process j : $P_j(s,t) = \sigma_j(s,t)/\sum_i \sigma_i(s,t)$

$\rightarrow$ For heavy quarks : $\sigma(s,t,m)$

Remarks on heavy quarks results

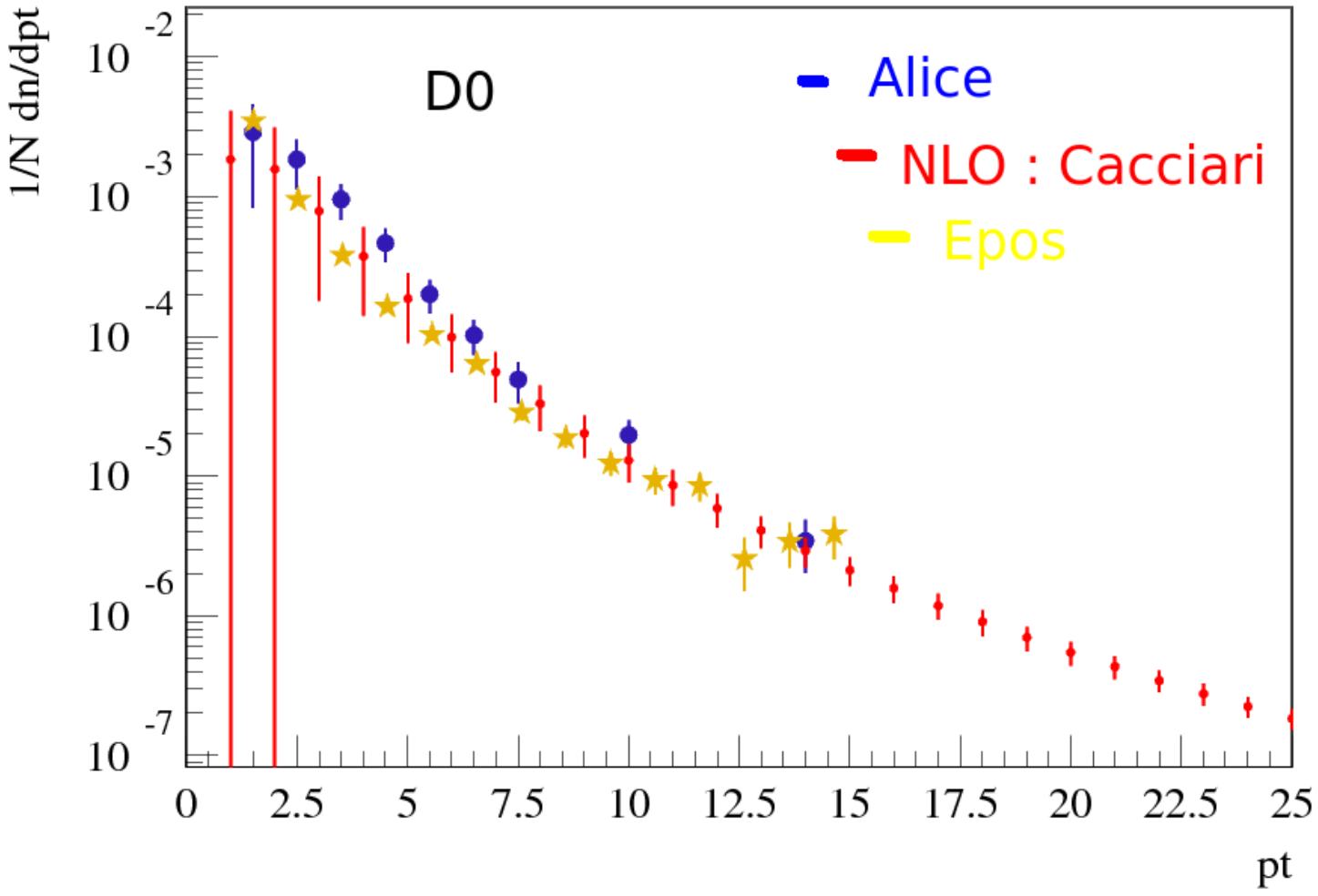
- Done with few statistics : quick check, not for a publication
- Only one parameter changed during my thesis : $\lambda_c = 0.14 \rightarrow 0.16$ for charm fragmentation
- No data corrections after the simulation

