

Recent progress from Les Houches WG

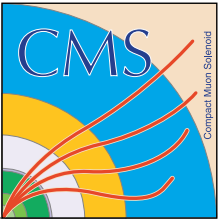
Photon isolation and fragmentation contribution

Workshop PPSHC - 30/03/2012

Nicolas Chanon - ETH Zürich

In behalf of the Photon Les Houches WG

N. Chanon, S. Gascon-Shotkin, J.P. Guillet, J. Huston, E. Pilon,
M. Schwoerer, M. Stockton, M. Tripana

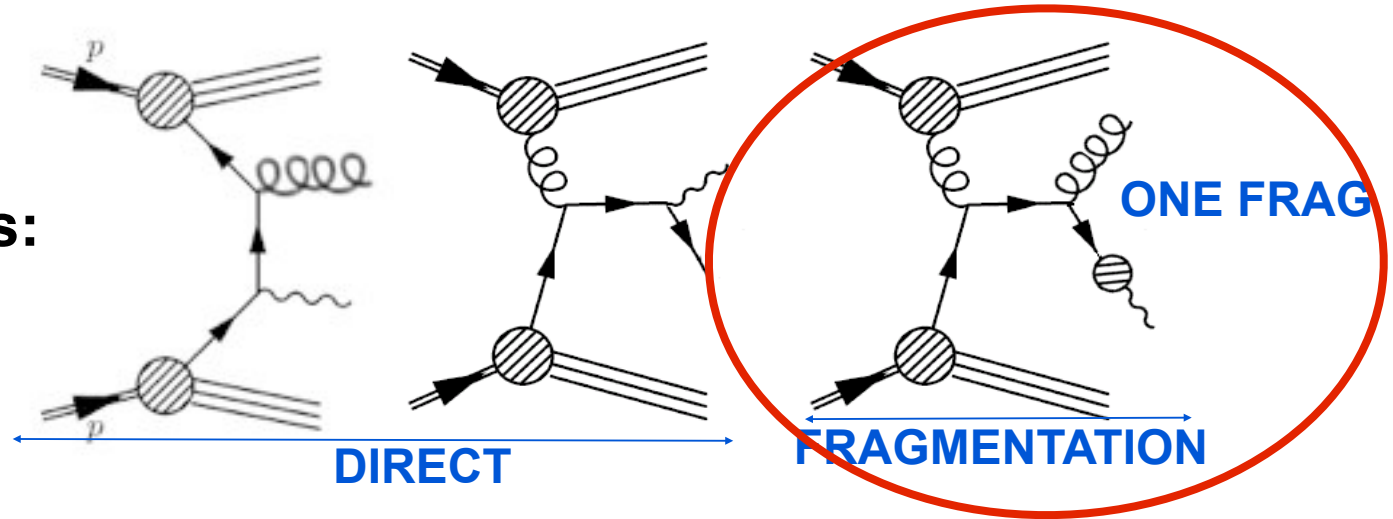


Outline

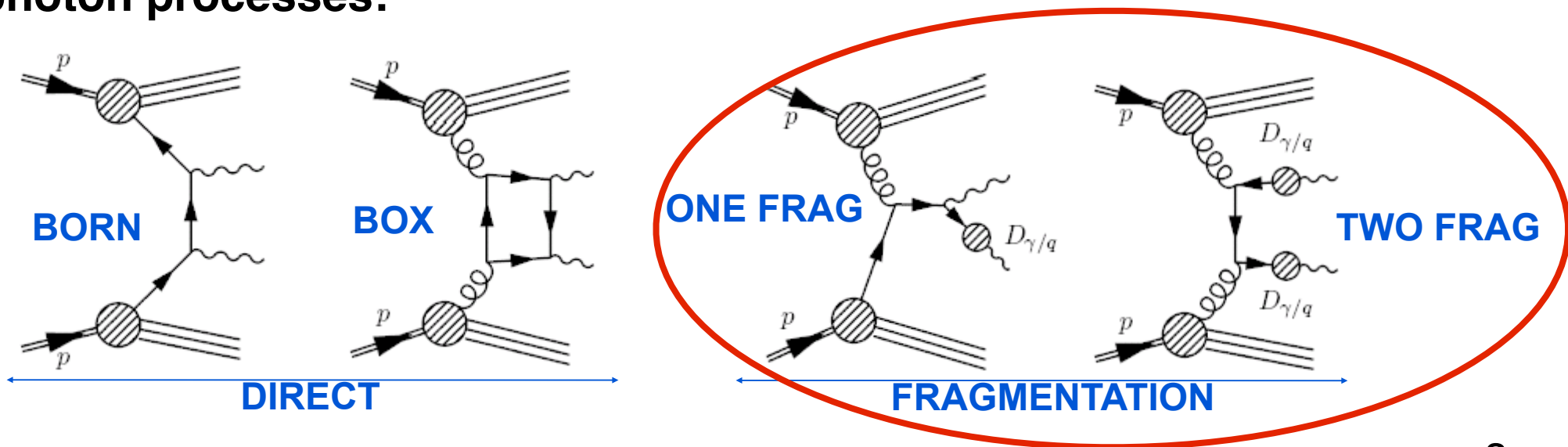
- **Introduction** on fragmentation and isolation in photon processes
- **Isolation for inclusive photons and diphotons at NLO**
 - Discretized Frixione prescription
 - Generalized prescription
 - Continuous versus discretized isolation
 - Scale dependence
- **Isolation for diphotons with Parton-shower Monte-Carlo**
 - Topology of fragmentation photons
 - Hollow cone isolation
 - Frixione isolation

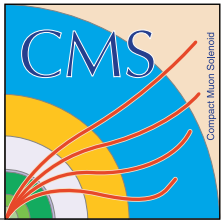
Fragmentation contribution in photon processes

Gamma+Jet processes:



Diphoton processes:

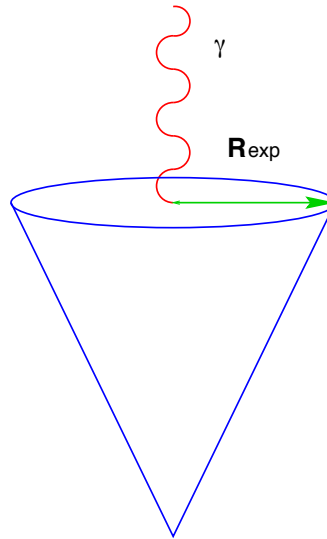
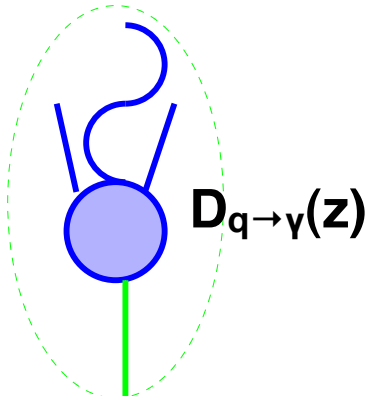




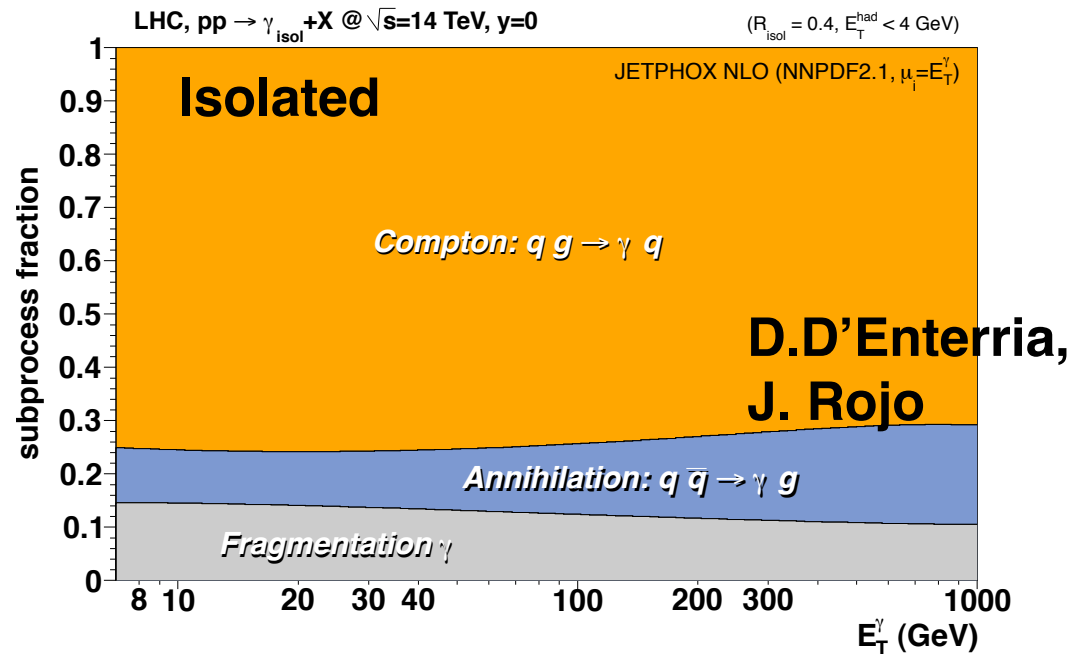
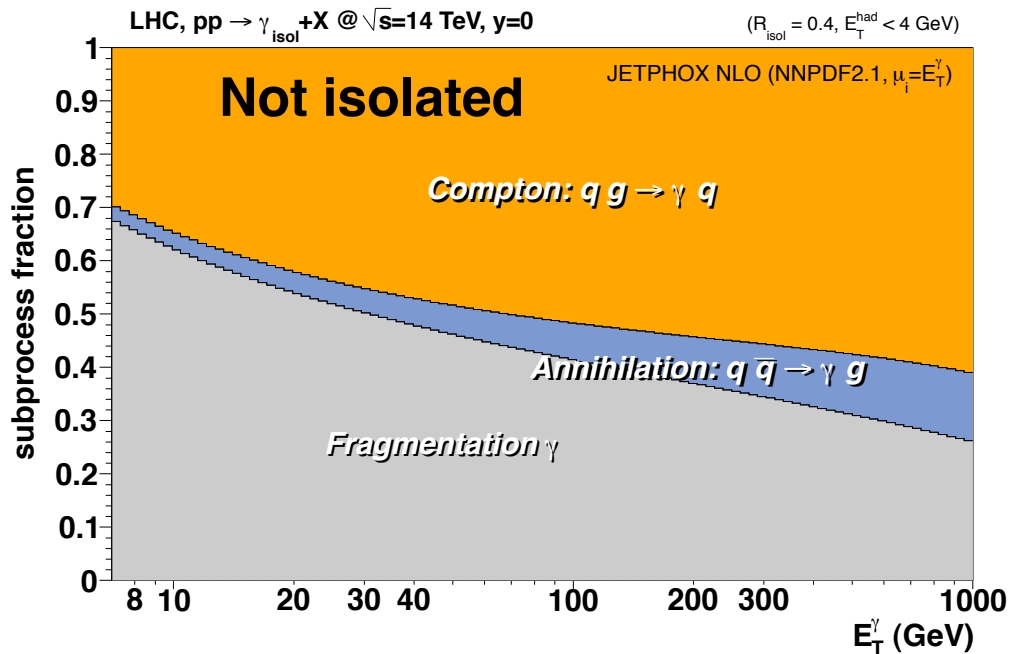
Fragmentation contribution : isolation

