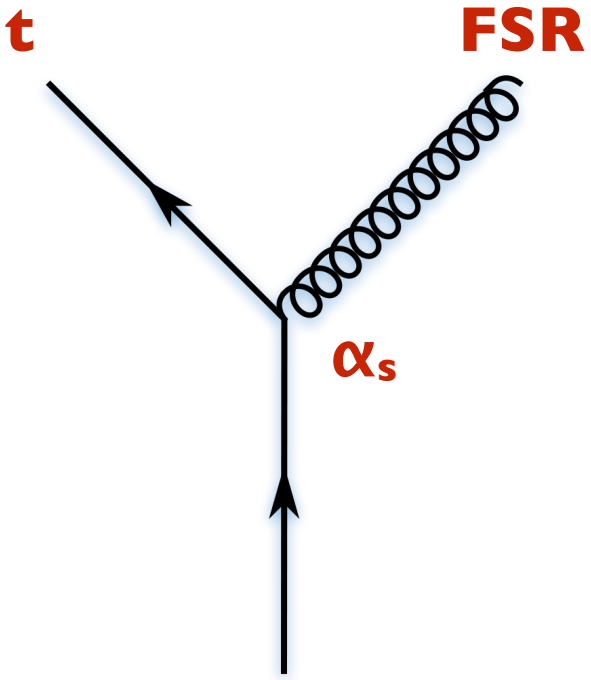
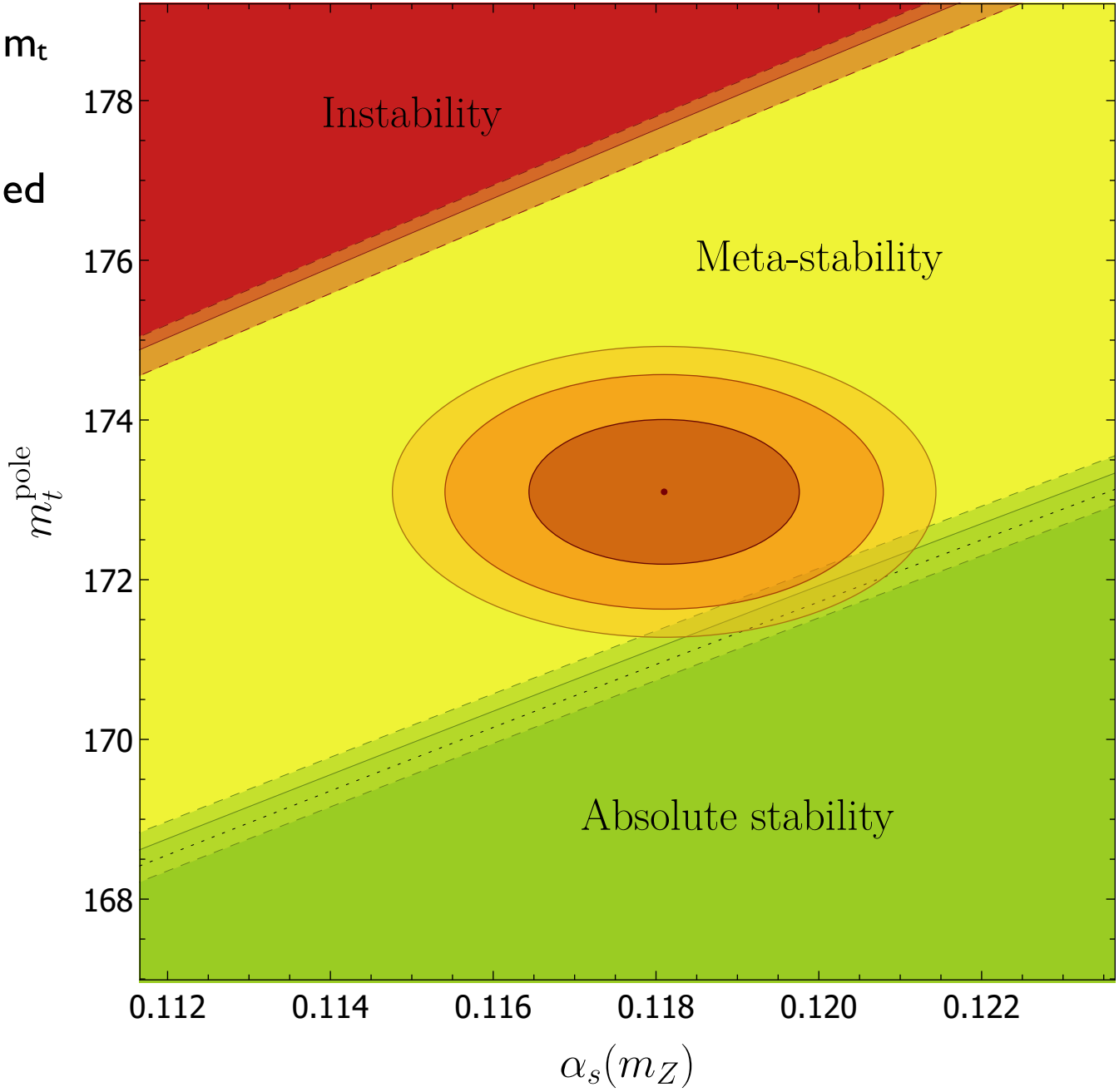
FSR and issues with jet multiplicity

Photo from JetMET100 workshop in Helsinki, www.hip.fi/jetmet100

FSR and the universe

- Vacuum stability defined by α_s, m_t
- α_s, m_t defined by FSR
- Thus, fate of the universe defined **by FSR**