D+ meson



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

D0 meson



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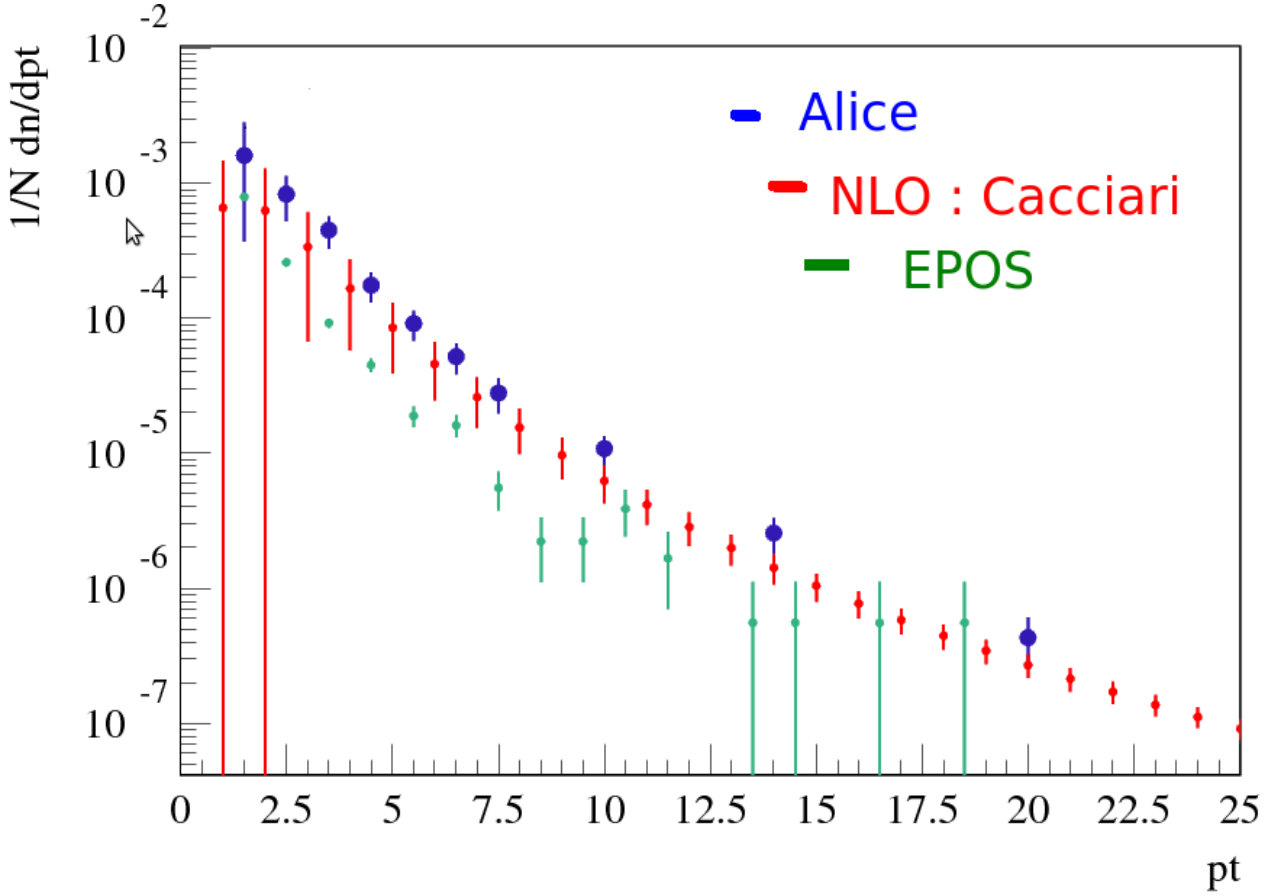
arXiv : 1111.1553v2, 2012

Conclusion on heavy quark physics in EPOS

So... everything is ok??

Conclusion on heavy quark physics in EPOS

$\Longrightarrow$ Nope : p_t distribution of $D+^*$ too low



Conclusion on heavy quark physics in EPOS

$\Longrightarrow$ Nope : p_t distribution of $D+^*$ too low

- Work on string fragmentation in EPOS ?