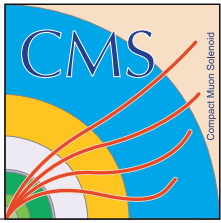
$$E_T^{had} \leq E_{Tmax} \text{ inside}$$

$$(y - y_\gamma)^2 + (\phi - \phi_\gamma)^2 \leq R_{exp}^2$$



- Fragmentation is reduced by isolation requirement - although not completely
- Will not discuss here the complications of isolation requirement at isolation level





Frixione prescription for isolation criterion

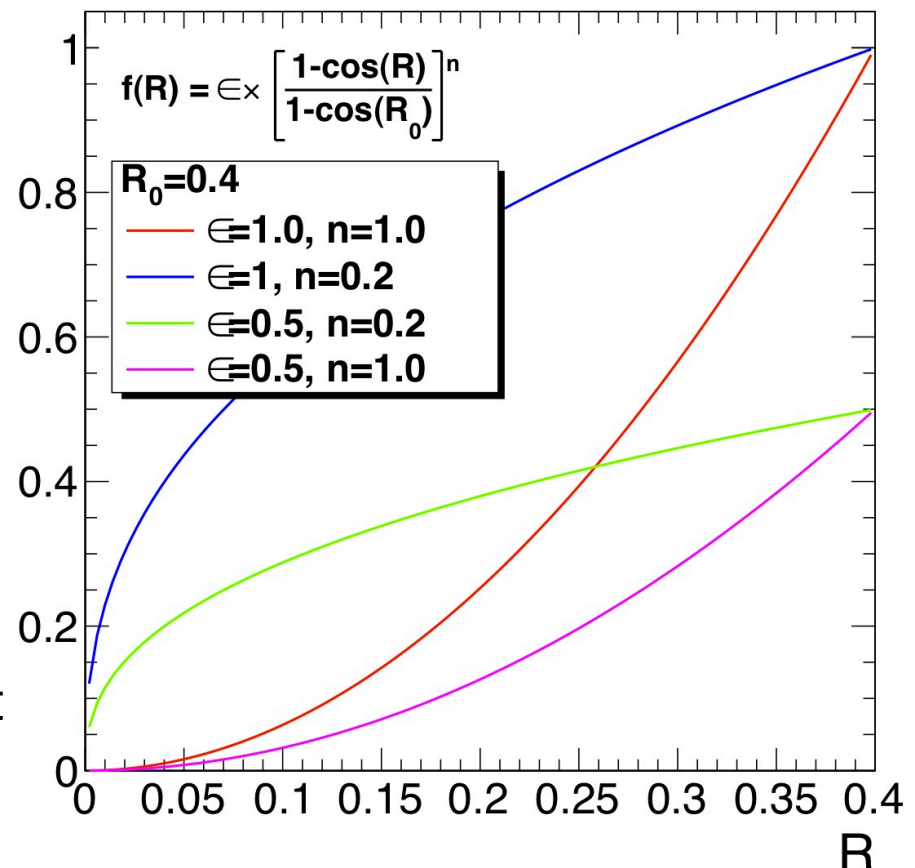
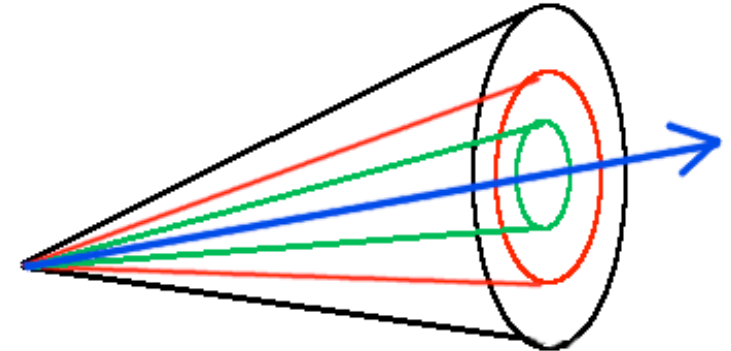
- To completely suppress the fragmentation contribution at theoretical level, S. Frixione [arXiv:hep-ph/9809397] proposed to use a **isolation requirement** which *cuts tighter in energy as the fragmentation photon gets closer to the parton*
- Should be Infrared safe at all order
- Allowed isolation energy in a cone of ΔR must go monotonically to 0 :

$$E_T^{\text{iso}}(R) < f(R)$$

$$f(R) \rightarrow 0 \text{ when } \Delta R \rightarrow 0$$

- Proposed functional form $f(R)$: see right plot

- **Exploration of Frixione isolation needed**



Isolation for inclusive photon and diphoton at NLO



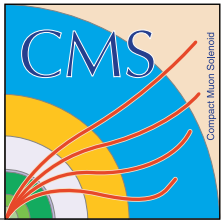
Study of Fragmentation at NLO with JetPhox and DiPhox

Some features of fragmentation at NLO in JetPhox and DiPhox :

- A fragmentation function $D_{q \rightarrow \gamma}(z)$ is used.
- BFG fragmentation function [*Eur. Phys. J. C* 2, 529–537 (1998)] : **beyond leading log**
- **Collinearity** of the photon and the quark remnant (angle information is lost)
- Fragmentation happens at some **scale M_f**
- **Only the sum of direct and fragmentation cross-section has a physical meaning** (because of M_f)

Concerns about the scale choice for Frixione isolation :

- $M_f \sim p_T^\gamma$ natural choice but problematic if in small cones $R \ll 1$. Reliability of the calculation is questionable
- $M_f \sim R \cdot p_T^\gamma$ might be preferable

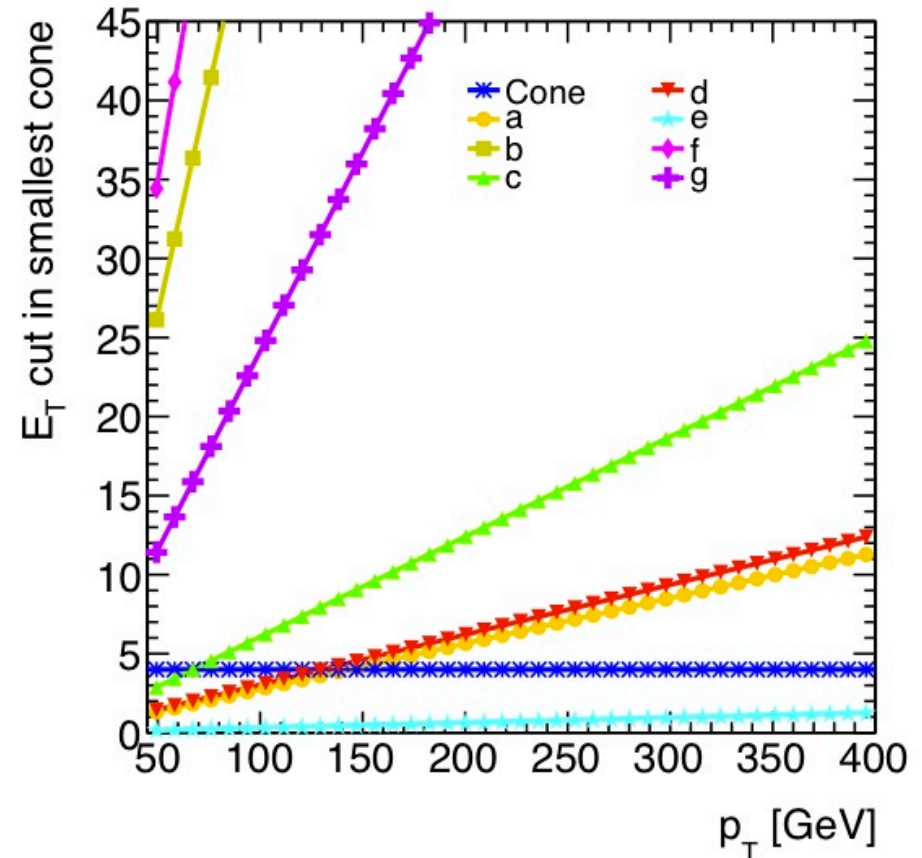
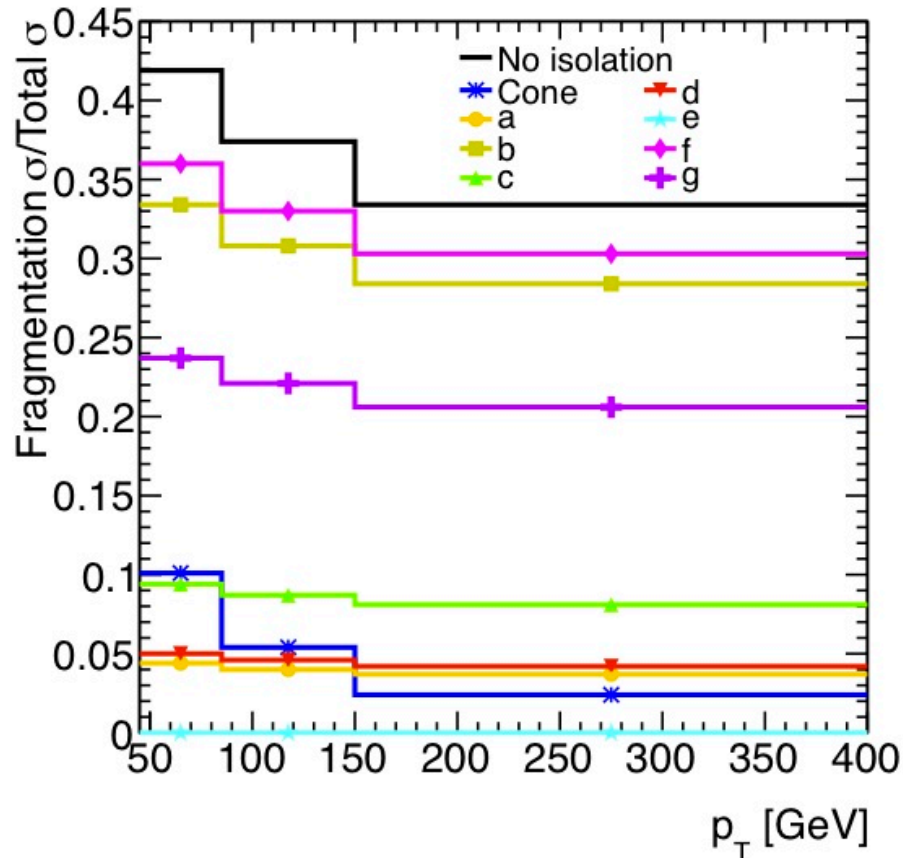


