PHOTON ISOLATION

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Les Houches Workshop Series
Physics at TeV Colliders
Session 1

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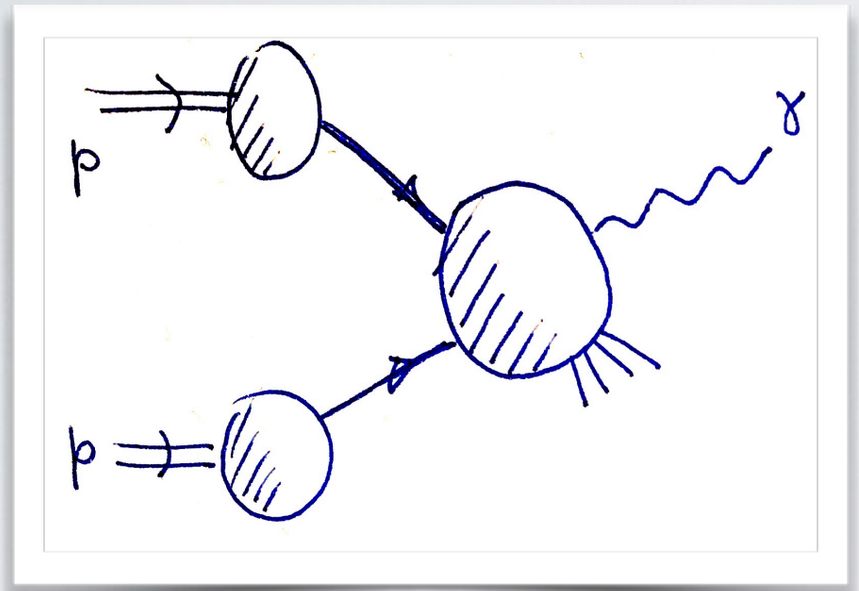
MOTIVATION

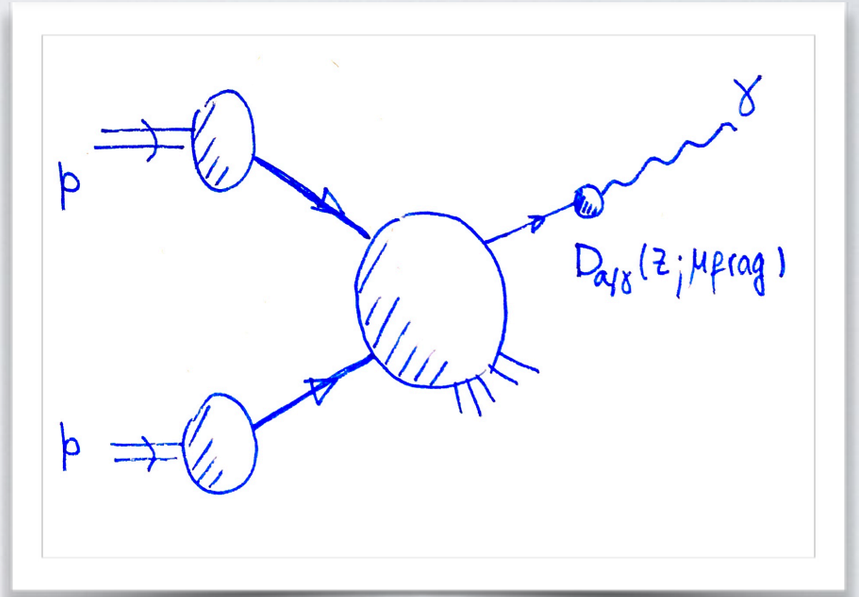
- Photon isolation criteria are necessarily applied in hadron collider experiments to suppress the very large reducible background of 'non-prompt' photons (e.g., photons that are faked by jets or produced by hadron decays)