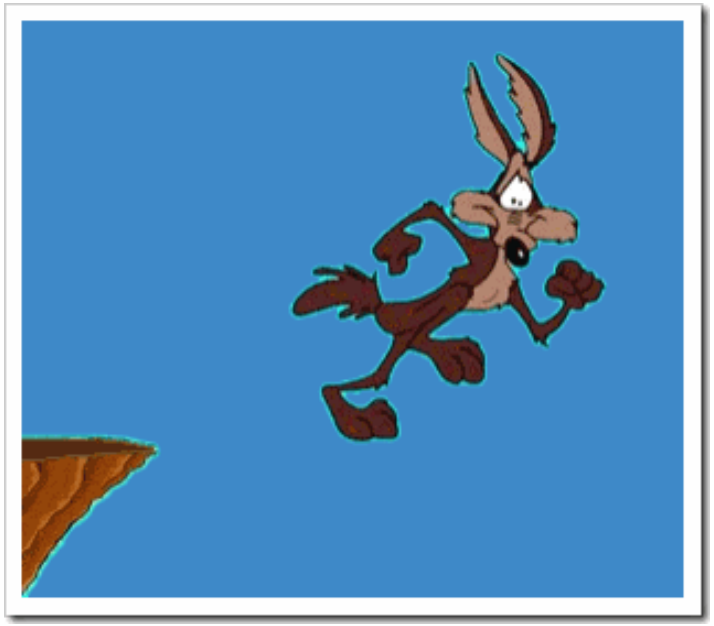


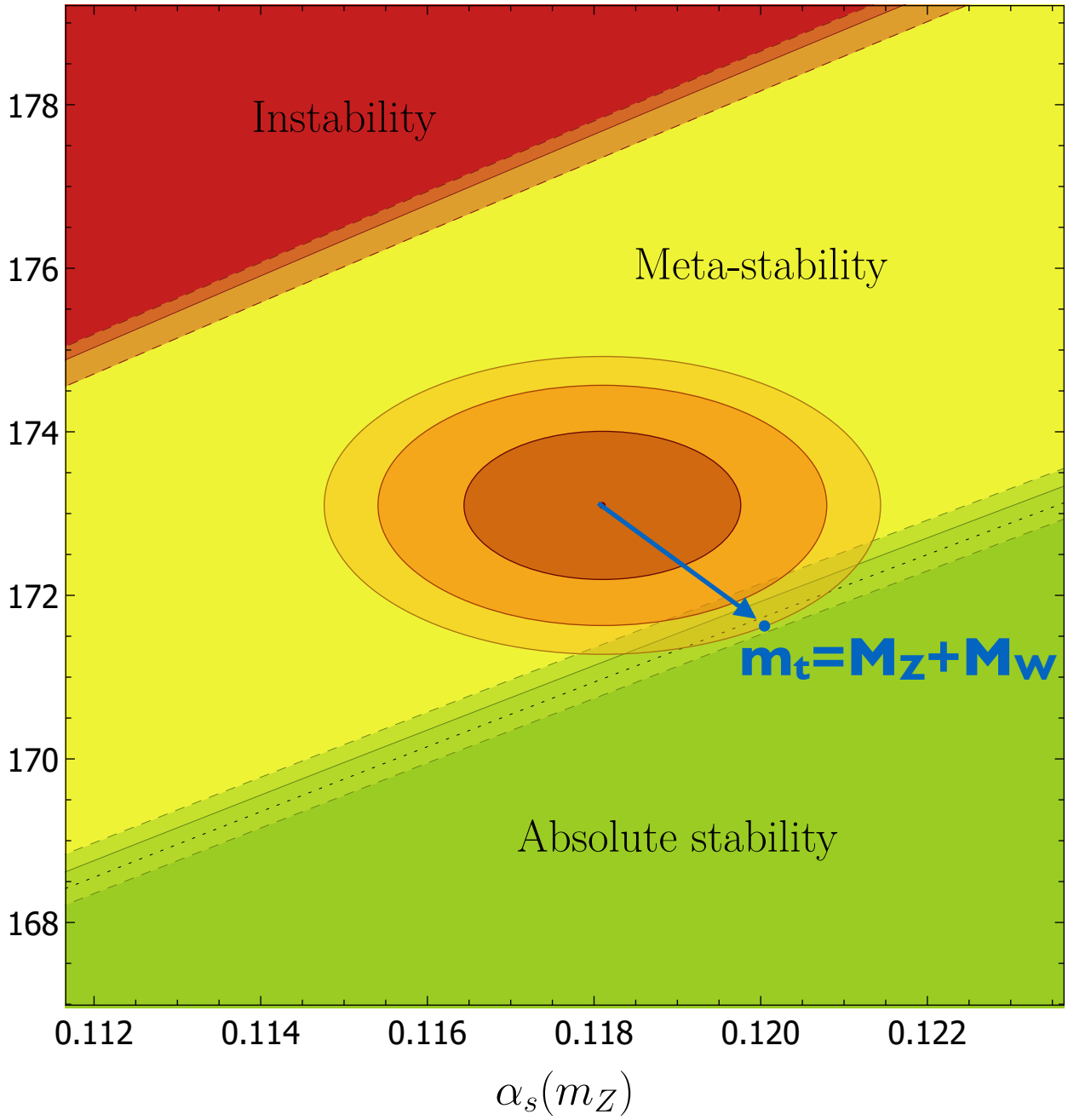


FSR and the universe

- Vacuum stability defined by α_s, m_t
- α_s, m_t defined by FSR
- Thus, fate of the universe defined **by FSR**

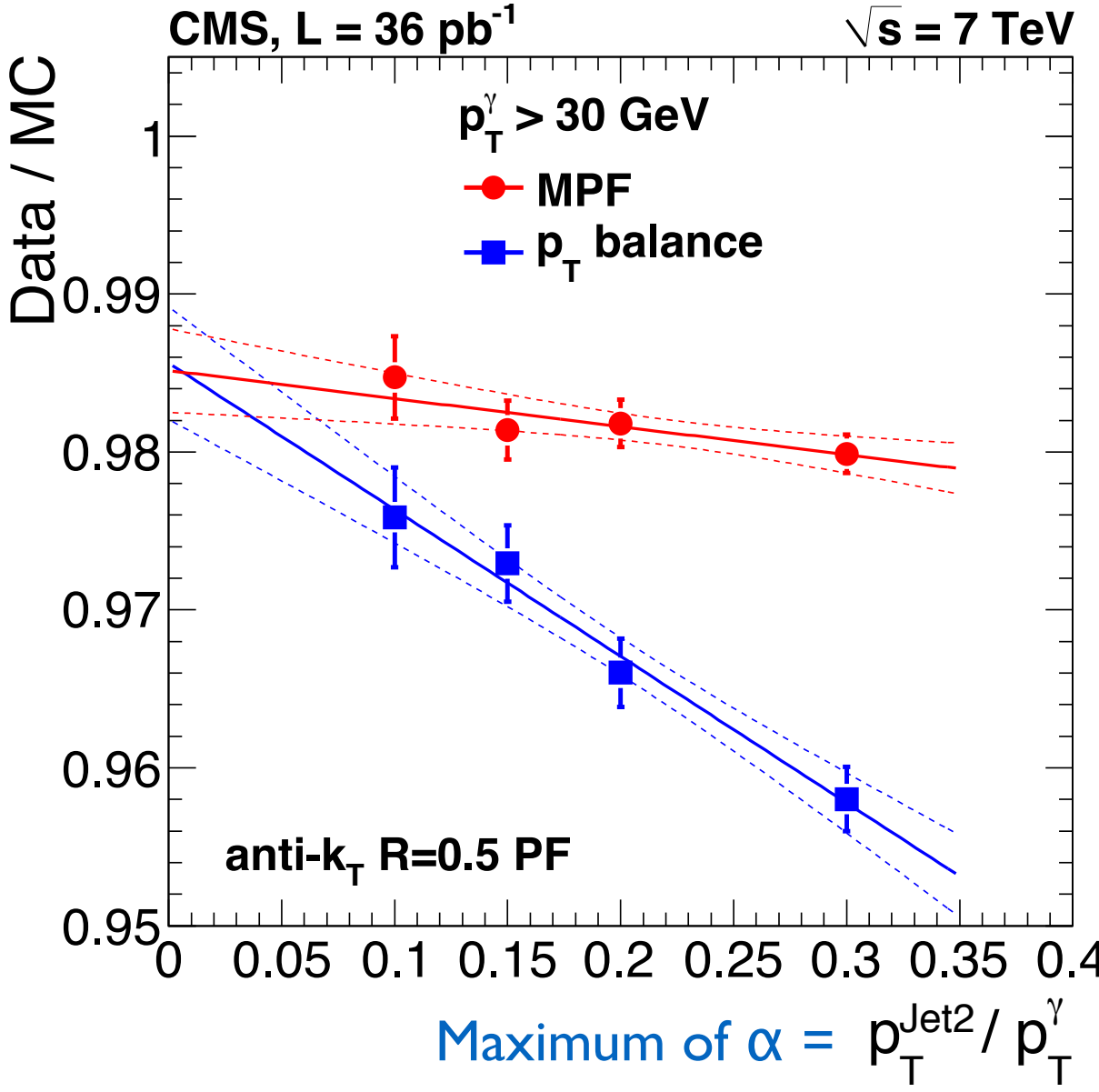
- With that out of the way, lets get to saving the universe





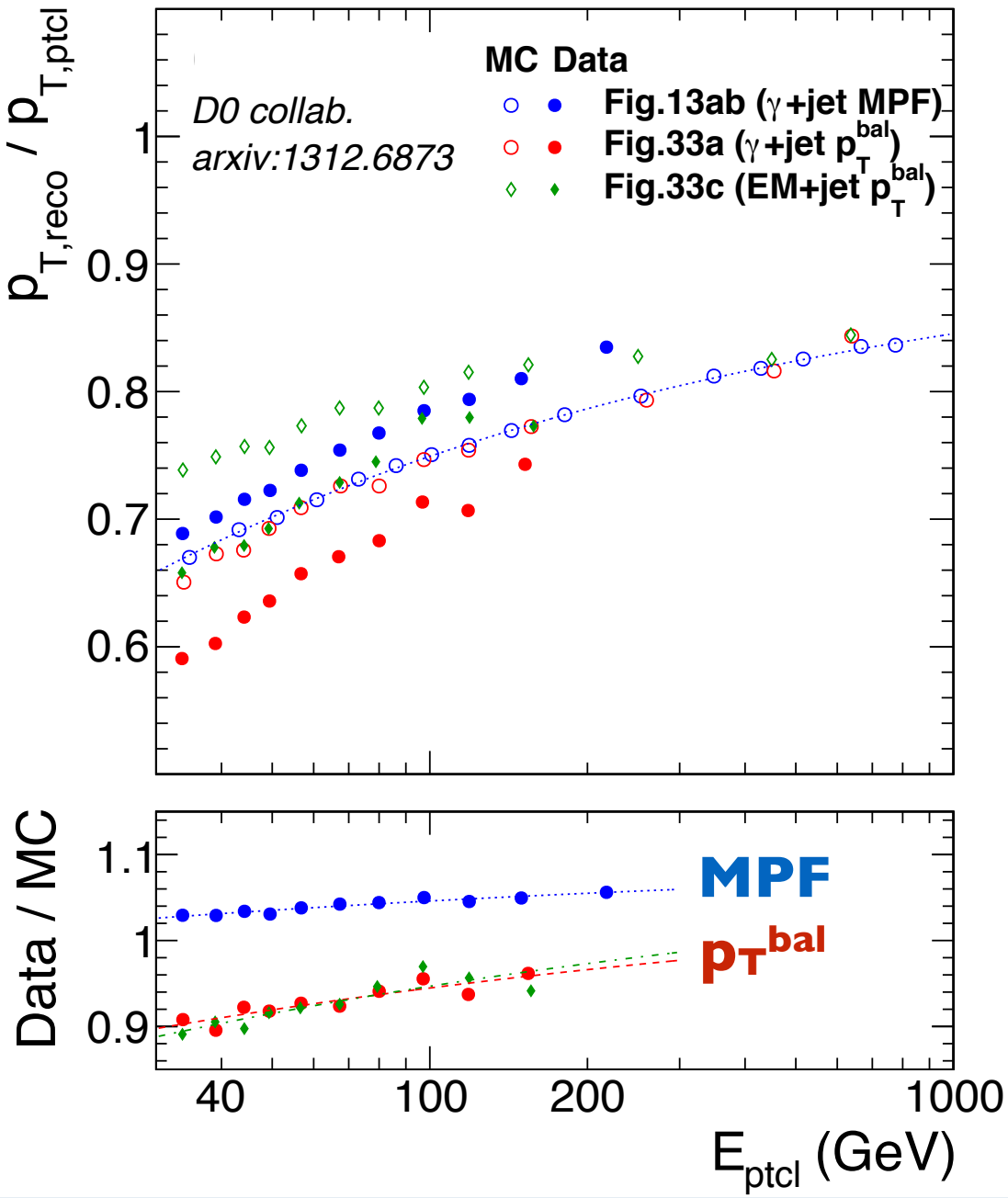
FSR in γ+jet (CMS)