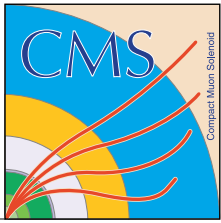
Frixione isolation in γ +jet at NLO

Try discretized Frixione isolation criteria with JetPhox

- Only one criterion performs better than standard isolation ($\epsilon=0.05$, $n=1$)
- Using **4 cones** or **8 cones** gives the same fragmentation fraction reduction within 1%

a: $\epsilon=0.05$ $n=0.2$ *b*: $\epsilon=1$ $n=0.2$ *c*: $\epsilon=1$ $n=1$ *d*: $\epsilon=0.5$ $n=1$
e: $\epsilon=0.05$ $n=1$ *f*: $\epsilon=1$ $n=0.1$ *g*: $\epsilon=1$ $n=0.5$



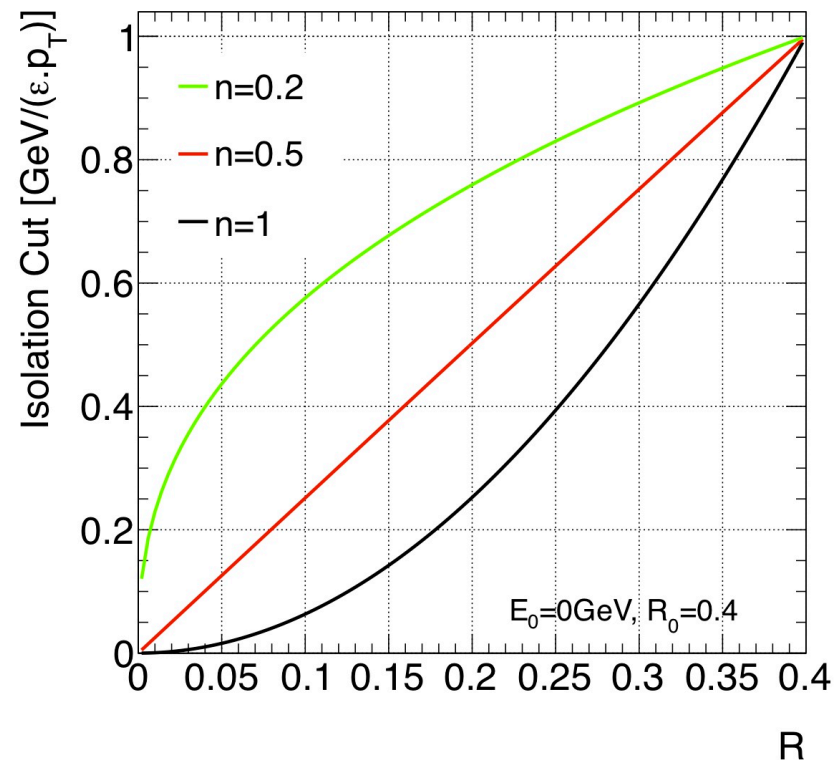
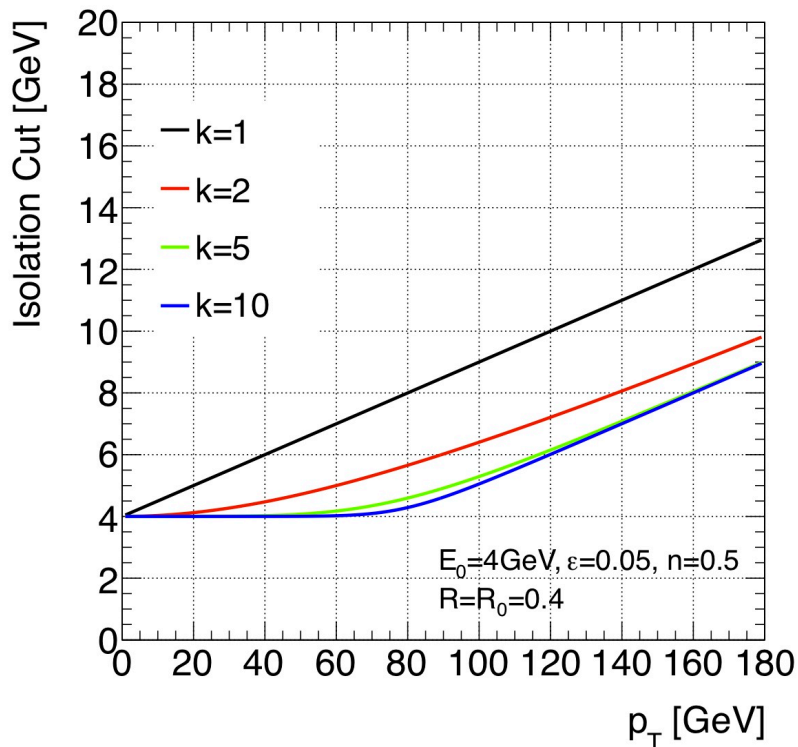


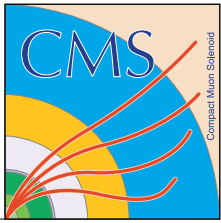
Generalized prescription

$$E_T^{iso} < \left((E_0)^k + (\varepsilon \cdot p_T)^k \right)^{1/k} \left(\frac{1 - \cos R}{1 - \cos R_0} \right)^n$$

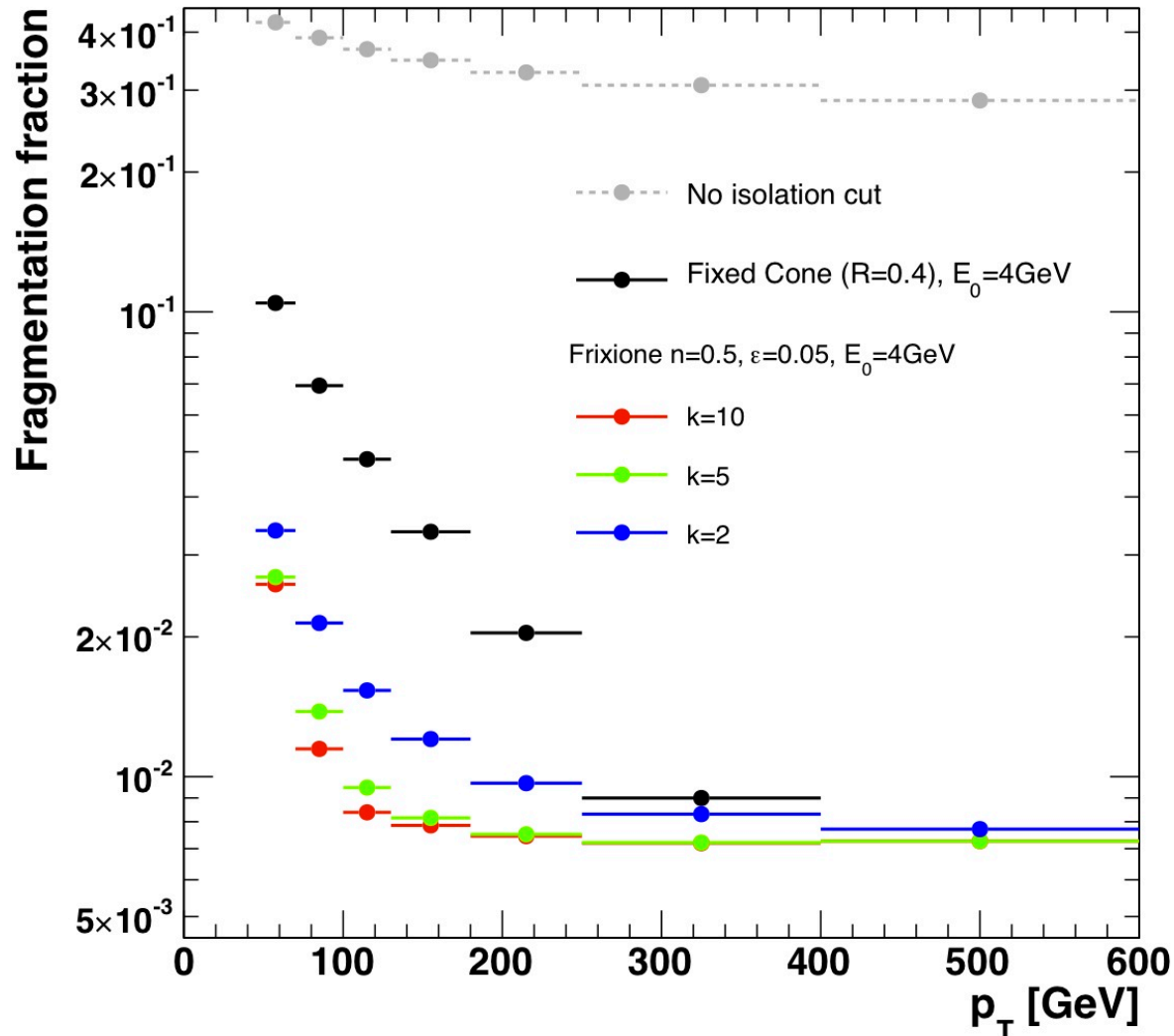
Add two extra-parameters for more flexibility :