PHOTONS

- Final-state prompt photons

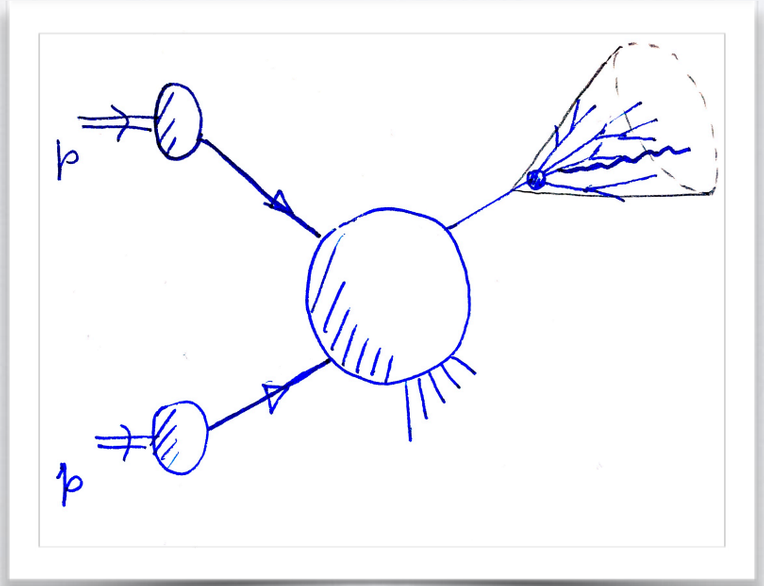


- Direct

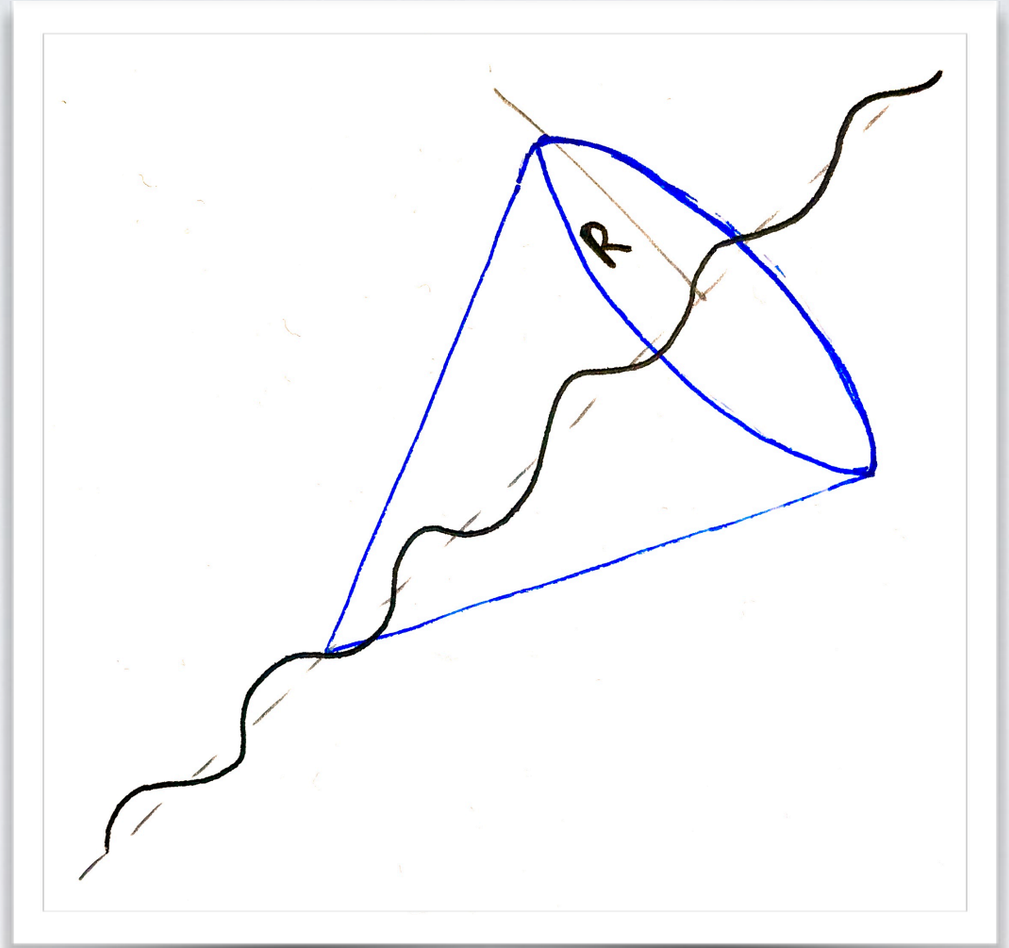


- Fragmentation

- 'Non-prompt' photons



ISOLATION PRESCRIPTIONS



$$E_T^{had}(r) = \sum_i E_{T\,i}^{had}\ \Theta(r - R_{i\gamma})$$

Usually, the criteria consider the amount of hadronic (partonic) transverse energy, inside a cone of radius r around the direction of the photon

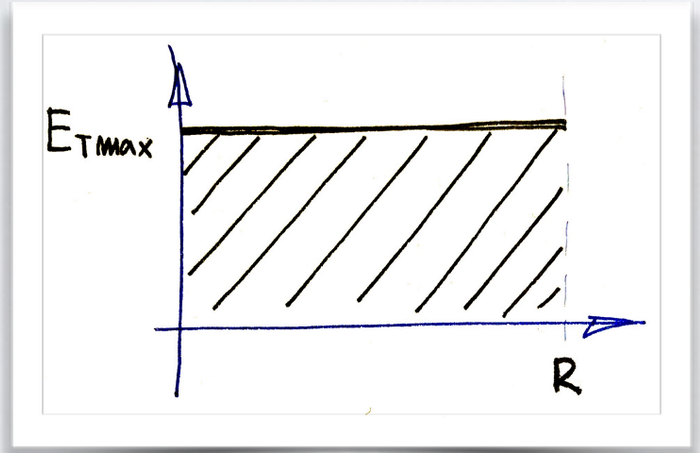
$$(R_{i\gamma}^2 = (y_i - y_\gamma)^2 + (\Phi_i - \Phi_\gamma)^2)$$

rapidity–azimuthal angle space

ISOLATION PRESCRIPTIONS

Standard cone criterion

- Typically used by experimental analyses
- It can be experimentally implemented in a relatively straightforward manner
- Solid and well understood
- It only suppresses part of the fragmentation contribution