- What about B mesons ? Maybe in few months
- Good results for D+ and D0 mesons

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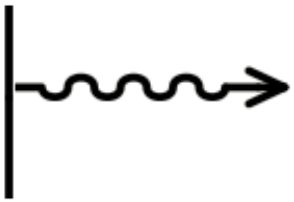
Our project

- In subatech, some people are working on Jetphox and isolated photons (for ALICE experiment)
  1. Study of isolation criteria
  2. Comparison Jetphox/EPOS
  3. γ/jet, γ/hadron correlation
- In order to compare our results $\rightarrow$ need of fragmentation photons and isolation subroutine

Implementation

- Fragmentation photons add in spacelike and timelike cascade



$\sim \alpha_{el}/\alpha_s$

$\sim \alpha_{el}^2/\alpha_s$: neglected

- $p_{q\to q\gamma}(x) \propto p_{q\to qg}(x)$

Main modification...

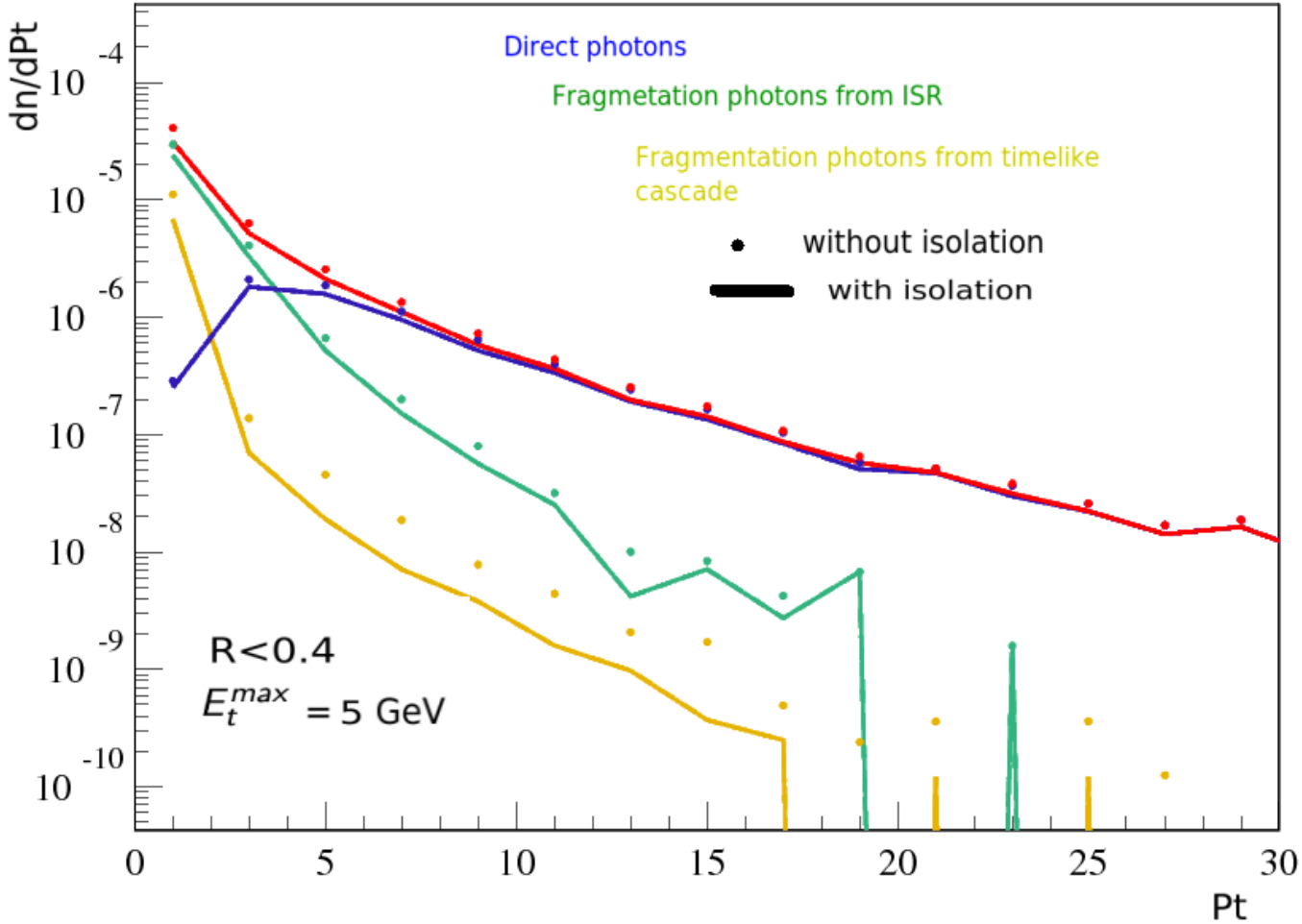
...Add the probability

$dp_{el} \propto \frac{\alpha_{el}}{2\pi}\frac{dQ^2}{Q^2}p_{q\to q\gamma}$ (vs $dp_{strong} \propto \frac{\alpha_s(p_t^2)}{2\pi}\frac{dQ^2}{Q^2}p_{q\to qg}$)