- Allowed energy increasing at high p_T
- Ensure that the allowed isolation energy has a **non-zero plateau at low p_T**



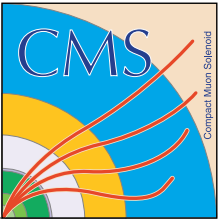


Generalized prescription in $\gamma\gamma+X$ at NLO



Tried generalized prescription with Diphox

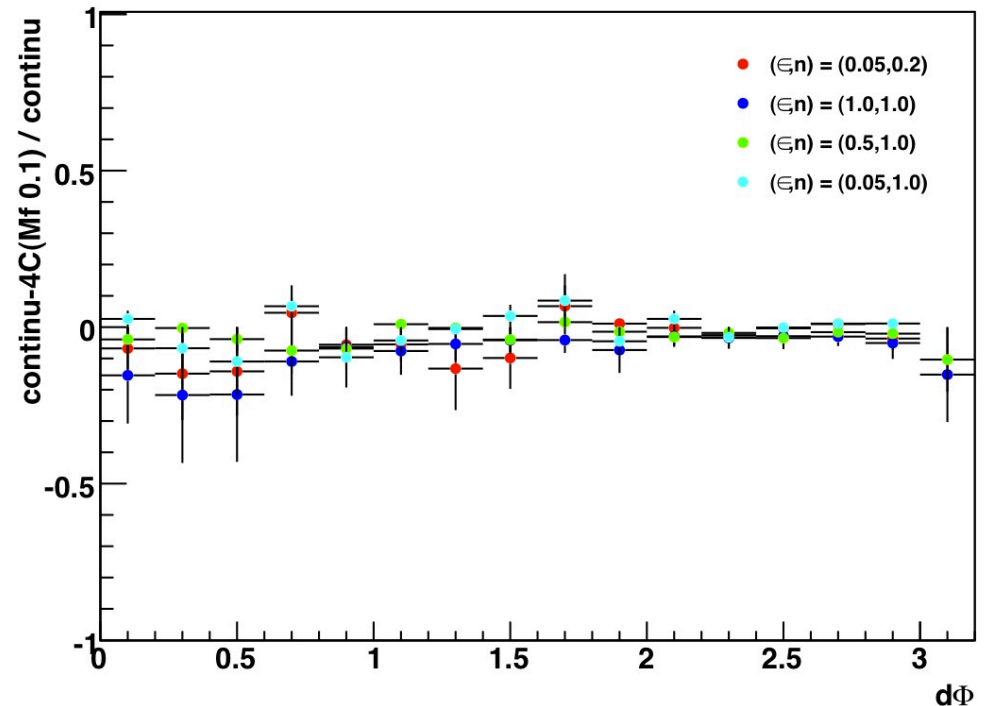
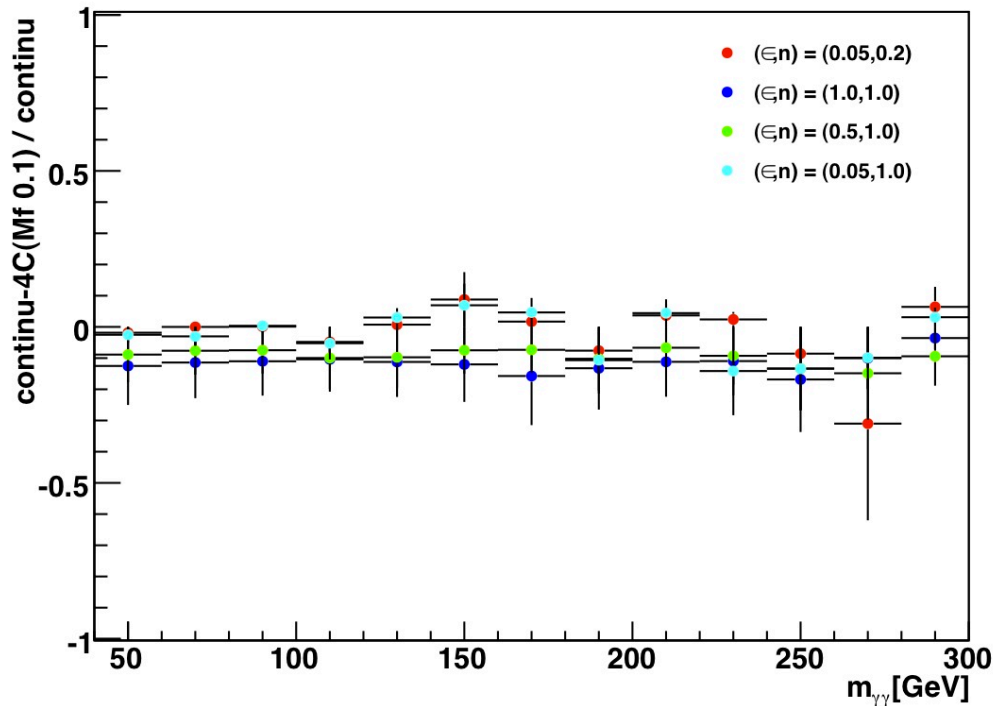
- It is possible for reduce the fragmentation contribution further than the fixed cone criterion
- Fragmentation fraction at the percent level are achievable

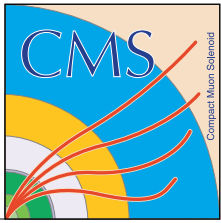


Discrete vs continuous criterion in $\gamma\gamma+X$ at NLO

Compare continuous and discretized Frixione criteria in Diphox :

- Generally less than 10% difference in cross-section
- Only the low $\Delta\Phi$ region is more affected (until 30% difference), because the fragmentation fraction is higher here

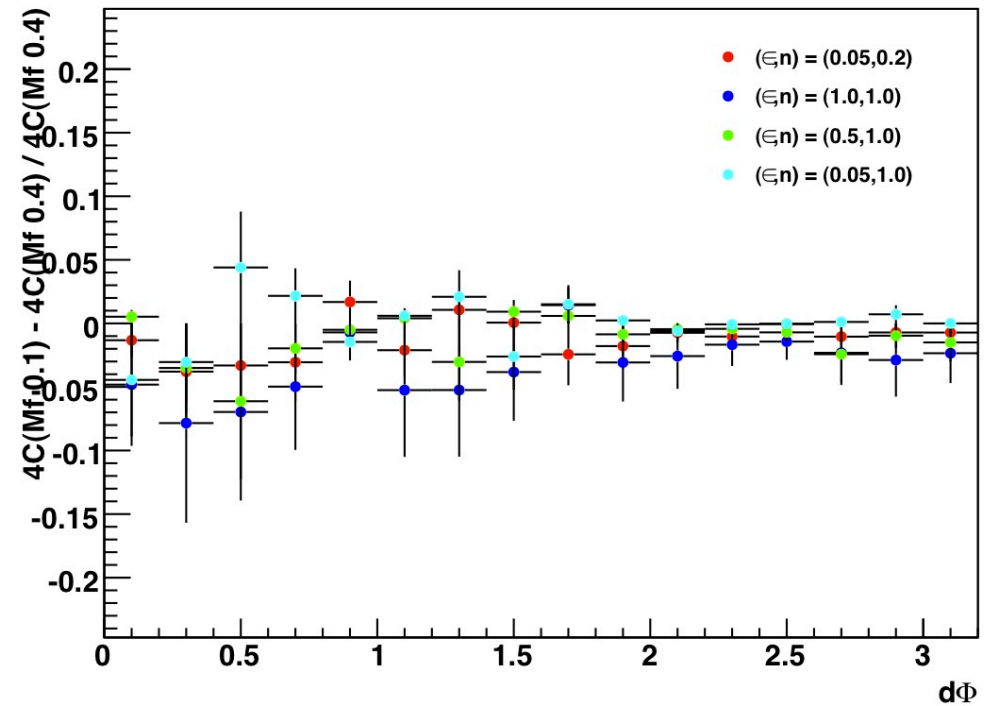
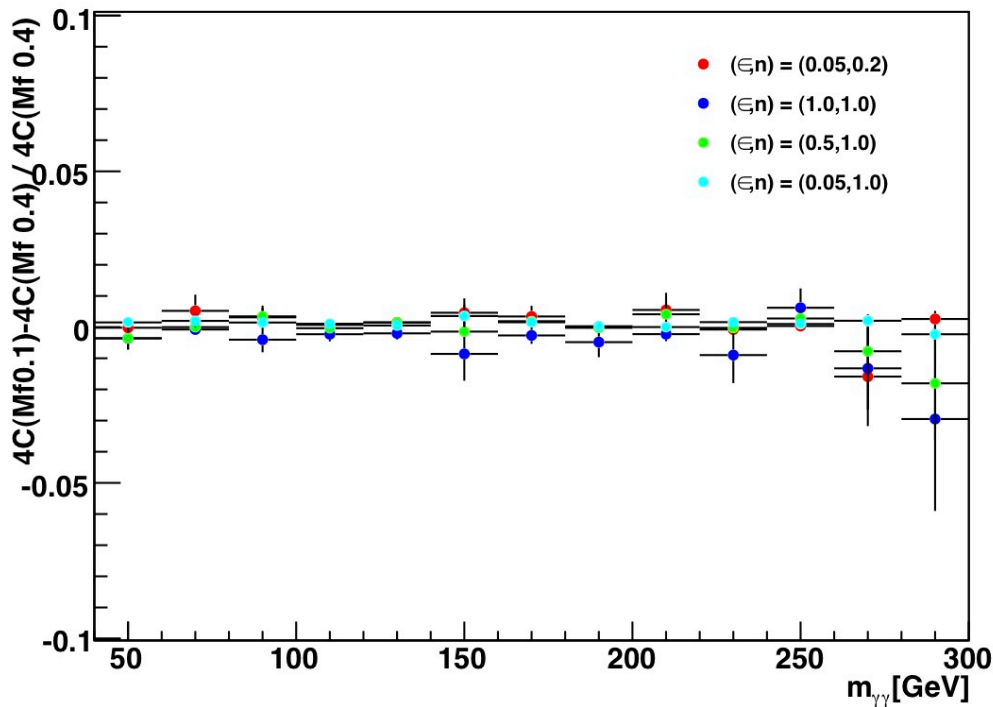