$$E_T^{had}(R) \leq E_{T\,\mathrm{max}}$$

$E_{T\,\mathrm{max}}$ fixed parameter

$E_{T\,\mathrm{max}} = \epsilon\, p_{T\gamma}$ with a fixed parameter ϵ

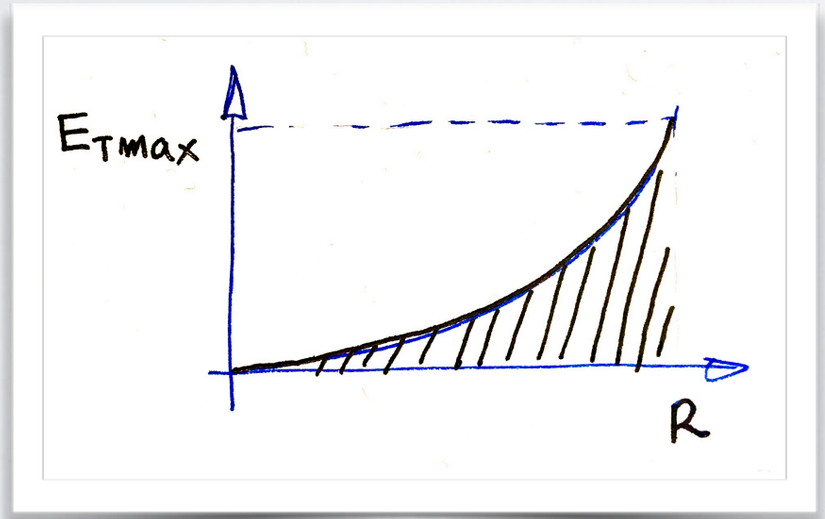
$E_{T\,\mathrm{max}} = \epsilon\, p_{T\gamma} + E_o$ with E_o fixed parameter

ISOLATION PRESCRIPTIONS

Smooth cone criterion

Frixione [1998]

- Typically used by theoretical tools
- Due to the finite granularity of the detectors, it cannot be directly applied at the experimental level in its original form
- It formally eliminates the entire fragmentation contribution



$$E_T^{had}(r) \leq E_{T\,\max}\ \chi(r;R)\ , \qquad \text{in } \textit{all} \text{ cones with } r \leq R$$

$$d\sigma_{\rm smooth}(R;E_{T\,\max}) < d\sigma_{\rm standard}(R;E_{T\,\max})$$

$$\chi(r;R) = \left(\frac{1-\cos(r)}{1-\cos(R)}\right)^n$$

$$\chi(r;R) = \left(\frac{r}{R}\right)^{2n}$$

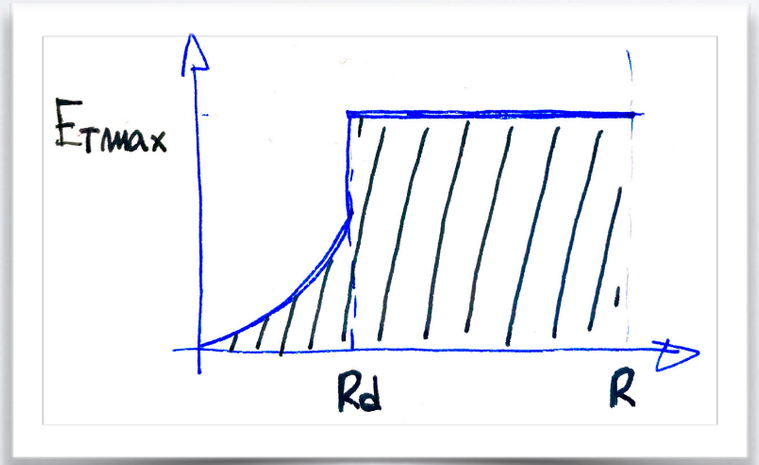
ISOLATION PRESCRIPTIONS

Hybrid cone criterion

Siegert [2016]
Chen, Gehrmann, Glover, Höfer, Huss[2019]

- Used by theoretical tools
- Due to the finite granularity of the detectors, it cannot be directly applied at the experimental level in its original form
- It formally eliminates the entire fragmentation contribution
- The aim of the method is reduce the strong suppression of the smooth cone prescription

$R^2 \gg R_d^2$



BRIEF LIST OF CODES

Process	Codes QCD	EW corrections (NLO)	Resummation
$pp \to \gamma + \mathrm{Jet}$	JetPhox: NLO(QCD)+NLO(Frag) [99'] MCFM: NNLO(QCD) [2016/2017] NNLOJET: NNLO(QCD) [2019]	Kuhn, Kulesza, Pozzorini, Schulze [2005] Becher, Garcia i Tormo [2013] Schwartz [2016]	Peter: N^3LL Threshold Resummation arXiv:1206.6115
$pp \to \gamma\gamma$	DiPhox: NLO(QCD)+NLO(Frag) [99'] 2yNNLO: NNLO(QCD) [2011] MCFM: NNLO(QCD) [2016] MATRIX: NNLO(QCD) [2016]	Bierweiler, Kasprzik, Kuhn. [2013] Chiesa,Greiner, Schoenherr, Tramontano [2017]	2yRes: [2015] qT Resummation NNLL+NNLO(QCD) Resbos: [1997] qT Resummation NNLL+NLO(QCD)
$pp \to \gamma\gamma + \mathrm{Jets}$	NLOJet++: NLO(QCD). [2003] 2yNNLO: NLO(QCD) [2011] Gehrmann, Greiner, Heinrich: NLO(QCD)+LO(Frag) [2013] Bern, Dixon, Febres Cordero, Hoeche, Ita, Kosower, Lo Presti, Maitre [2013] Badger, Guffanti, Yundin [2013] Greiner, Fäh [2017]	Chiesa,Greiner, Schoenherr, Tramontano [2017]	
$pp \to Z\gamma$ $pp \to W\gamma$	MATRIX: NNLO(QCD) [2015] MCFM: NNLO(QCD) (Zy) [2017]	Denner, Dittmaier, Hecht, Pasold [2015] Denner, Dittmaier, Hecht, Pasold [2014]	

BRIEF LIST OF CODES

(Fixed order + Resummation) tools that use smooth cone isolation (in red)