- Results from CMS 7 TeV JEC paper
  - JINST 6 (2011) 11002 / arXiv:1107.4277
  - γ+jet MC is Pythia6 (LO + PS)
- Poor modeling of FSR, O(5%) bias
- MPF mostly immune, expectation of bias is <20% of p_T balance
- Inclusive α (=p_T^2/p_T^γ) binning used
- Take home: Pythia6 way off for FSR



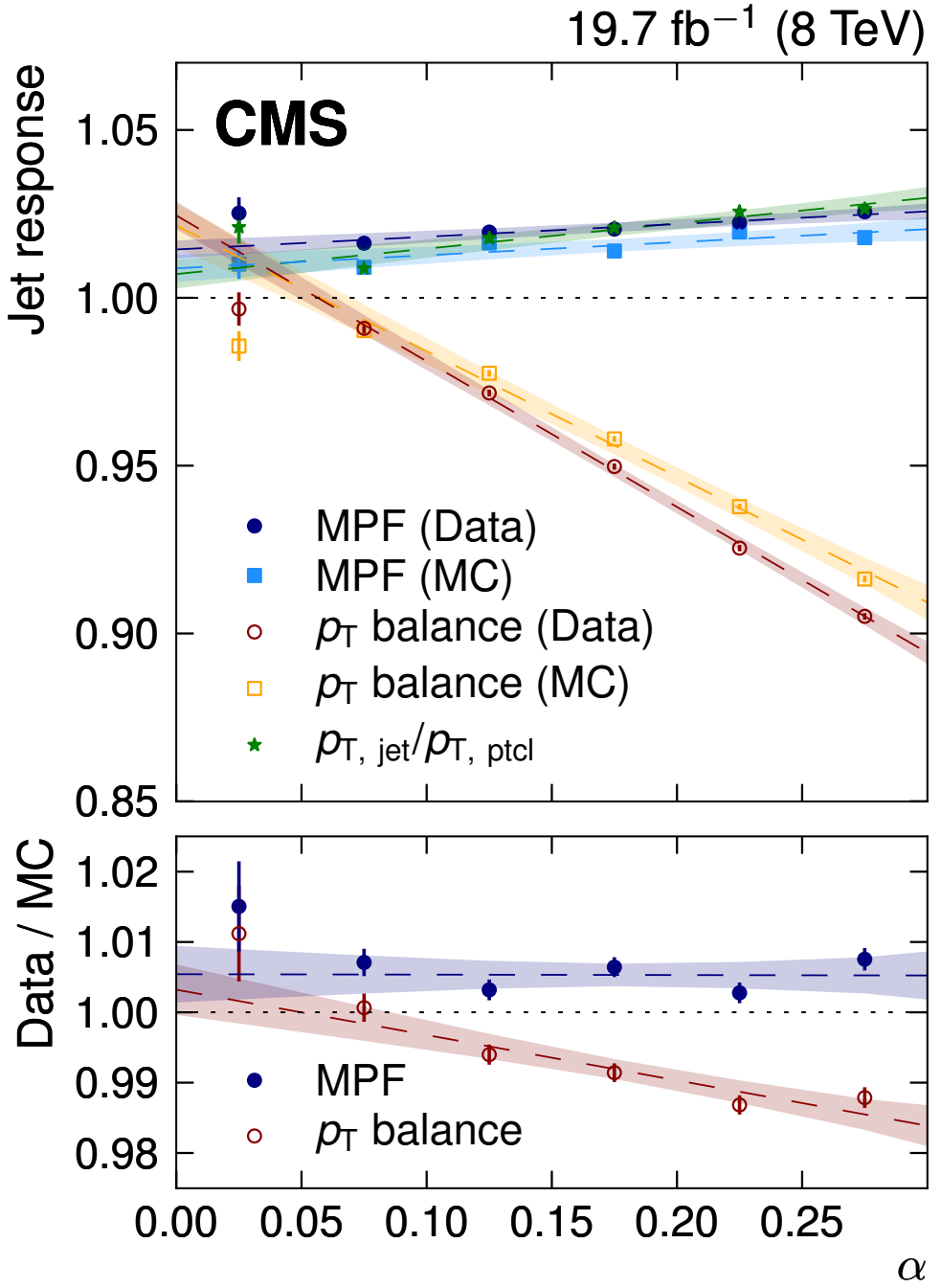
FSR γ+jet (D0)

- Results *extracted* from D0 JEC paper
  - Ref. JINST / arXiv
  - γ+jet MC is Pythia6 (LO + PS)
  - dijet (EM+jet) is Pythia6 (LO + PS)
- About 9–13% difference between MPF (stable), and p_T balance (biased)
- Similar Data / MC for γ+jet and EM+jet (dijet with leading $\pi^0 \to \gamma\gamma$)
- Take home: Pythia6 way off for FSR

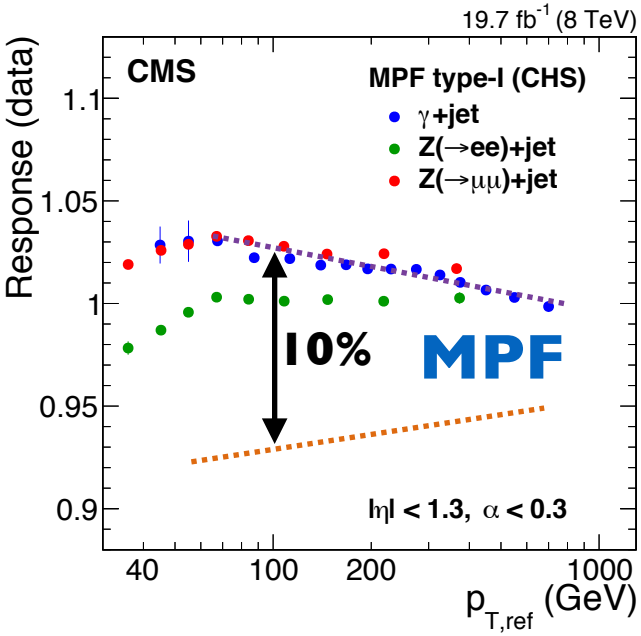


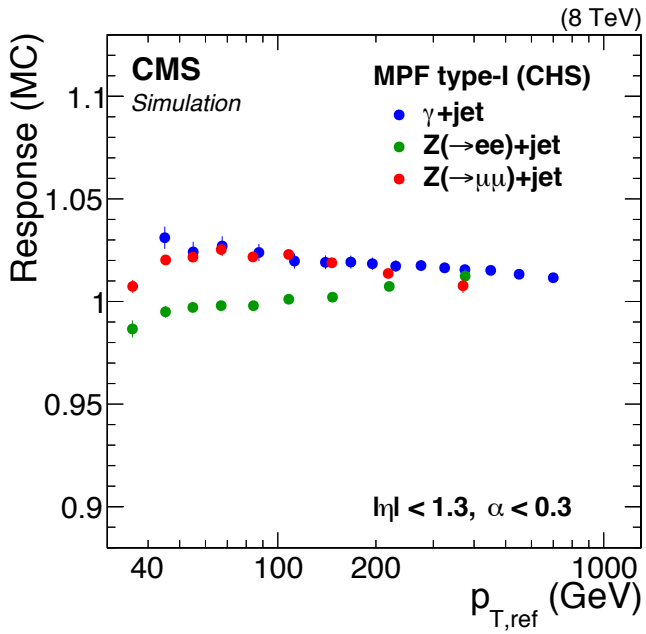
FSR in Z+jet

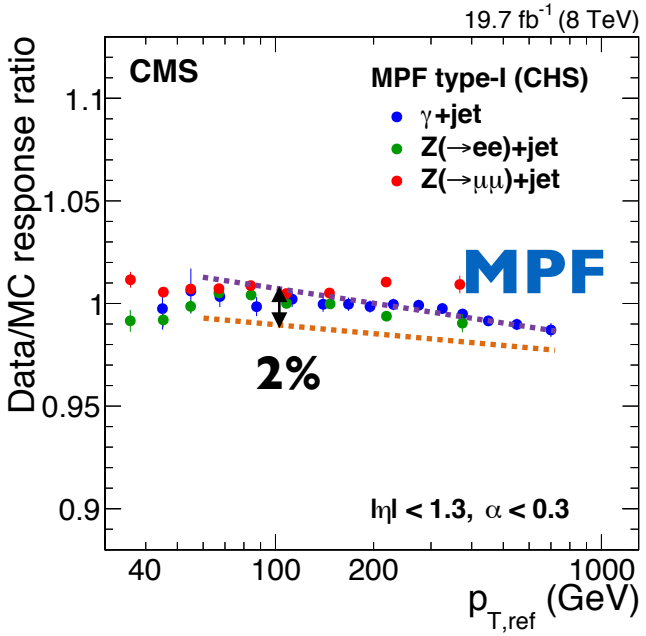
- Results from CMS 8 TeV JEC paper
  - JINST 12 (2017) P02014 / arXiv:1607.03663
  - Z+jet MC is MadGraph (LO multileg + PS)
- Decent modeling of FSR, O(1%) bias
- MPF mostly immune
- Exclusive α binning used for this plot, but final results with inclusive α binning
- Take home: MadGraph decent, 2% bias