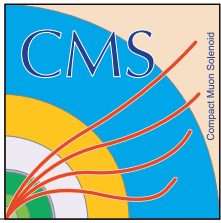
Fragmentation scale dependence in $\gamma\gamma+X$ at NLO

Compared two fragmentation scales in Diphox :

- $M_F = R_{\min} \cdot \min(p_{T1}, p_{T2})$ with $R_{\min} = 0.1$
- $M_F = R_{\max} \cdot \min(p_{T1}, p_{T2})$ with $R_{\max} = 0.4$
- Very small scale dependence is observed (less than 5%)



Fragmentation photons in parton- shower Monte-Carlo



Study of Fragmentation with parton-shower MC

Motivation

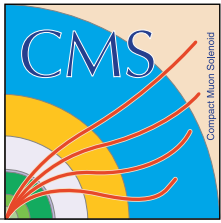
- Frixione isolation already studied or at least available in higher order codes (Jetphox/Diphox/Gamma2MC/Resbos, 2gNNLO)
- Data/theory comparisons of photon processes with Frixione isolation are needed
- How does the Frixione isolation impacts the fragmentation contribution in showered events ?

Fragmentation photons in Pythia

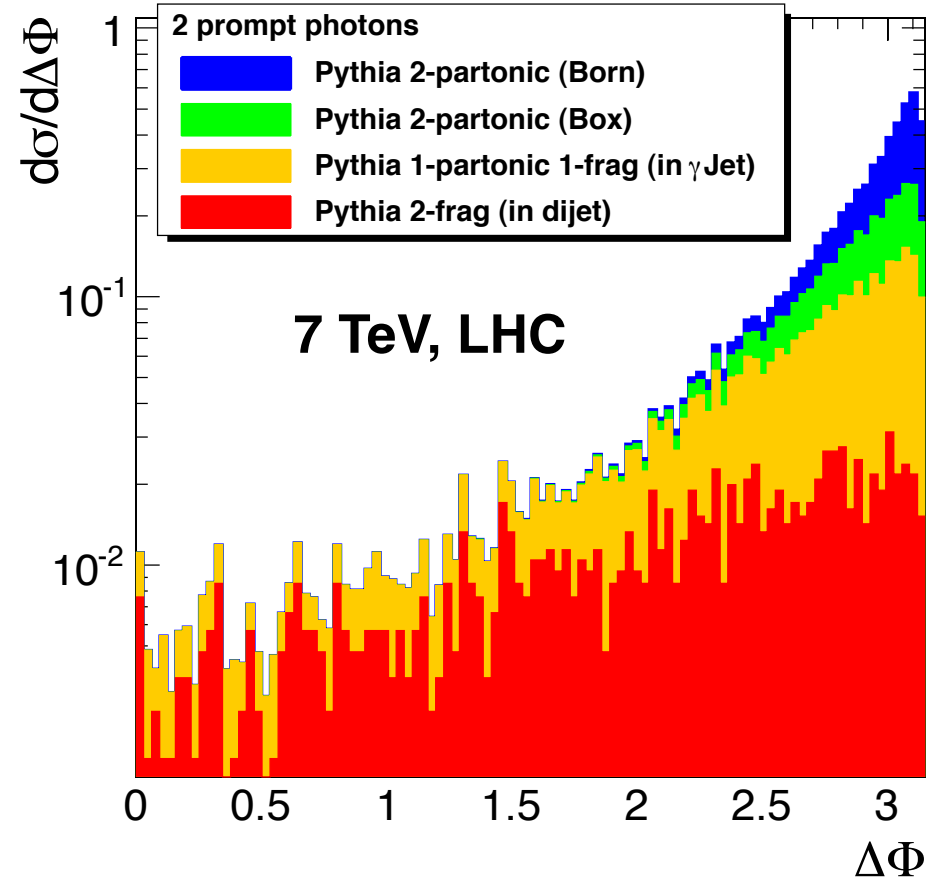
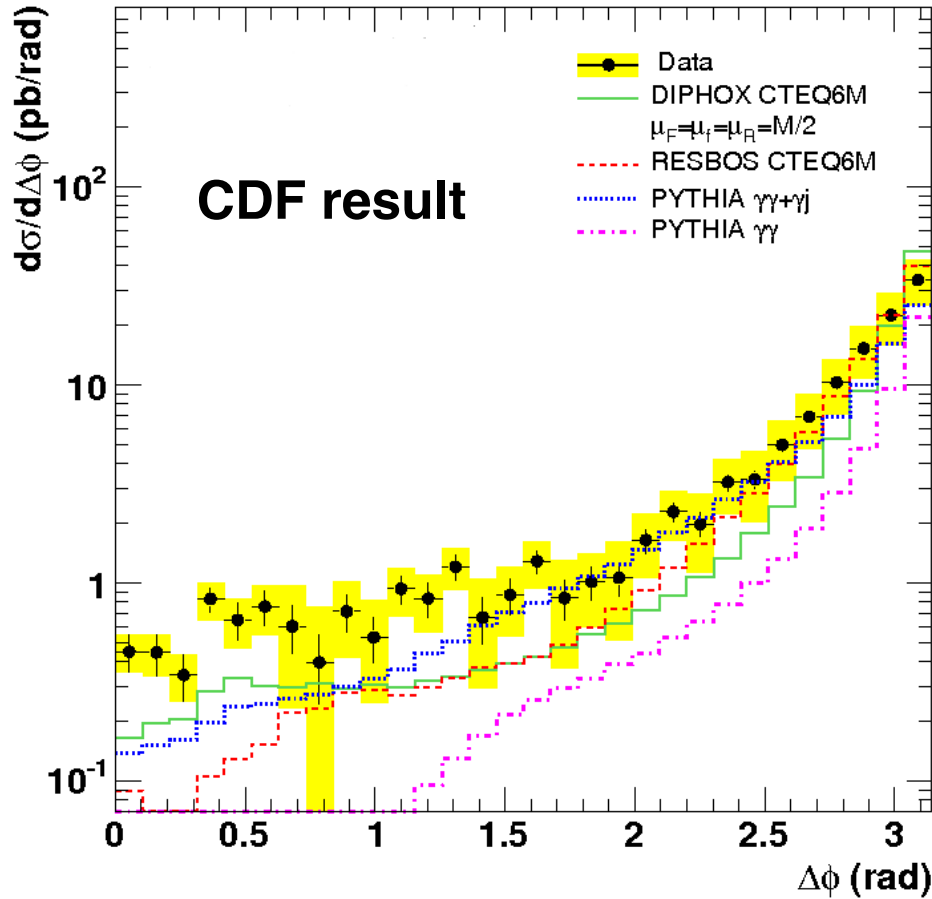
- QED radiation off the the quark or the gluon (ISR or FSR) during the showering process
- Leading log accuracy + momentum conservation
- Emission at non-zero angle : how ?
- Probability of photon emission follows the **branching fraction** (at a running scale) :

$$P_{q \rightarrow q\gamma}(z) = e_q^2 \frac{1+z^2}{1-z}$$

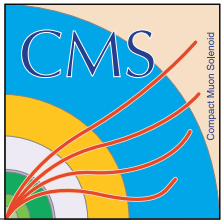
With z fraction of the quark momentum carried by the photon