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ISOLATION STUDIES

Brief bibliography

- **Catani, Fontannaz, Guillet, Pilon [2002]**
- **Les Houches (Chanon, Gascon-Shotkin, Guillet, Huston, Pilon, Schwoerer, Stockton, Tripiana) [2011]**
- **Les Houches (LC, de Florian) [2013]**
- **Les Houches (LC, Heinrich) [2015]**
- **Catani, Fontannaz, Guillet, Pilon [2013]**
- **Catani, LC, de Florian, Ferrera, Grazzini [2018]**

$$\chi(\delta) = \left(\frac{1-\cos(\delta)}{1-\cos(R_0)}\right)^n$$

Eric: that was proposed because it matches e+e- dynamics

In hadronic collisions better use $2\left(\cosh(\Delta y) - \cos(\Delta\phi)\right) \sim [(\Delta y)^2 + (\Delta\phi)^2] = r^2$

$$E_T^{had} \leq E_{T\,max}^{had} \left(\frac{r}{R}\right)^{2n}$$

new at LH

	Isolation	$\sum E_T^{had} \leq$	$\chi(r)$	σ_{total}^{NLO}(fb)
i	Frixione	2GeV	$\left(\frac{1}{2} - \frac{1}{2}\cos(\frac{\pi r}{R})\right)$	3760
ii	Frixione	2GeV	$\left(\frac{1}{2} - \frac{1}{2}\cos(\frac{\pi r}{R})\right)^{0.5}$	3921
iii	Frixione	2GeV	r/R	3769
iv	Frixione	2GeV	$(r/R)^2$	3731
v	Frixione	2GeV	$\left(\frac{1-\cos(r)}{1-\cos(R)}\right)$	3724
v	Standard	2GeV	1	3731

← Eric

← Cone

"LH tight photon isolation accord"

- EXP: use (tight) Cone isolation — solid and well understood
- TH: use smooth cone with same R and E_{Tmax} — accurate, better than using cone with LO fragmentation

Estimate TH isolation uncertainties using different profiles in smooth cone

L.Cieri + ALL — Define "tight isolation" + conventional parameters

Les Houches TH Summary [2013]
de Florian talk

ISOLATION STUDIES

New at Les Houches 2019

- Comparison of standard, smooth and hybrid prescriptions using `JETPHOX` and `DIPHOX`
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Regarding f.o tools

ISOLATION STUDIES

The diphoton example

Catani, LC, de Florian, Ferrera, Grazzini [2018]

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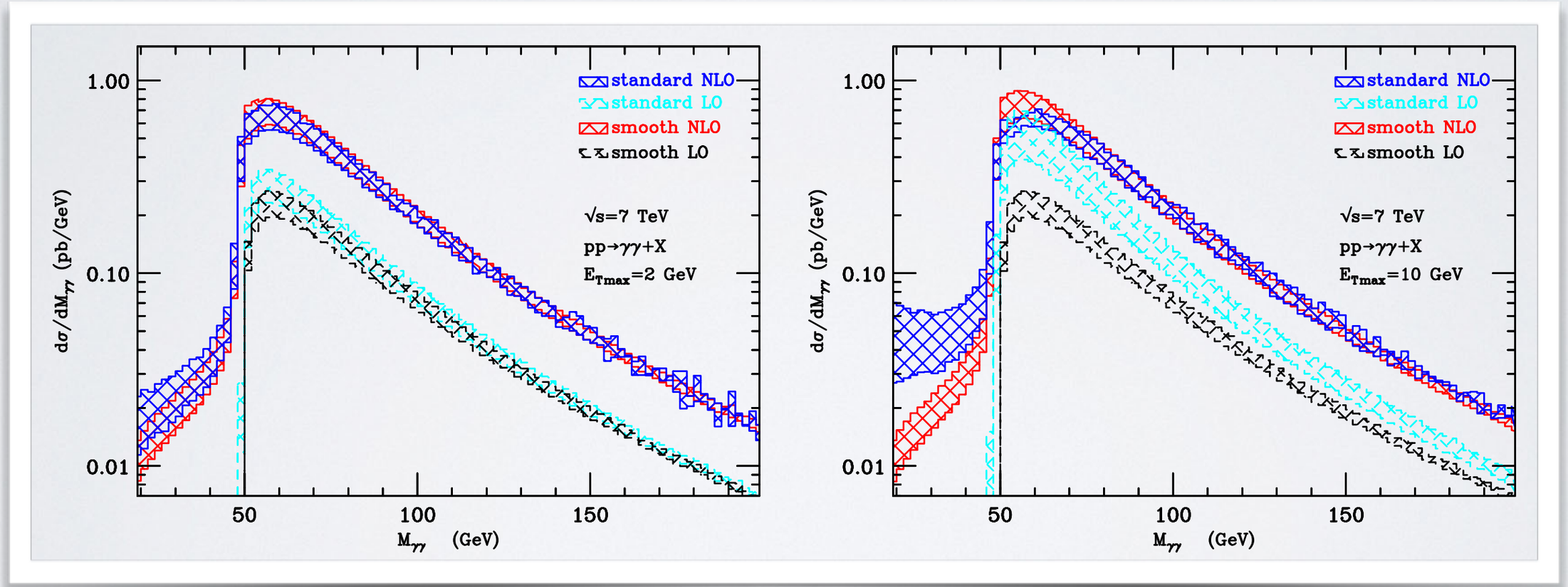