Isolation subroutine

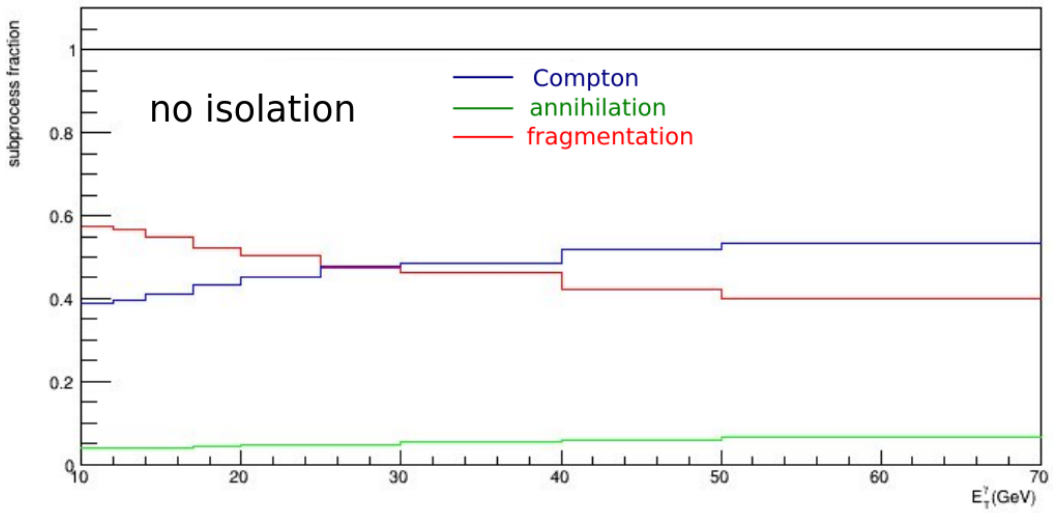
- Cone defined by $R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$
- $\sum p_t < E_t^{max}$ GeV; p_t =transverse impulsion of particles inside the cone
  - Neutron not seen by detectors : we ignore its energy
- Several choices :
  - $R = 0.4$ and $E_t^{max} = 5$ GeV
  - $E_t^{max} =$ few % of photon's energy
- Effective radius given for simulations (in experimental papers)

Qualitative result with EPOS



- One can see contributions from ISR and FSR : Not the case when using fragmentation functions

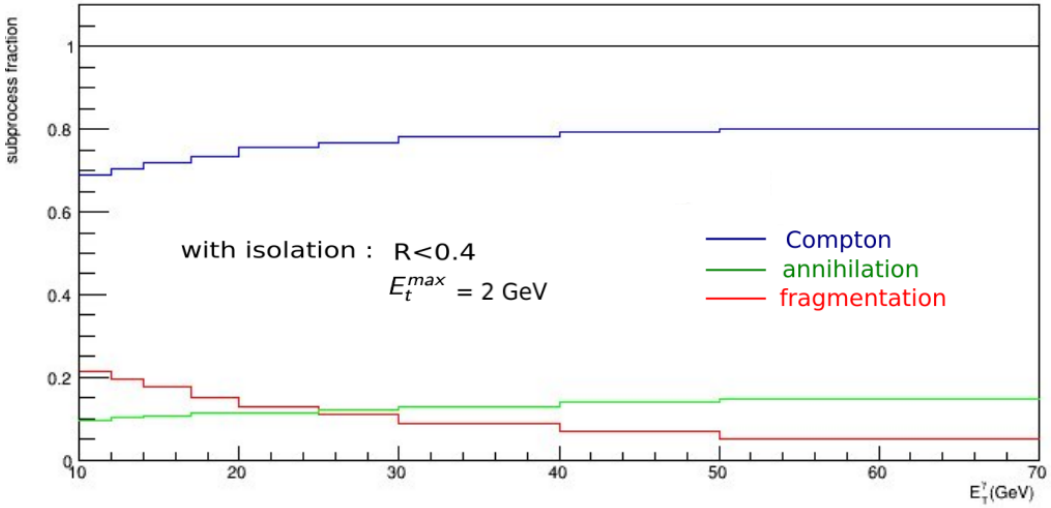
Jetphox results for pp at 7 TeV



plot from Lucile Ronflette, subatech, during her Master2

- Fragmentation and compton photons of the same order without isolation
- At low E_t fragmentation contribution bigger than the compton contribution