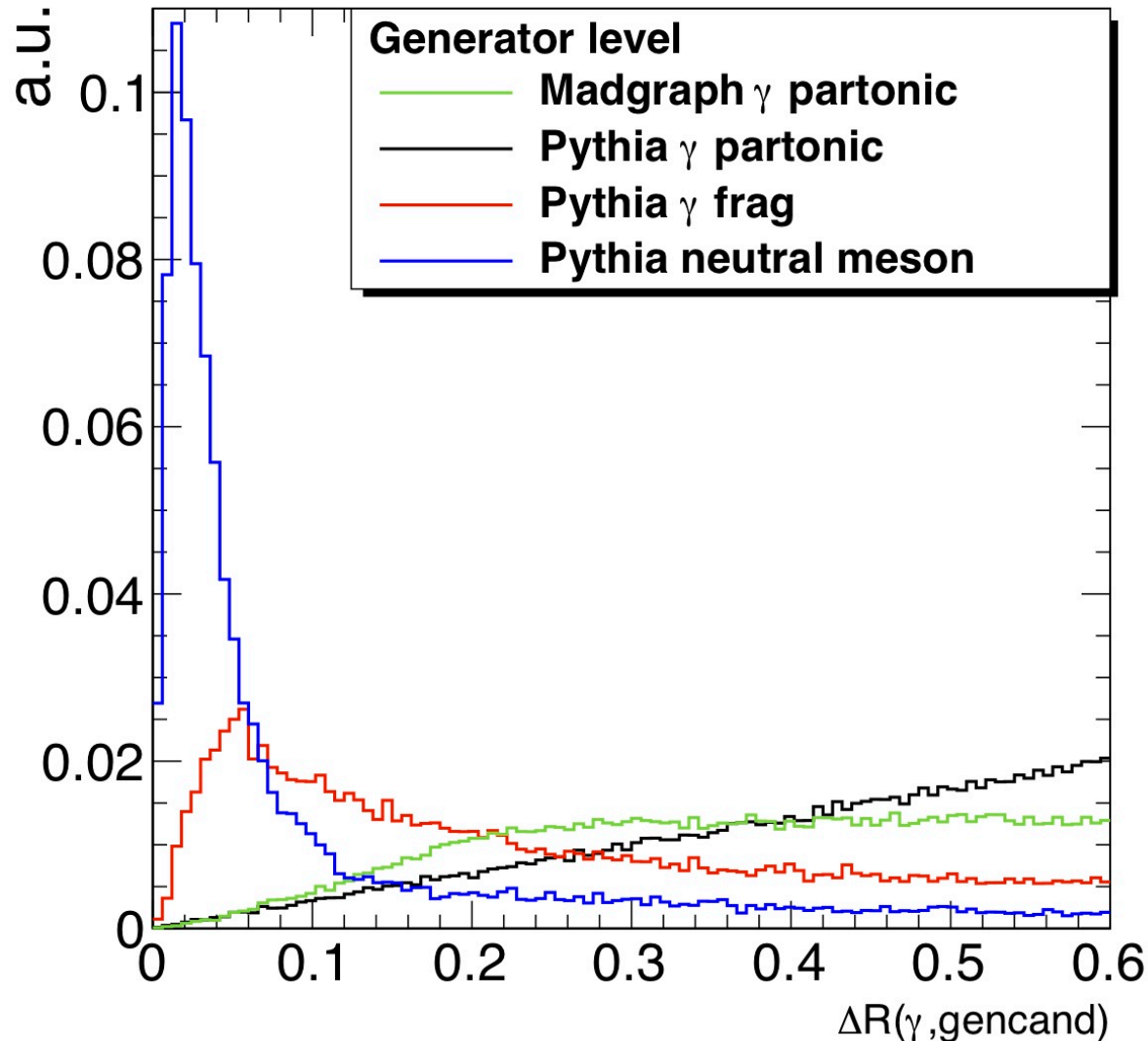
Pythia 2-prompt distribution : $\Delta\phi_{\gamma\gamma}$



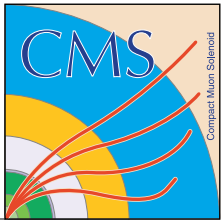
- **Pythia 2-prompt** : Born, Box, 1-frag from γ +jet, 2-frag from dijet process
- Tail at **low $\Delta\phi_{\gamma\gamma}$** populated only by **fragmentation** contribution in Pythia
- About **~50% of fragmentation contribution in Pythia (ISR/FSR)**, both at Tevatron and LHC



Non-collinearity of the fragmentation in Pythia

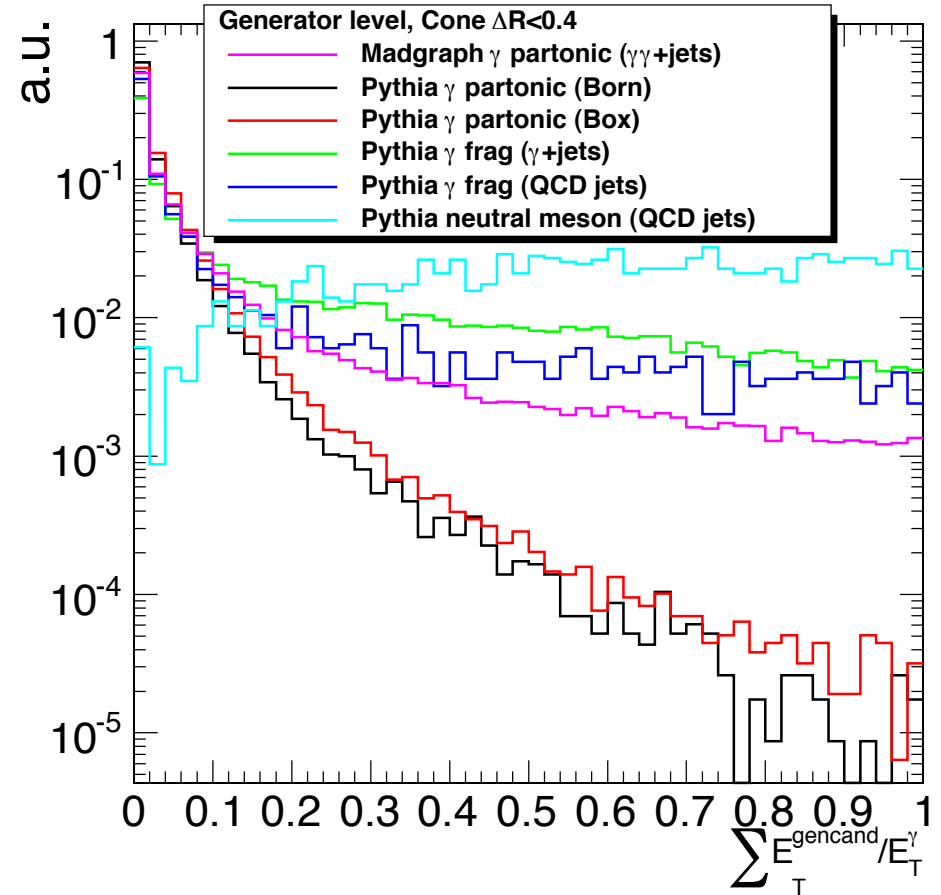
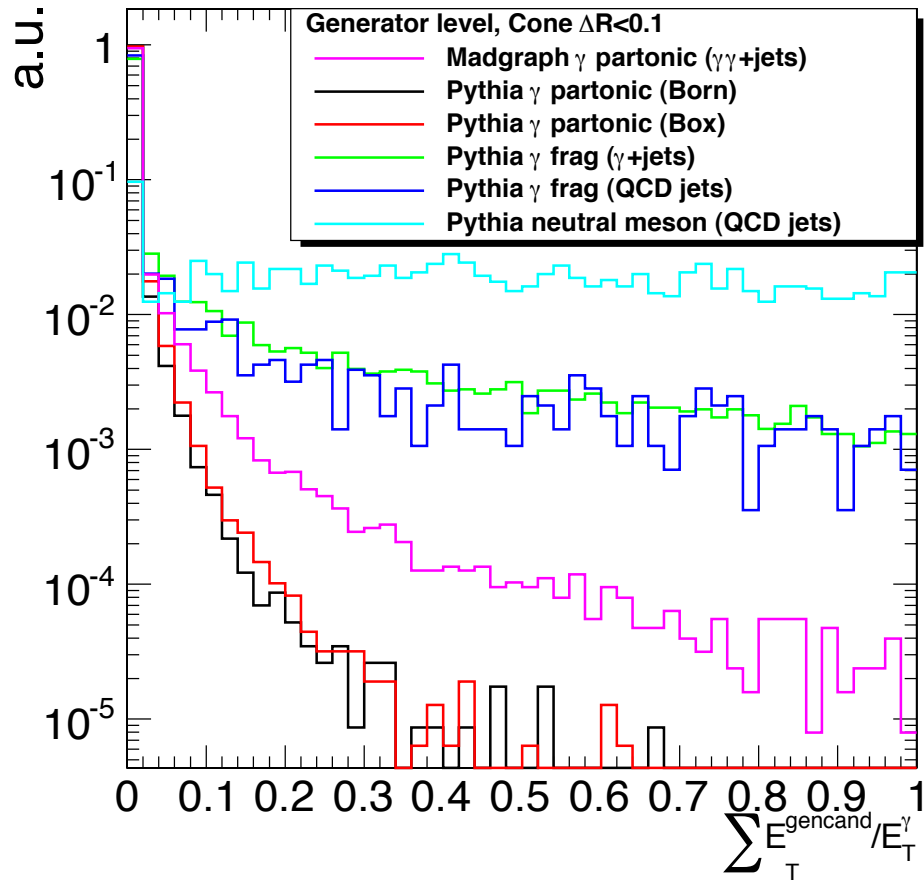


- One entry : E_T of one gen candidate at a given ΔR from the photon
- **Gen level without pile-up, after showering, hadronization and underlying-event (UE)**
- Partonic have linear profile (UE)
- Fragmentation (ISR/FSR) and fake photons are peaked close to $\Delta R \sim 0$
- Madgraph $\gamma\gamma$ +jet has fragmentation as brem contribution at ME level \Rightarrow more away from the quark debris



Isolation energies in cones

$\Delta R < 0.1$ and $\Delta R < 0.4$



- Define (normalized) **isolation energy in a ΔR cone as $\Sigma E_{T,gencand}/E_{T,\gamma}$**
- Using narrower cones, discrimination against fragmentation photons (and neutral mesons) is increased



'Hollow' (or 'crown') isolation

Hollow cones :

- **allows energy in the inner-most cone around the photon**
=> Try to enhance fragmentation contribution (assuming fragmentation is colinear)
- Also more similar to experimental isolation

- It works NLO and it impacts kinematics

<http://indico2.lal.in2p3.fr/indico/getFile.py/access?contribId=35&sessionId=2&resId=0&materialId=slides&confId=1109>

- **Very small increase of fragmentation fraction at parton-shower level**
- Possible explanation : criteria on $\Delta R < 0.4$ and $\Delta R < 0.1$ are more correlated in parton-shower