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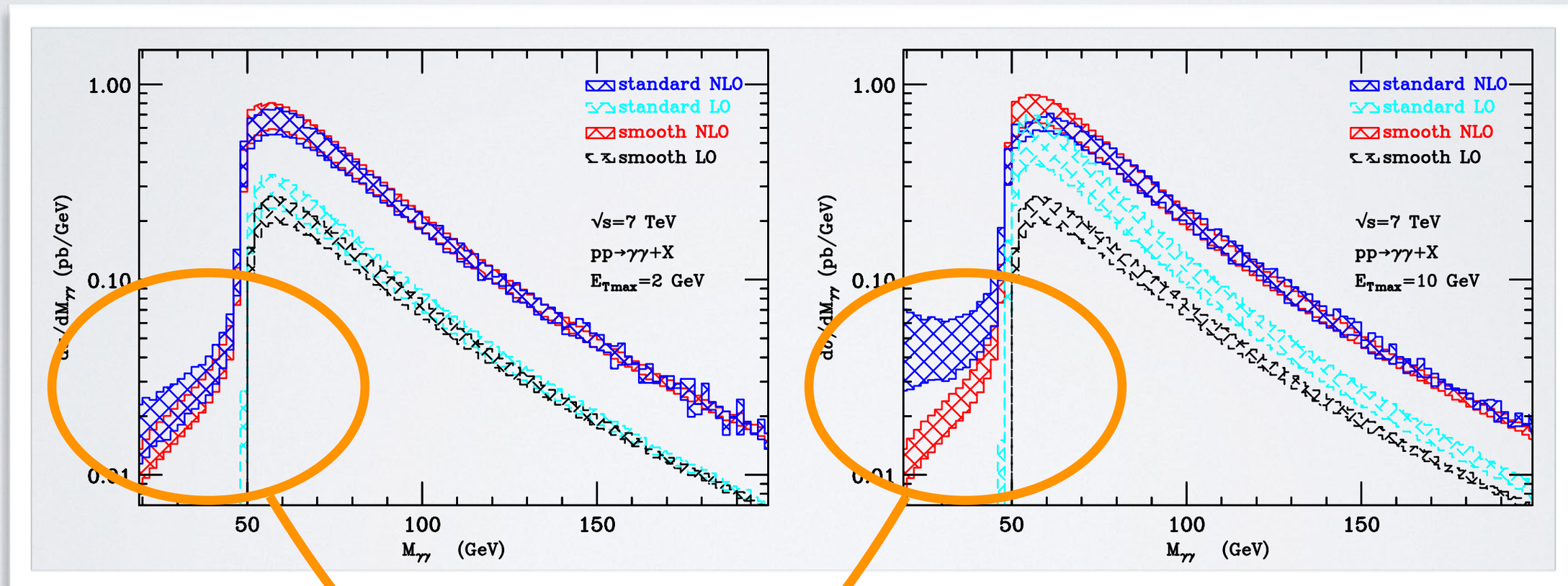

Far away from the back-to-back regions are not affected by changes in the isolation parameters at NLO (using smooth cone)

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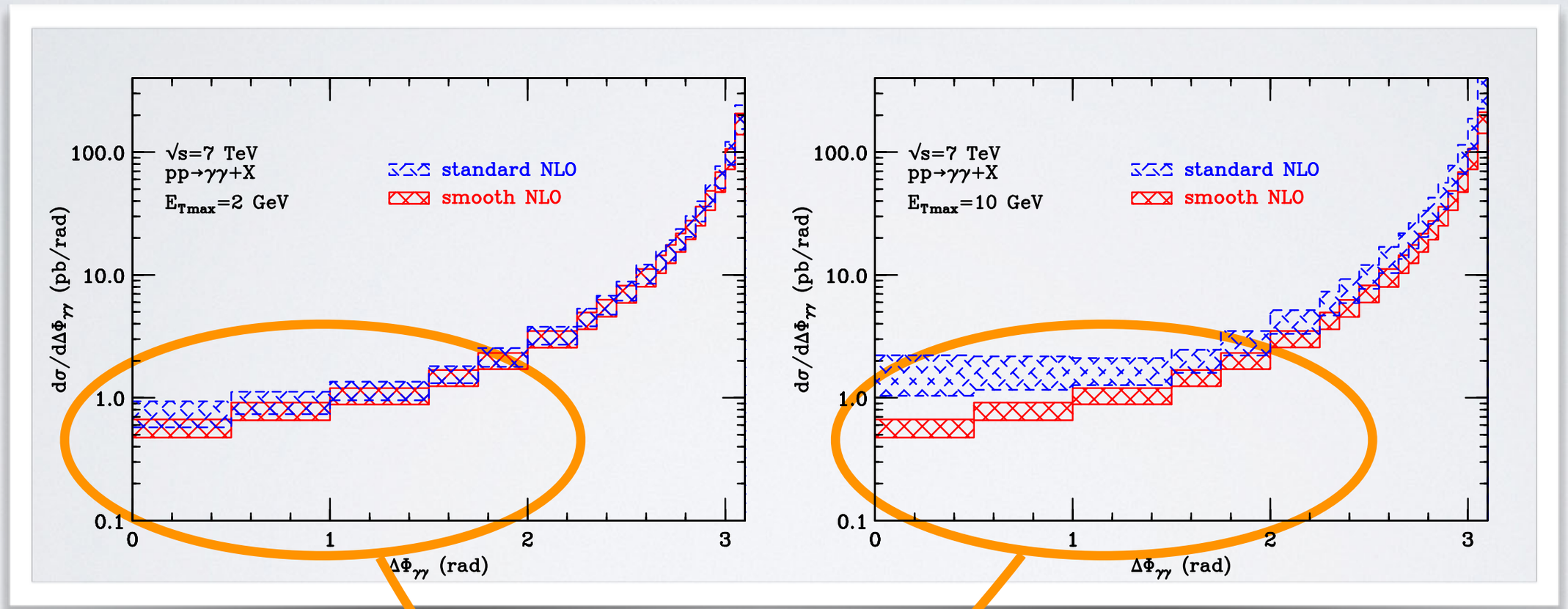