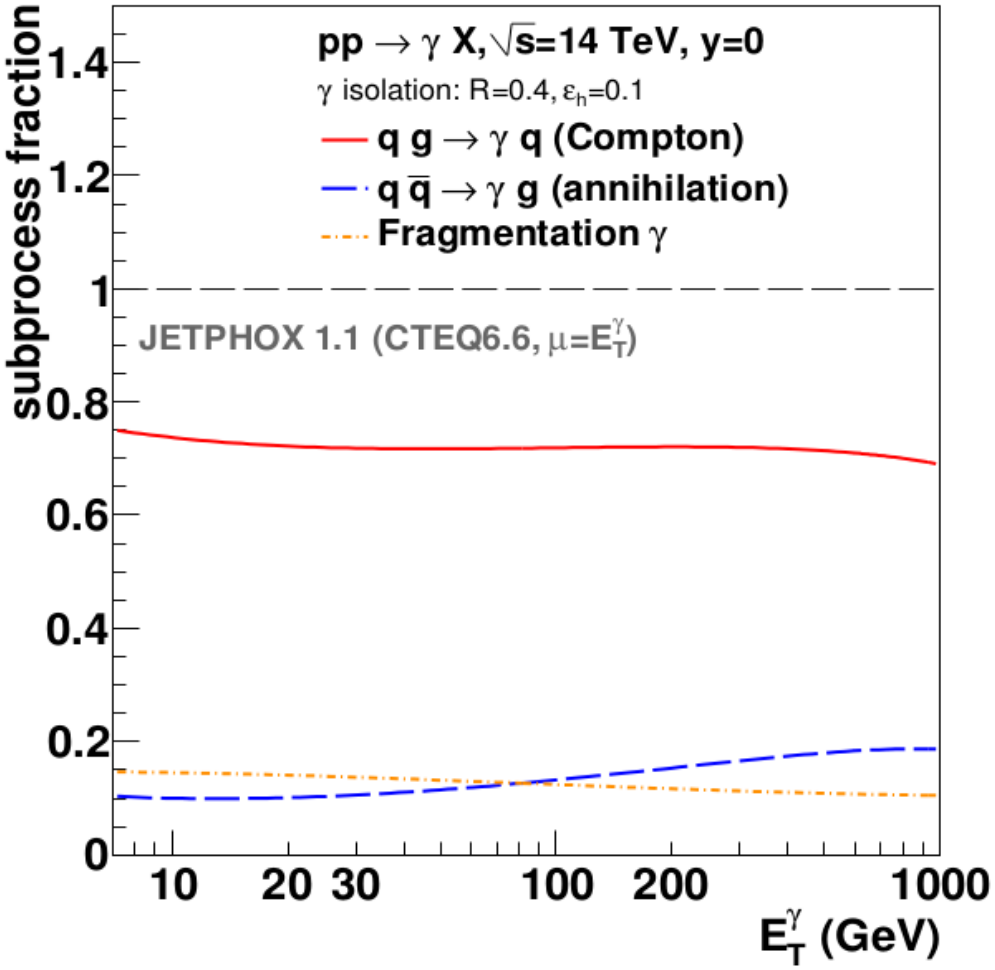
Jetphox results for pp at 7 TeV



plot from Lucile Ronflette, subatech, during her Master2

- Frag photons strongly suppressed by isolation
- Frag photons decrease up to 5%

Jetphox results for pp at 14 TeV



- Frag photons $\sim 10\%$, nearly constant: Not the same behaviour compare to fixed E_t^{max}

A more detailed study with EPOS... as soon as possible

arxiv : 1005.4529v2

Summary

- EPOS give satisfying results for low and high energy physics
- Simulation are long for rare events
- Heavy quark physics in EPOS begin to give satisfying results
- Outlook :
  - Comparison Jetphox/EPOS
  - $D+$ multiplicity (soon)
  - J/ψ

acknowledgment : projet together