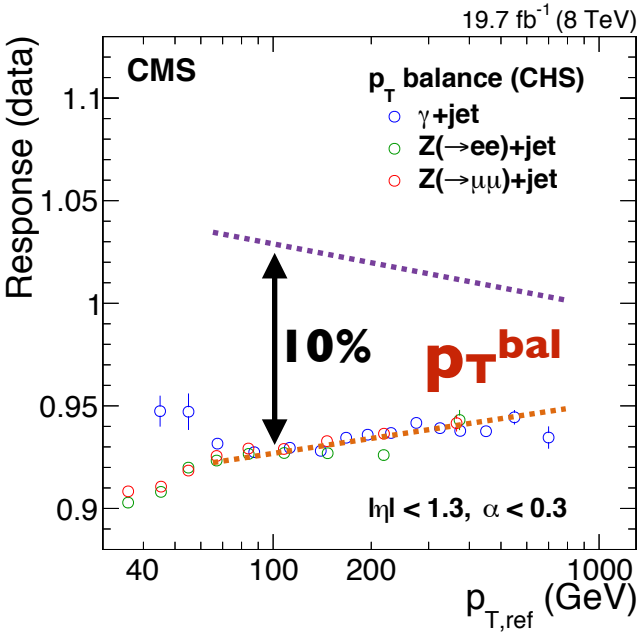


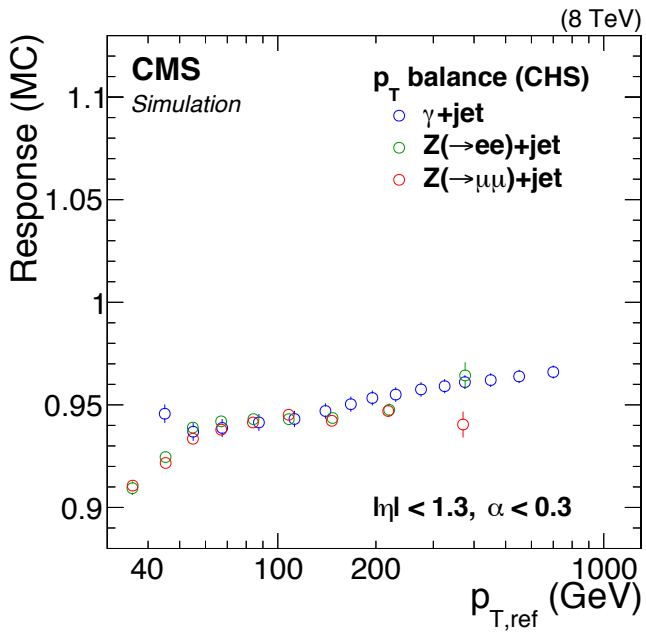
Z+jet vs γ+jet


19.7 fb-1 (8 TeV)
CMS
MPF type-I (CHS)
γ+jet
Z(→ee)+jet
Z(→μμ)+jet
10%
MPF
|η| < 1.3, α < 0.3
Response (data)
pT,ref (GeV)


(8 TeV)
CMS
Simulation
MPF type-I (CHS)
γ+jet
Z(→ee)+jet
Z(→μμ)+jet
|η| < 1.3, α < 0.3
Response (MC)
pT,ref (GeV)


19.7 fb-1 (8 TeV)
CMS
MPF type-I (CHS)
γ+jet
Z(→ee)+jet
Z(→μμ)+jet
MPF
2%
|η| < 1.3, α < 0.3
Data/MC response ratio
pT,ref (GeV)


19.7 fb-1 (8 TeV)
CMS
pT balance (CHS)
γ+jet
Z(→ee)+jet
Z(→μμ)+jet
10%
pTbal
|η| < 1.3, α < 0.3
Response (data)
pT,ref (GeV)


(8 TeV)
CMS
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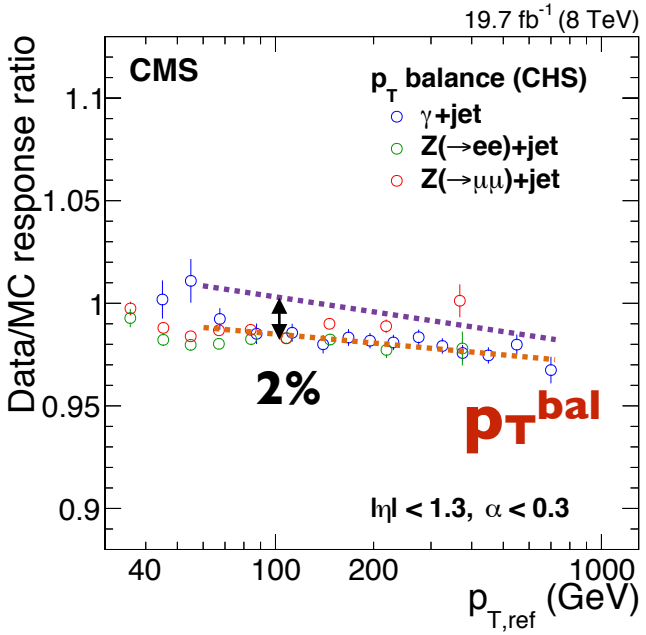
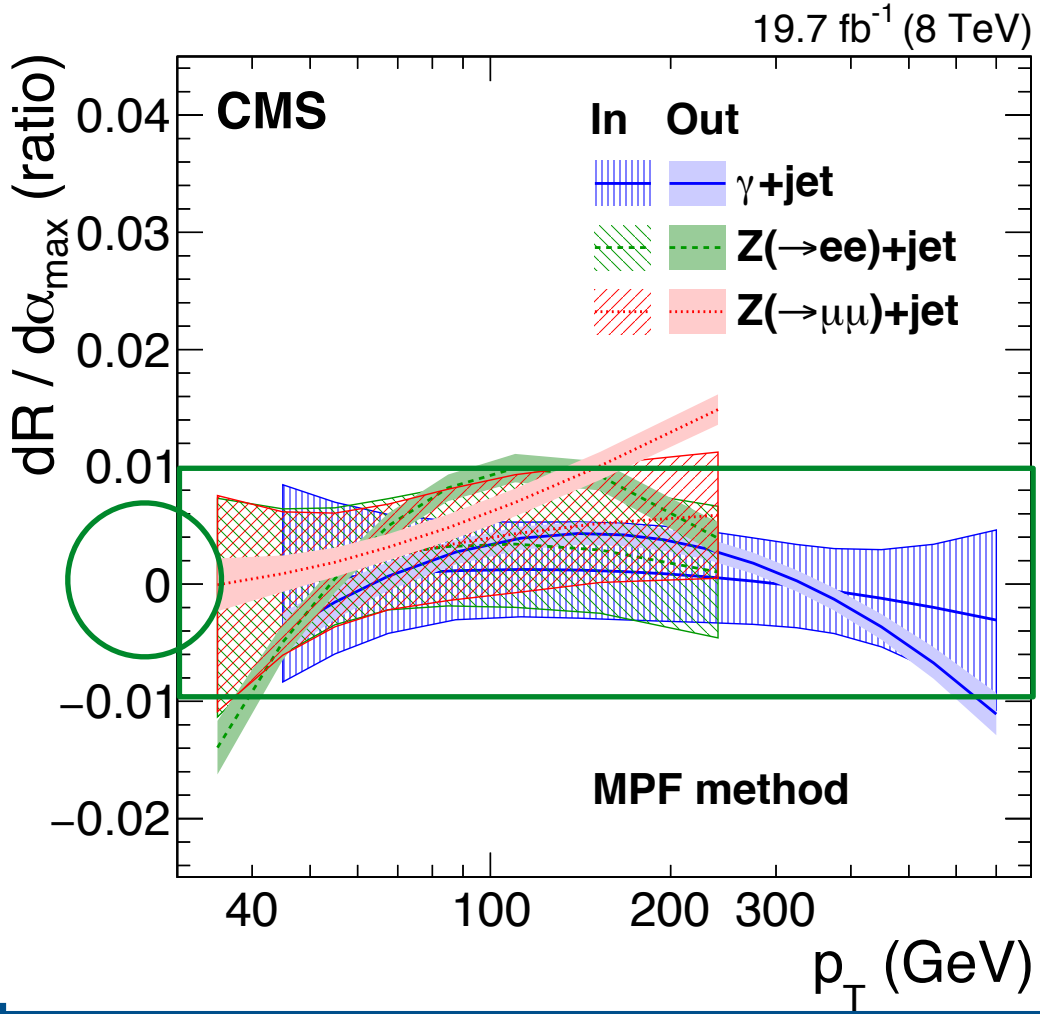
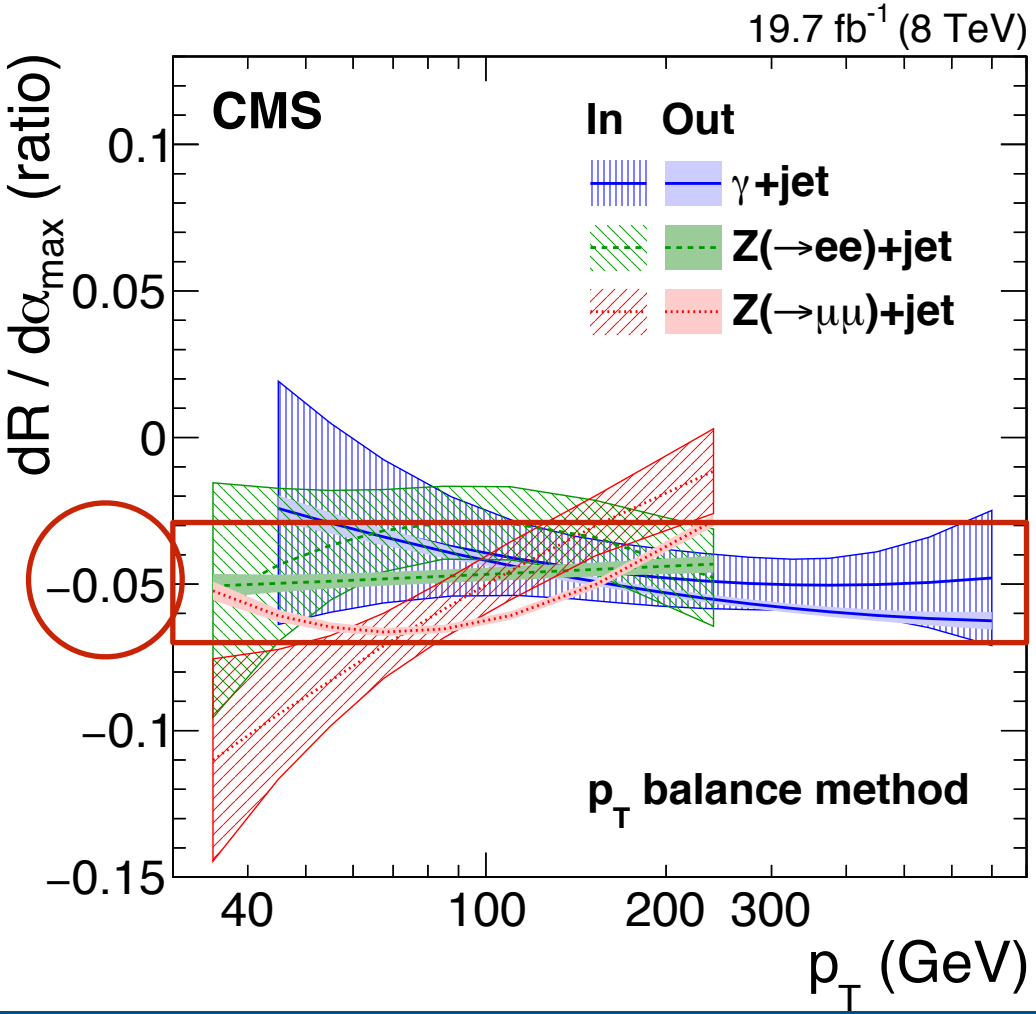
pT,ref (GeV)