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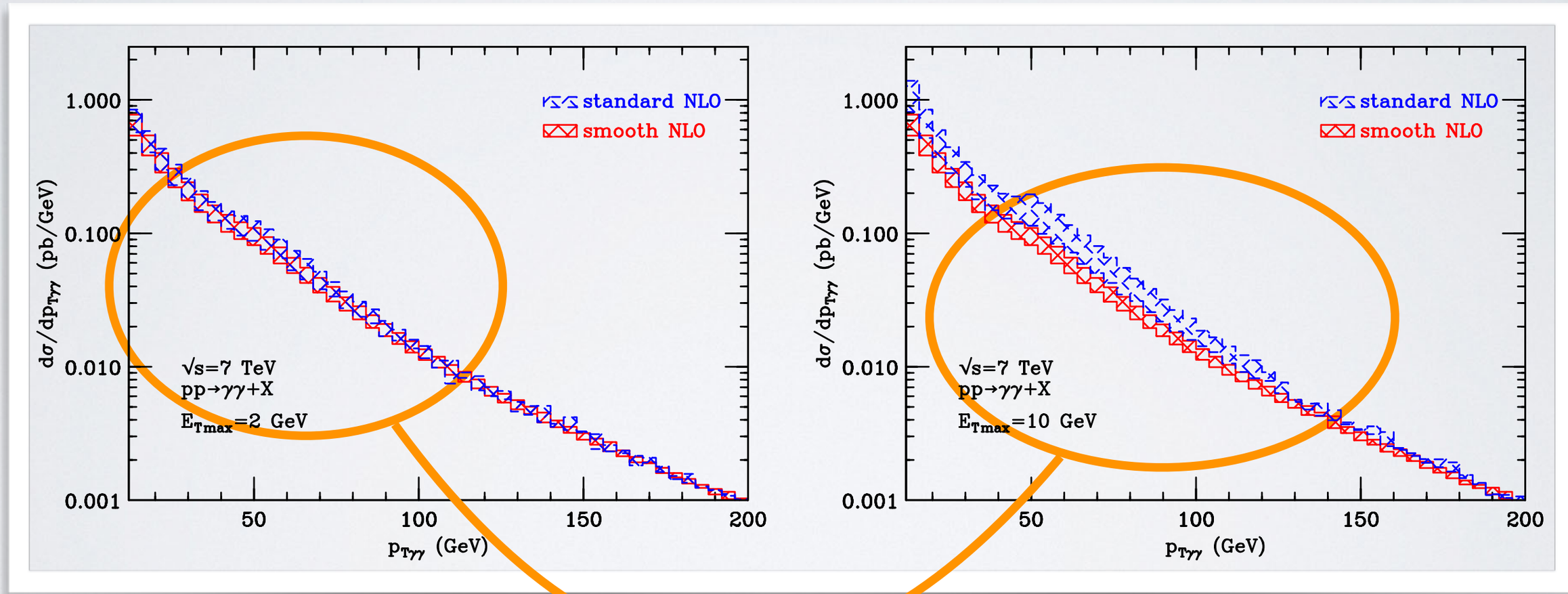

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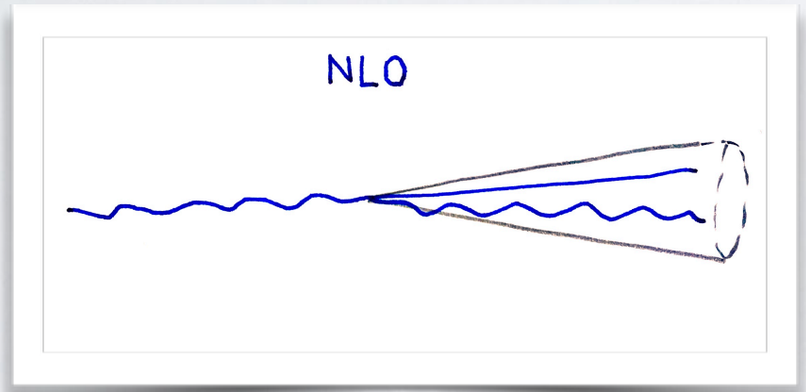
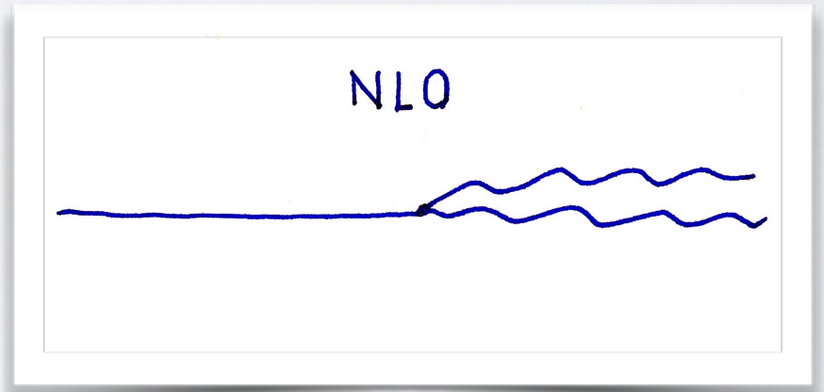


Configurations which are sensible to changes in isolation parameters are near the Born like



Regions far away from the back-to-back configuration are not affected by changes in the isolation parameters at NLO (using smooth cone)