Criteria	1-frag fraction	2-frag fraction	1,2-frag fraction
Solid $\Delta R < 0.4, E_T^{iso} < 5 \text{ GeV}$	0.335	0.157	0.492
Hollow $0.1 < \Delta R < 0.4, E_T^{iso} < 4 \text{ GeV}$	0.337	0.168	0.505

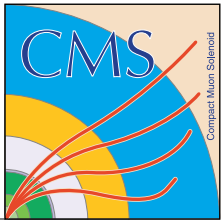


Frixione isolation

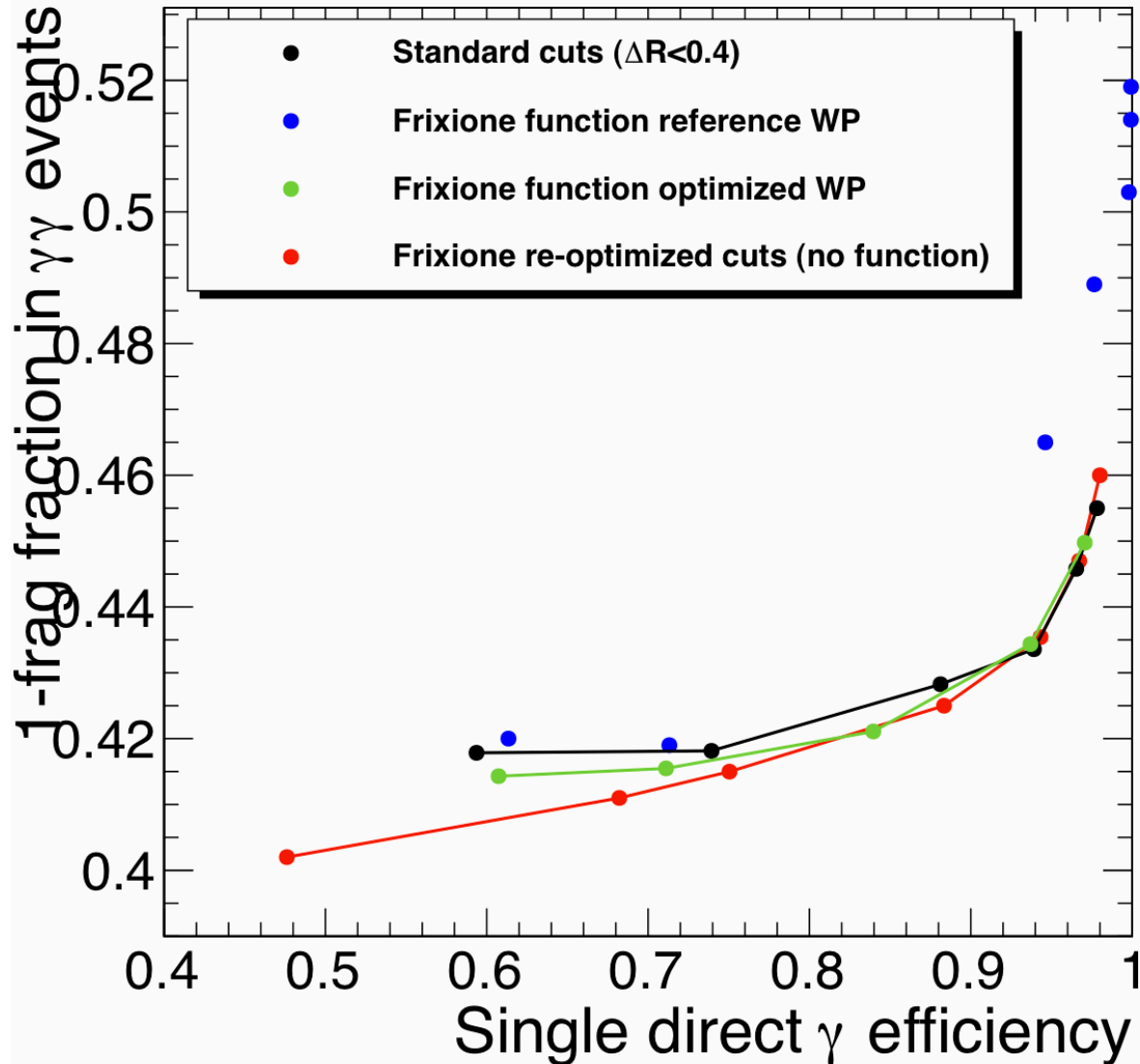
- Tried the same working points as those tested with JetPhox/Diphox previously
- **The fragmentation fraction can be reduced by only 7% with respect to the standard isolation**
- Will need to optimize the working points

Table 2: Purity of 1-fragmentation contribution for various Frixion isolation criteria in Pythia two-prompt photon samples (without enrichment filter).

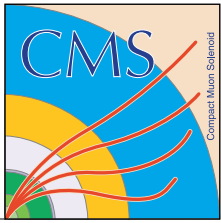
Criteria	1-frag purity
Solid $\Delta R < 0.4, E_T^{iso} < 5 \text{ GeV}$	0.455
Hollow $0.1 < \Delta R < 0.4, E_T^{iso} < 4 \text{ GeV}$	0.458
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.05, n = 1.0$	0.420
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.05, n = 0.2$	0.419
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.2$	0.514
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.1$	0.519
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 1.0$	0.489
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.5$	0.503
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.5, n = 1.0$	0.465



Frixione isolation : performance



- **BLACK** : standard isolation in a cone $\Delta R < 0.4$
- **BLUE** : working points as those tested with JetPhox/Diphox previously (not optimized)
- **GREEN** : optimized working points found by scanning over ε and n in the Frixione functional form
- **RED** : optimized working points found by re-optimizing each cut on the cones 0.1, 0.2, 0.3, 0.4 (no functional form used)



Conclusions / perspectives

NLO studies :

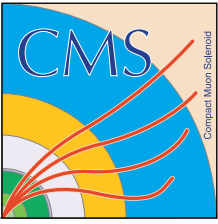
- Discretized Frixione isolation : independent of the number of cones used
- **Generalized Frixione prescription** allows to reduce significantly **fragmentation fraction**, while not cutting too tight at low p_T : very promising
- **Fragmentation fraction can be reduced at the per-cent level**

Parton-shower studies :

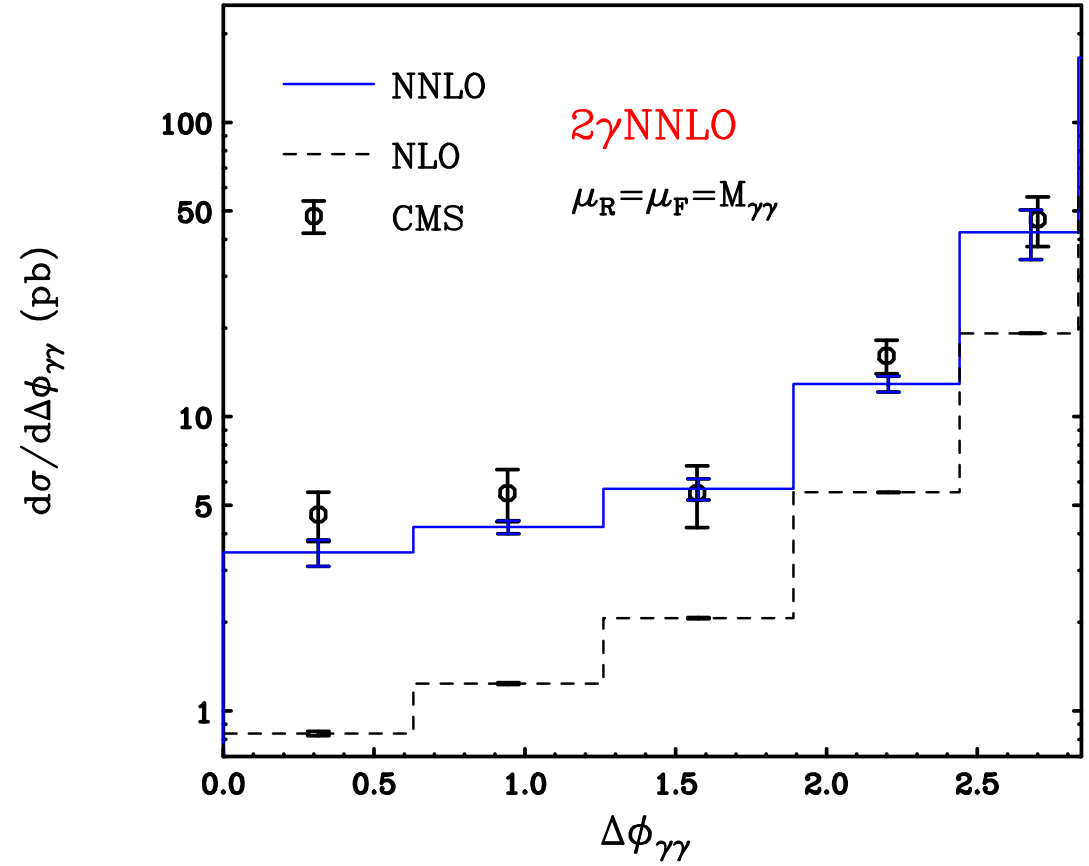
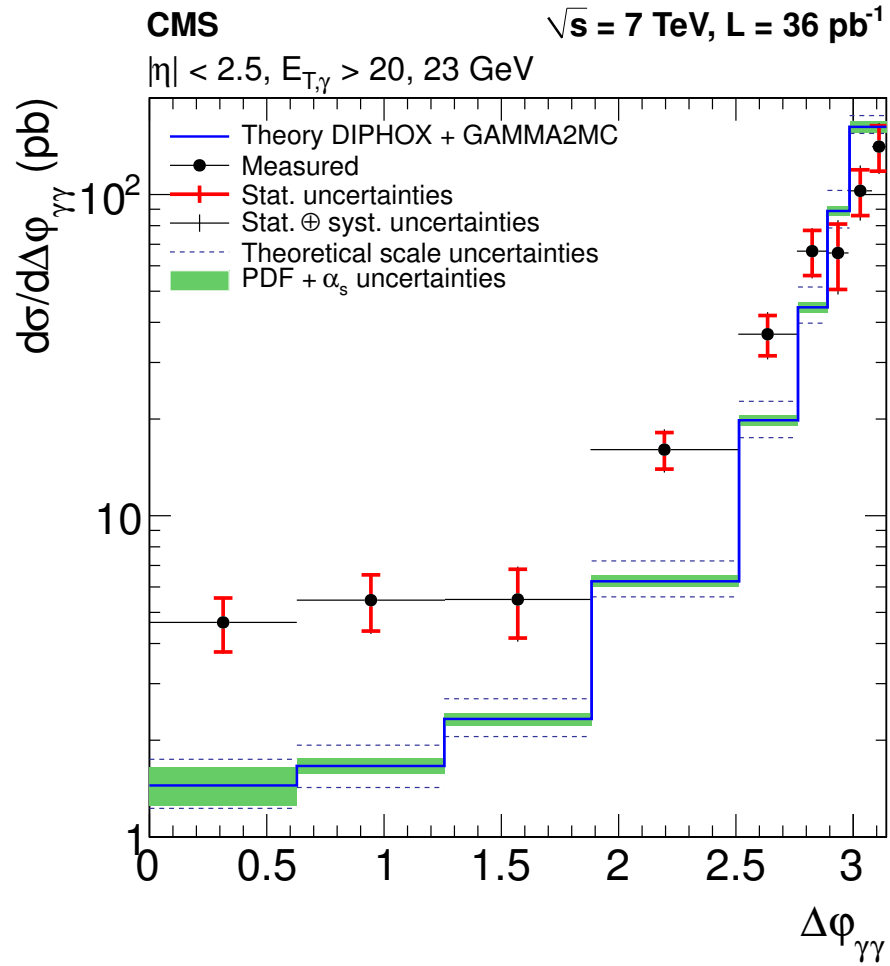
- Isolation profile of fragmentation photons is **not collinear anymore** because of **showering, hadronization**
- **10% decrease in fragmentation fraction** can be achieved at a cost of **~60% signal efficiency loss**.
- Usual Frixione functional form has been found to be not completely optimal.
Reoptimizing the cuts for each cones helps to increase signal efficiency
- **More work is needed to make compatible isolation prescriptions at NLO and in parton-shower Monte-Carlo**
- **How to get closer to a parton-level isolation in showered events ?**