19.7 fb-1 (8 TeV)
CMS
pT balance (CHS)
γ+jet
Z(→ee)+jet
Z(→μμ)+jet
2%
pTbal
|η| < 1.3, α < 0.3
Data/MC response ratio
pT,ref (GeV)

FSR in Z/γ+jet vs p_T

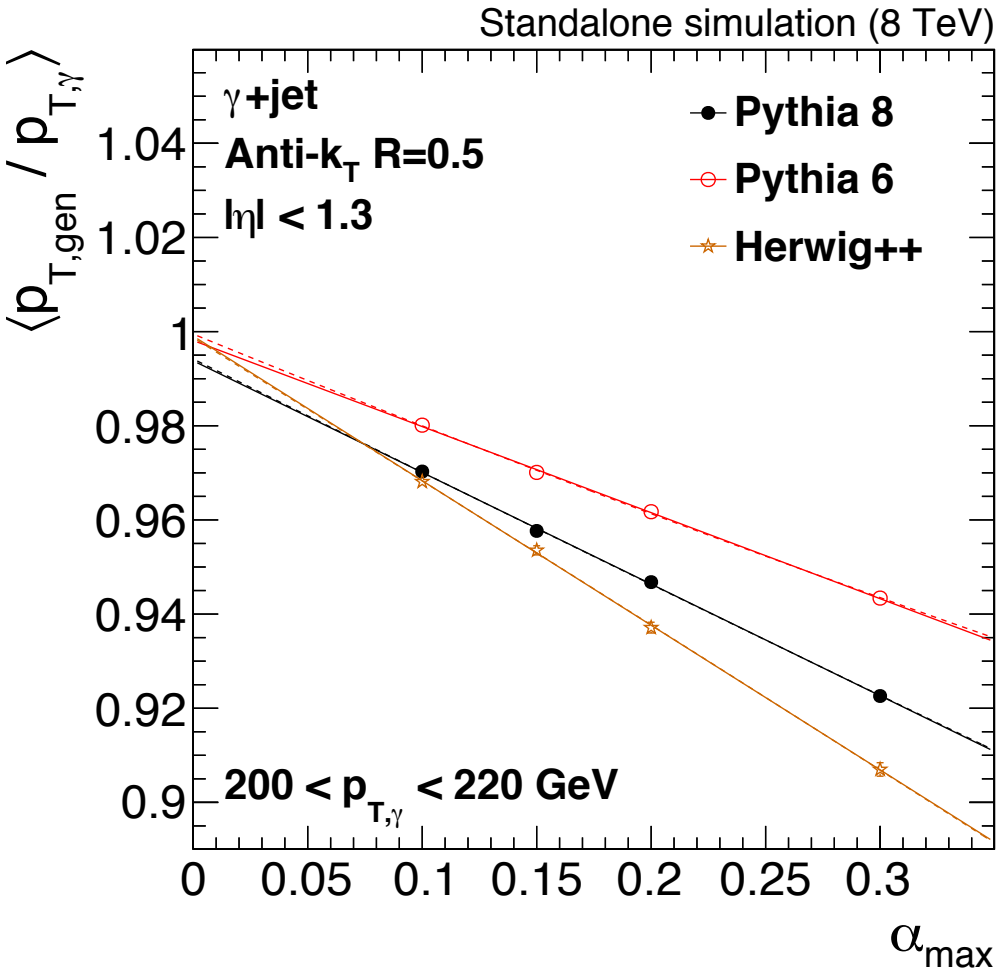
- Global fit including FSR ($dR/d\alpha_{max}$) shows MPF stable to <1%, p_T balance biased 3—7%
- Impact on $\alpha_{max}<0.3$ is ~1.5% (0.9—2.1%)