ISOLATION STUDIES

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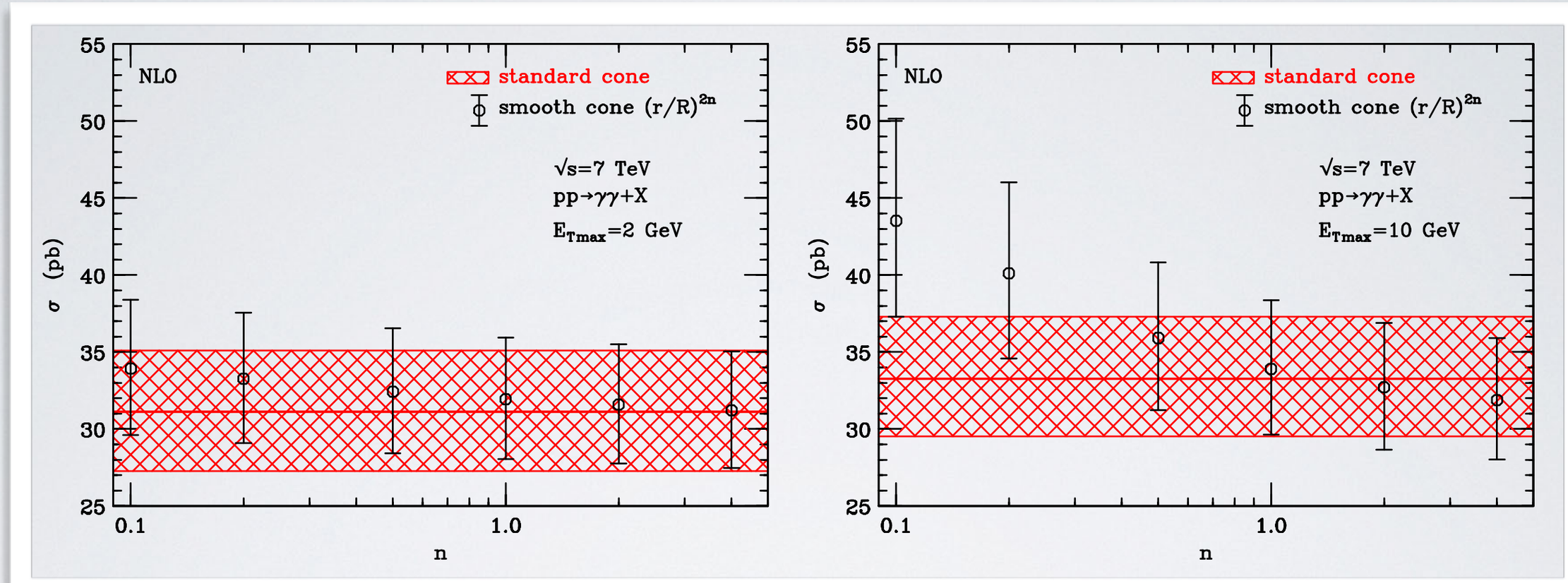
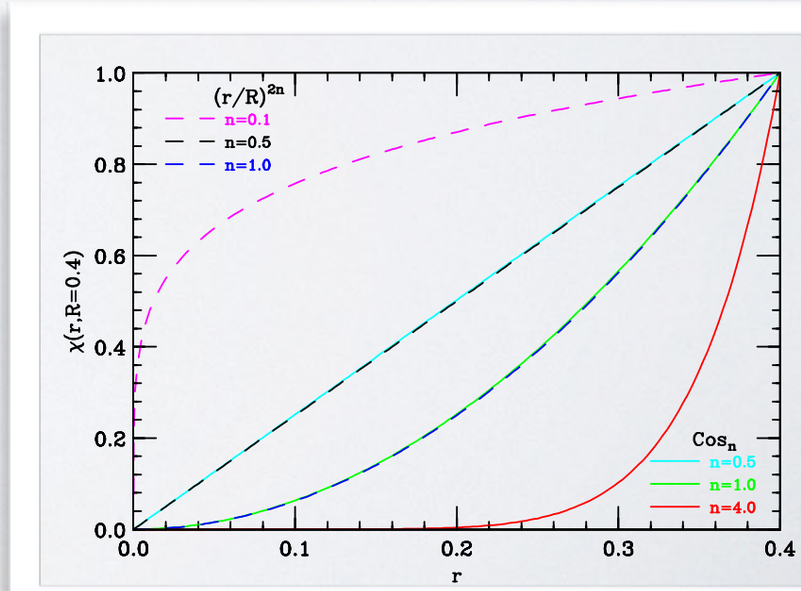


$$\delta^{NLO,\mathrm{soft}}_{\mathrm{smooth}} \propto -\alpha_S R^2 \left(\ln\left(\frac{Q}{E_{T\,\max}}\right) + n \right) , \qquad (n \gg 1)$$