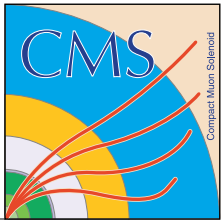


BACK-UP SLIDES

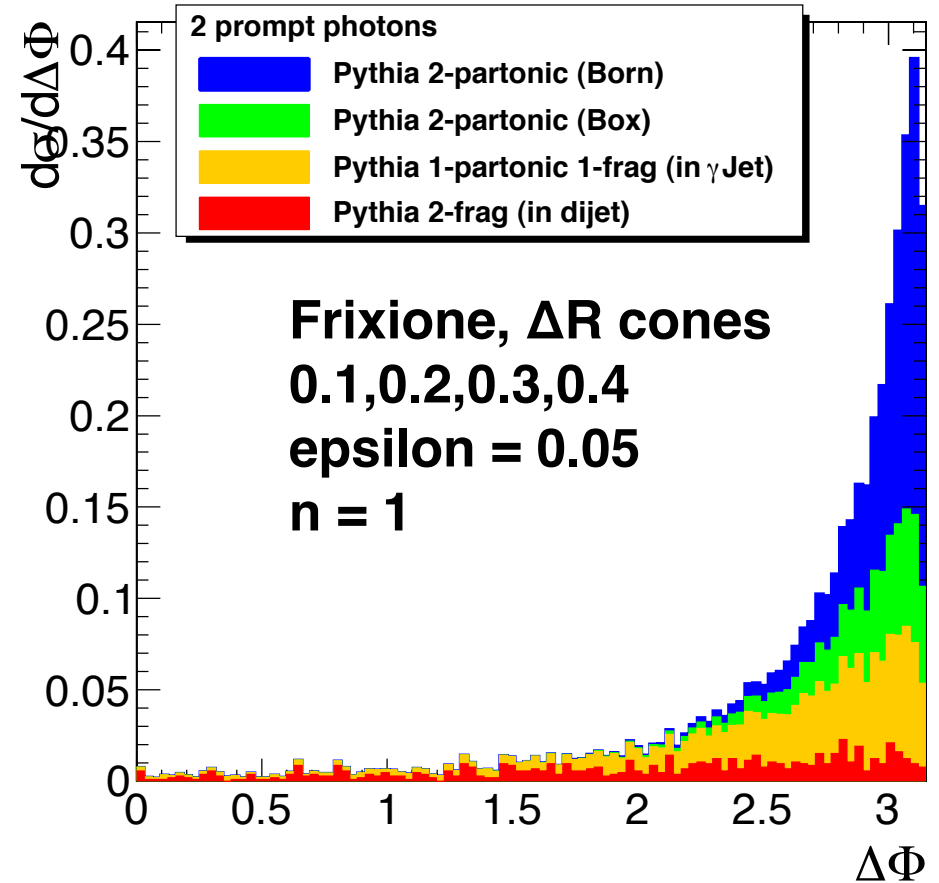
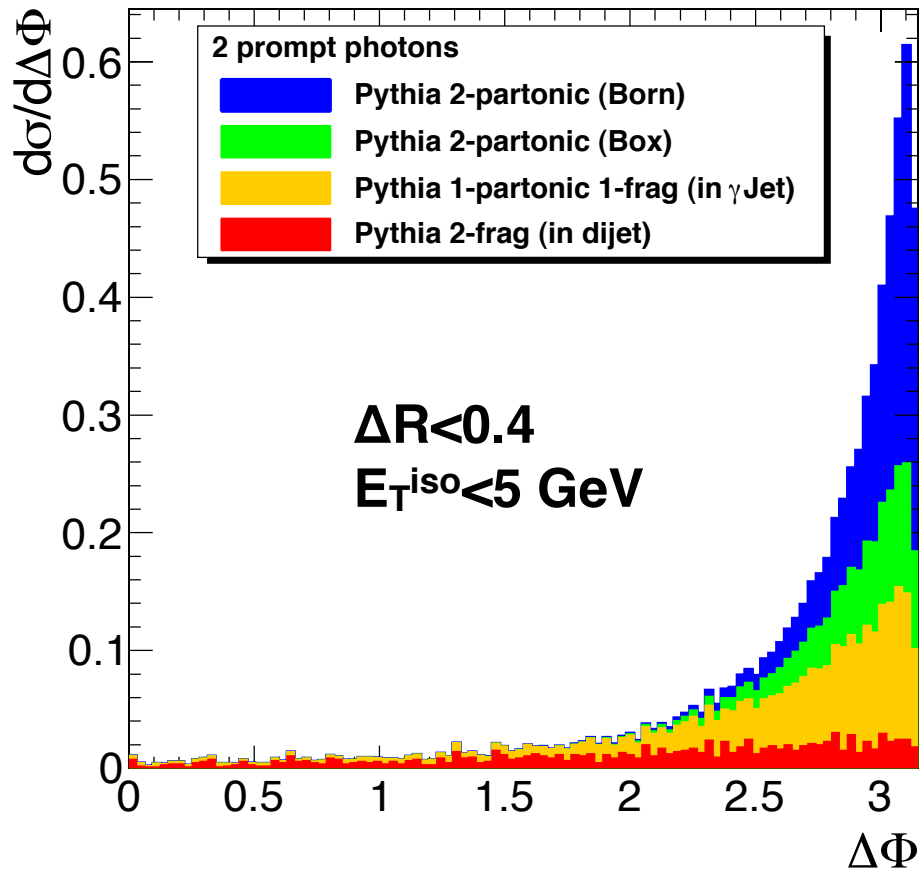


$\Delta\phi_{\gamma\gamma}$: Data/MC

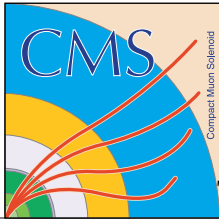




Frixione isolation : example



- $\Delta\phi$ shown for illustration (in Pythia, low $\Delta\phi$ tail is populated only with frag)
- Frixione isolation seems to reduce slightly the fragmentation contribution (numbers next slide) with respect to standard isolation



Impact of Frixione isolation

Table 1: Purity of 1-fragmentation and 2-fragmentation contributions for various Frixion isolation criteria in Pythia two-prompt photon samples (with electromagnetic enrichment filter).

Criteria	1-frag purity	2-frag purity	1,2-frag purity
Solid $\Delta R < 0.4, E_T^{iso} < 5 \text{ GeV}$	0.335	0.157	0.492
Hollow $0.1 < \Delta R < 0.4, E_T^{iso} < 4 \text{ GeV}$	0.337	0.168	0.505
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.05, n = 1.0$	0.322	0.145	0.467
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.05, n = 0.2$	0.318	0.147	0.466
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.2$	0.372	0.228	0.599
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.1$	0.374	0.232	0.601
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 1.0$	0.353	0.192	0.545
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 1.0, n = 0.5$	0.365	0.212	0.577
Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.5, n = 1.0$	0.343	0.176	0.518

Table 2: Purity of 1-fragmentation contribution for various Frixion isolation criteria in Pythia two-prompt photon samples (without enrichment filter).

Criteria	1-frag purity
Solid $\Delta R < 0.4, E_T^{iso} < 5 \text{ GeV}$	0.455
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Frixione 8 cones, $E_T = 20 \text{ GeV}, \epsilon = 0.05, n = 1.0$	0.420
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Reference working
points from Les
Houches 2009