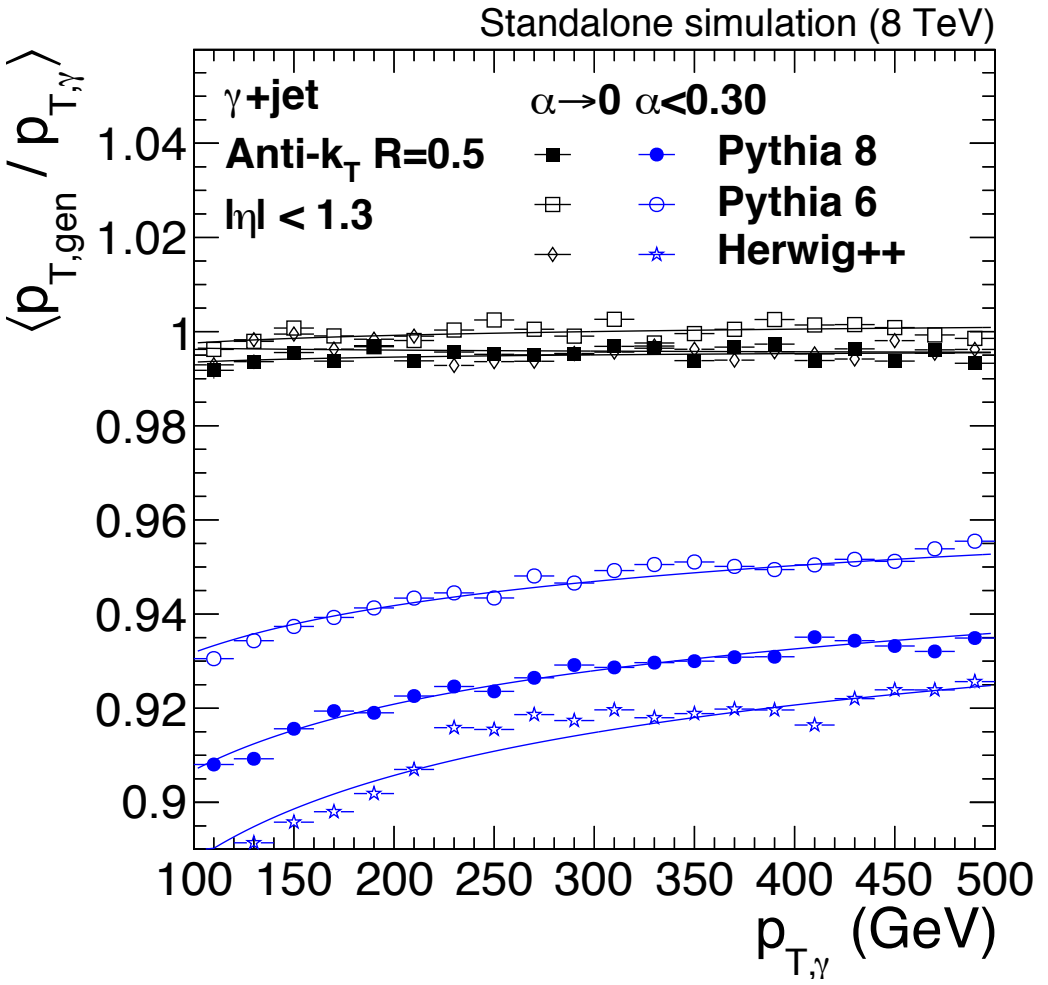




Comparing generators

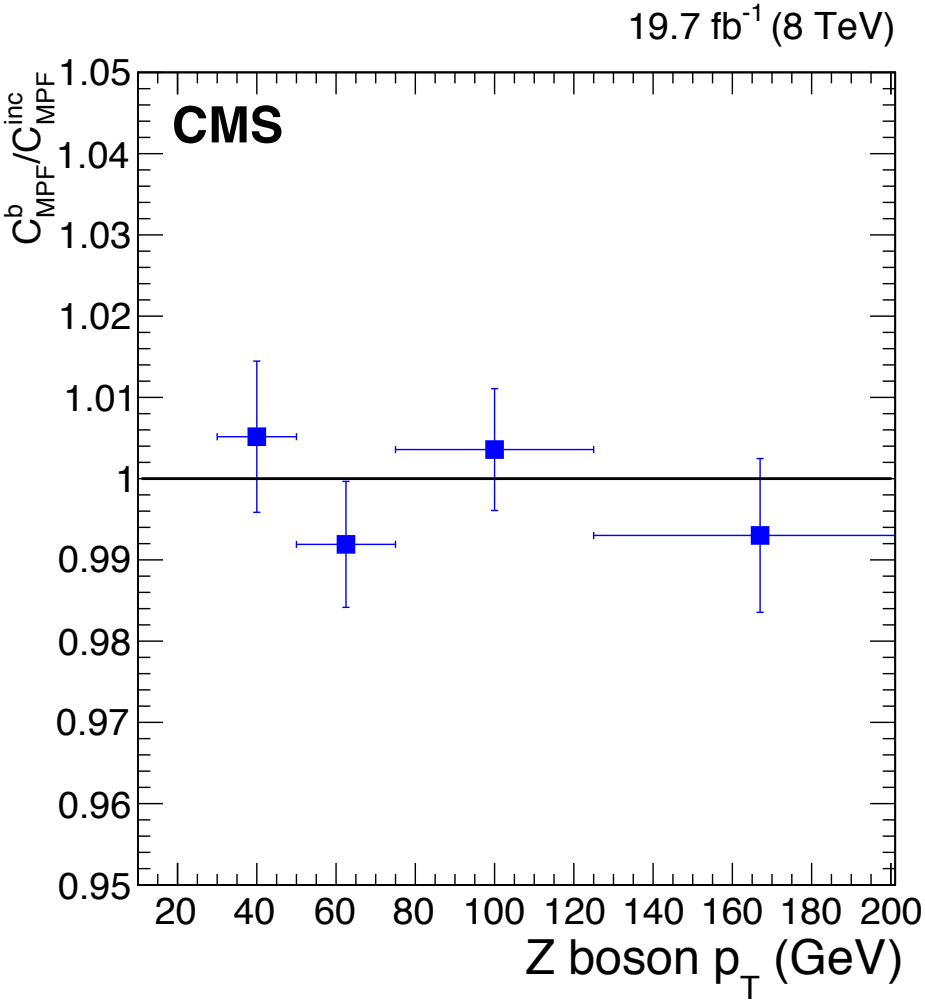
- Standalone Z/γ+jet samples may be useful for testing MC generators for FSR modeling
  - Z(->μμ, ee) and γ at are good approximations of parton p_T
  - Particle jet $p_{T,gen}$ approaches parton $p_{T,parton}$ at α->0
- Possible to repeat study on data vs MC with detector simulation

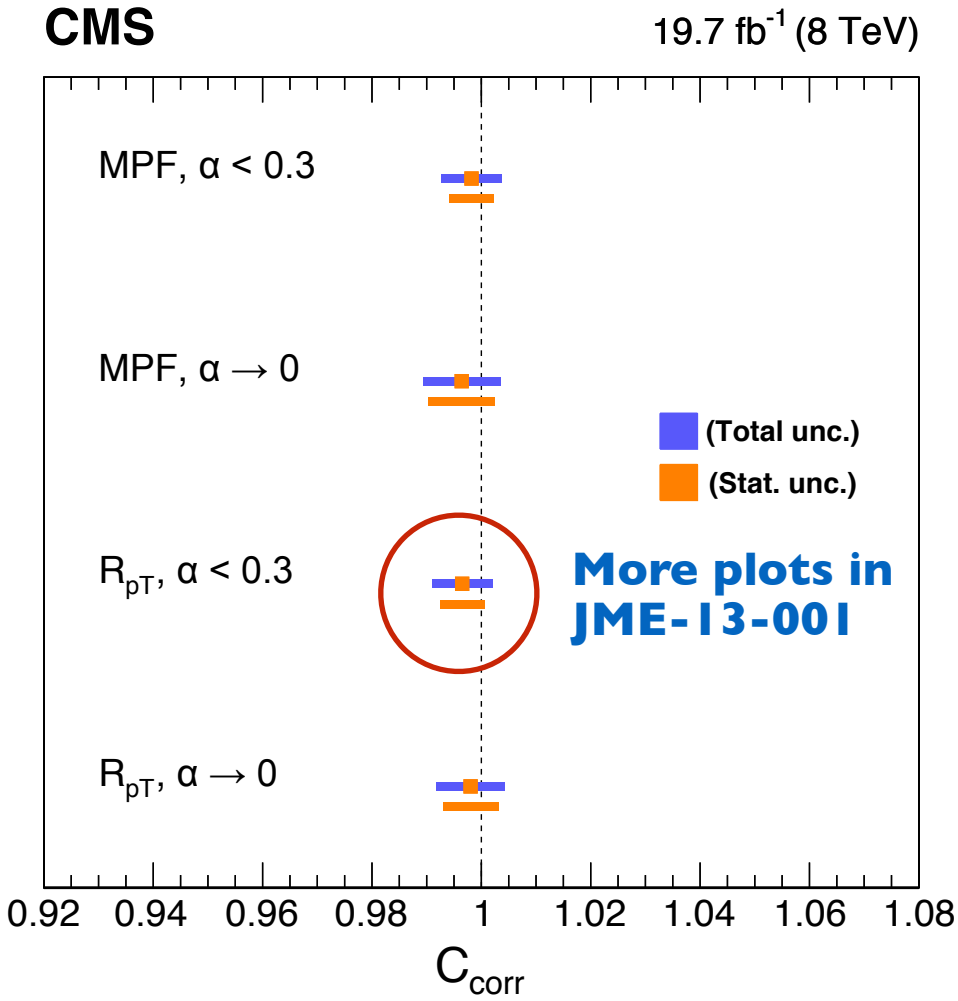




FSR in Z + b-jet

- Results from CMS 8 TeV JEC paper
  - JINST 12 (2017) P02014 / arXiv:1607.03663
  - Z+jet MC is MadGraph (LO multileg + PS)
- Z+b done as a ratio to Z+jet (inclusive)