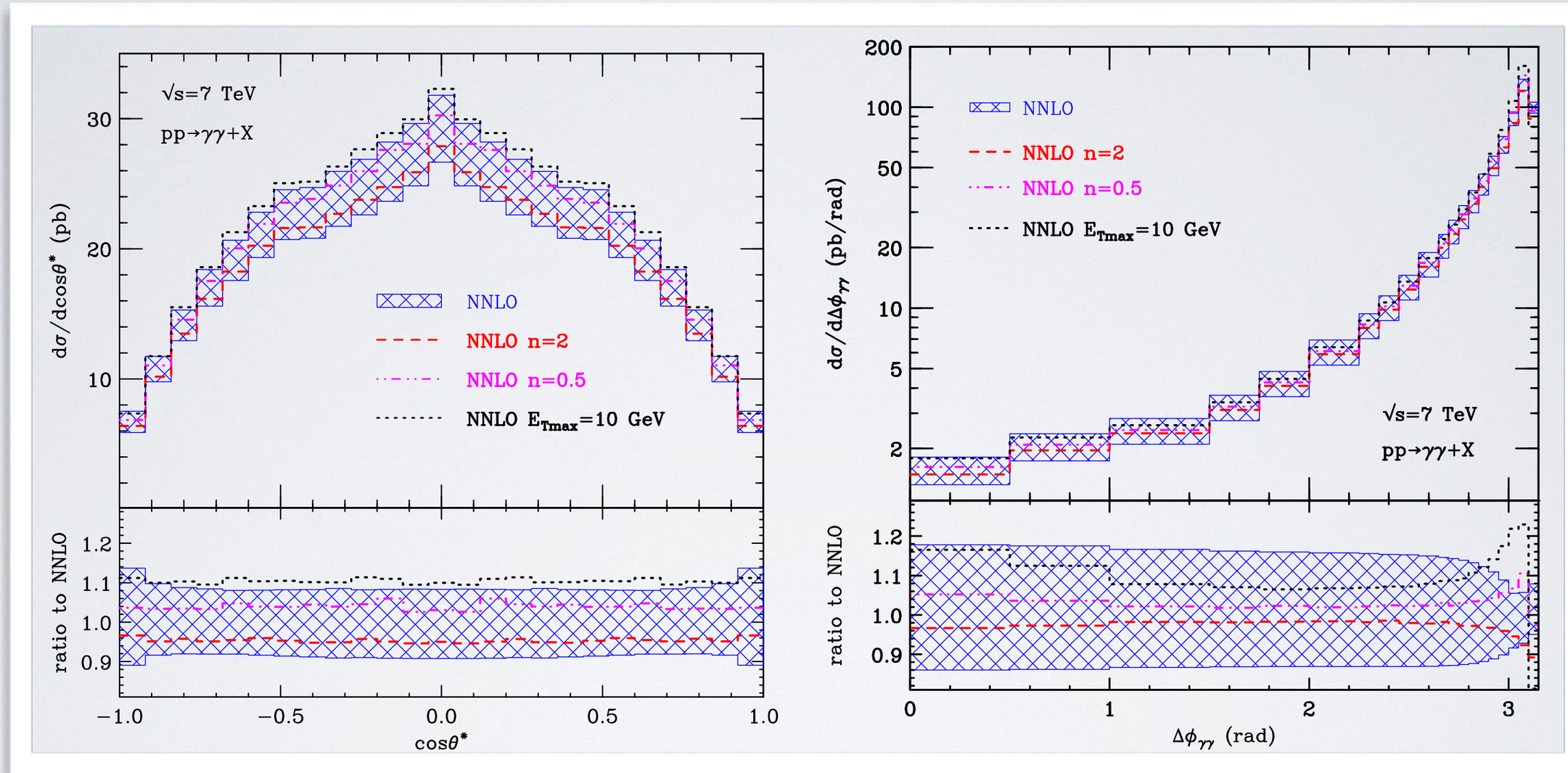
$$\delta^{NLO,\mathrm{coll}}_{\mathrm{smooth}} \propto +\frac{\alpha_S}{n}\frac{E_{T\,\max}}{Q} , \qquad (n \ll 1)$$

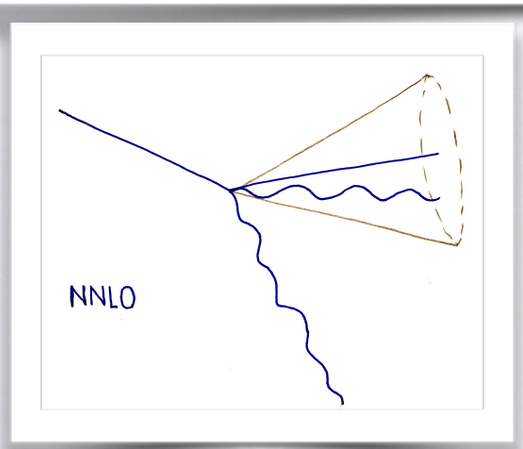


ISOLATION STUDIES

The diphoton example at NNLO

Catani, LC, de Florian, Ferrera, Grazzini [2018]





At NNLO, regions far way from the b-t-b configurations are sensible for first time to changes in the isolation parameters.

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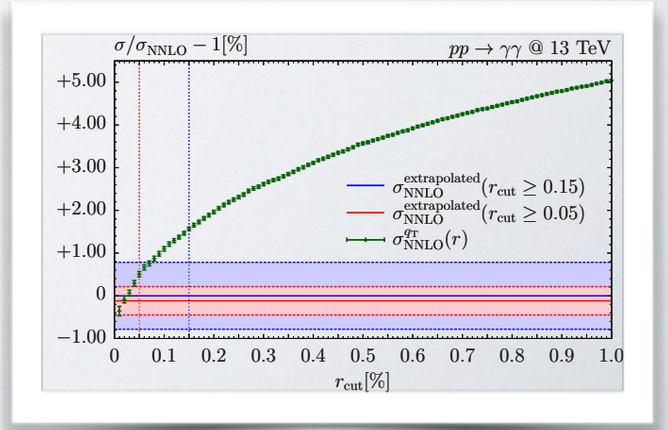

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- Accord avoiding tuning smooth/hybrid isolation parameters from comparison with NLO tools with fragmentation
- Power corrections to the qT-subtraction formalism induced by smooth cone isolation
- How many inner cones can use the EXP?

BACKUP SLIDES

ISOLATION STUDIES

The diphoton example

Catani, LC, de Florian, Ferrera, Grazzini [2018]