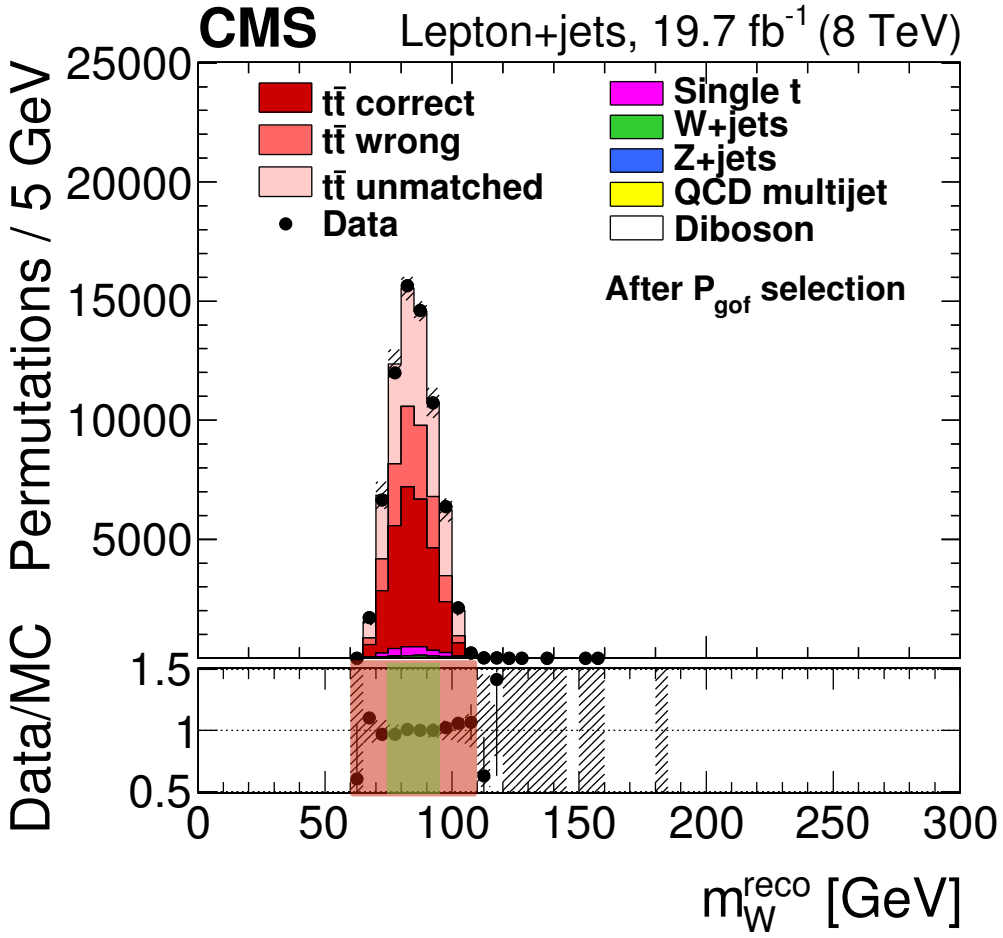


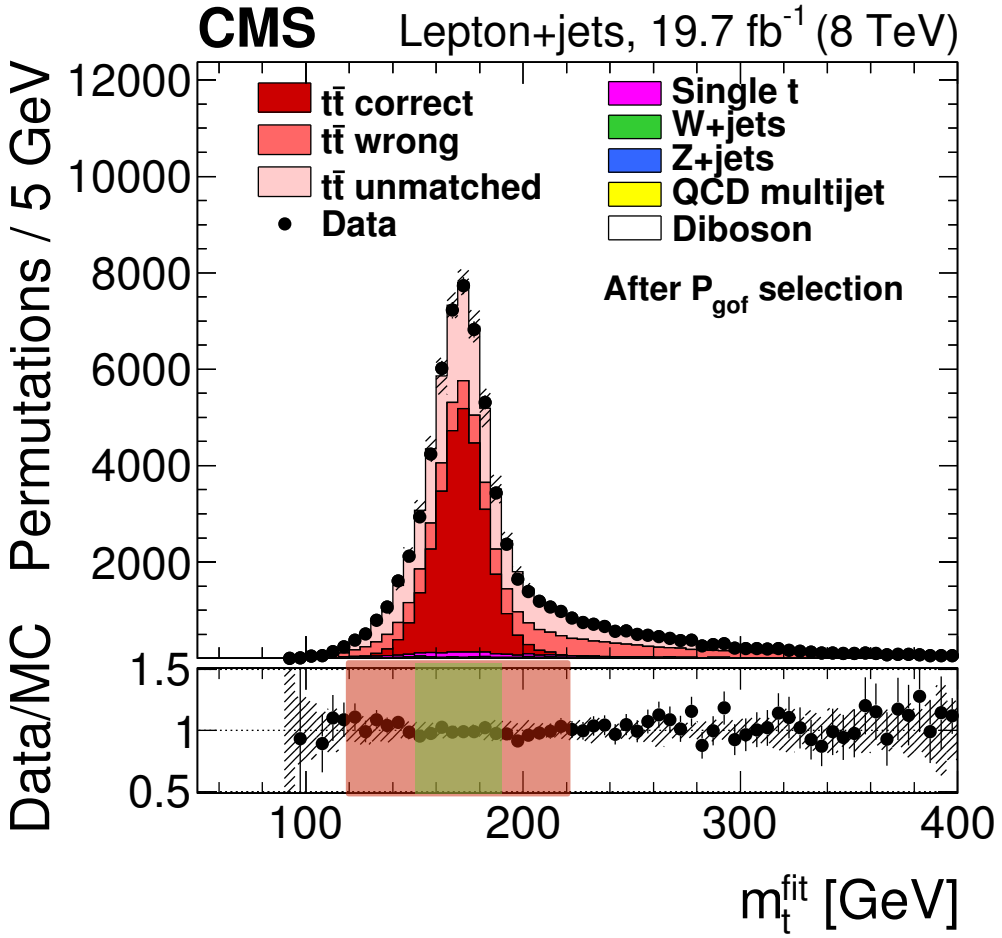
- p_T balance with α<0.3 consistent with MPF and α->0 results at O(0.5%) level
- Suggests that b-jet FSR modelling not significantly different from light jets

FSR in tt+jet

- Hypothesis: there is an implicit α_{max} in kinematic m_t measurements
  - Guesstimate for M_W: window 60—110 GeV limits α_{max}<1-60/80.4=0.25
  - Guesstimate for m_t: m_t^{fit}(tt correct)~120—220 GeV limits α_{max}<1-120/172.5=0.30
- Maximum α_{max}=0.3 similar to JEC (peak of dN/dα), effective α_{max} maybe half that

PRD 93 (2016) 072004 / arXiv:1509.04044

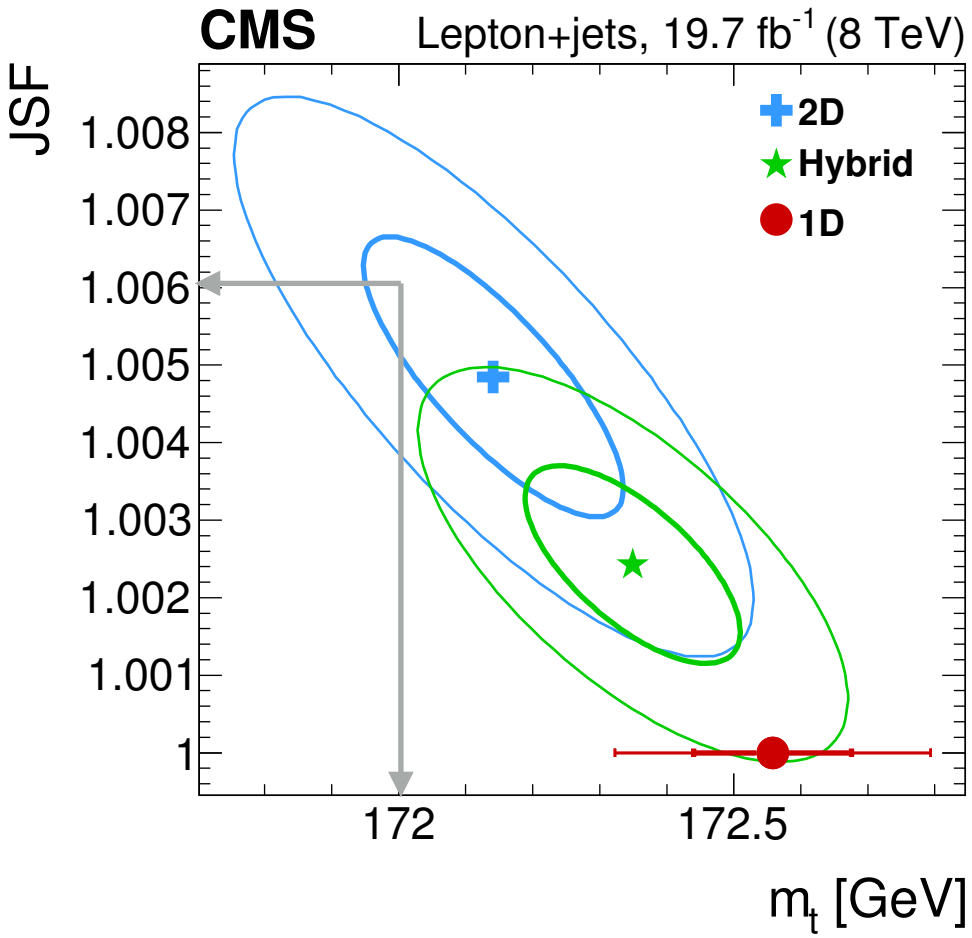


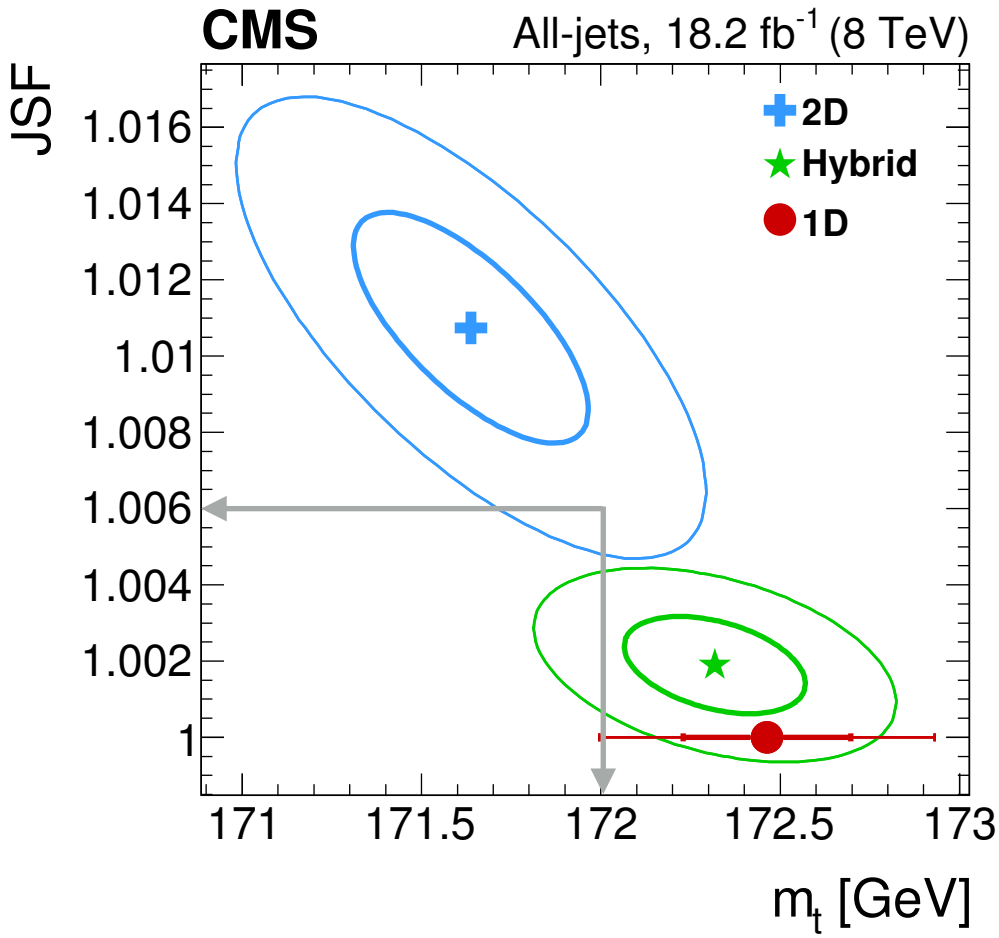


FSR and m_t

- So far: (1) α_{max} for M_W^{reco} and m_t^{fit} similar, and (2) b-jet and light-jet FSR similar
- Therefore, expect M_W=80.4 GeV constraint to absorb most of FSR bias
  - JSF is not only a measure of ΔJEC (certain to 0.32%), but of ΔFSR (expect bias of up to ~1%)
  - JSF-1 sign at 8 TeV is just opposite to that seen in JEC studies with MadGraph…

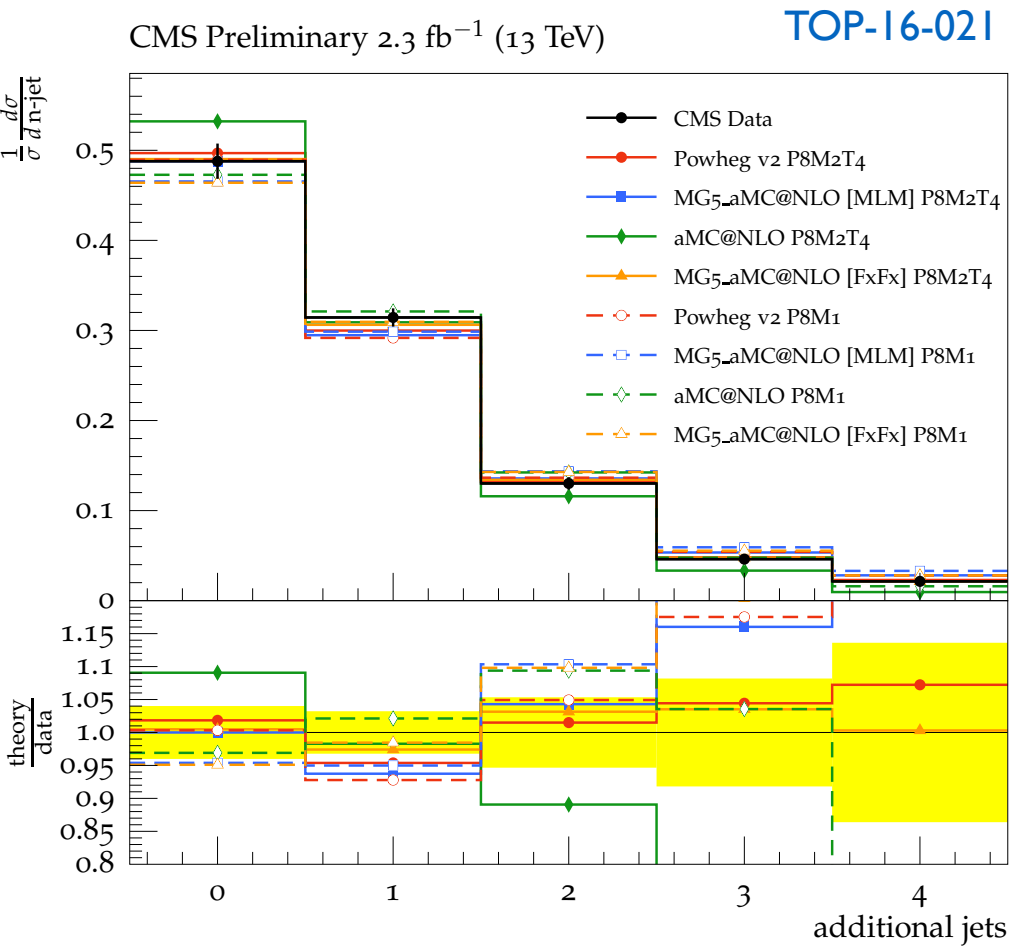
PRD 93 (2016) 072004 / arXiv:1509.04044

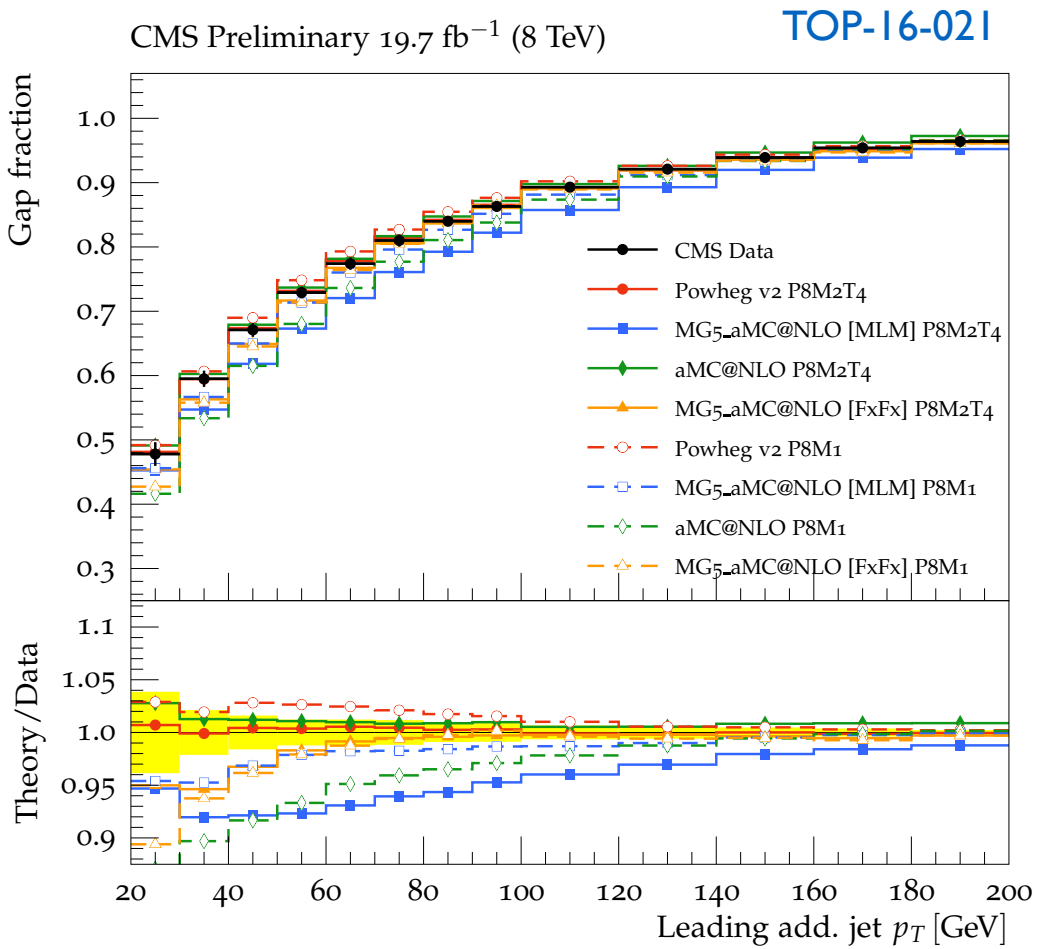




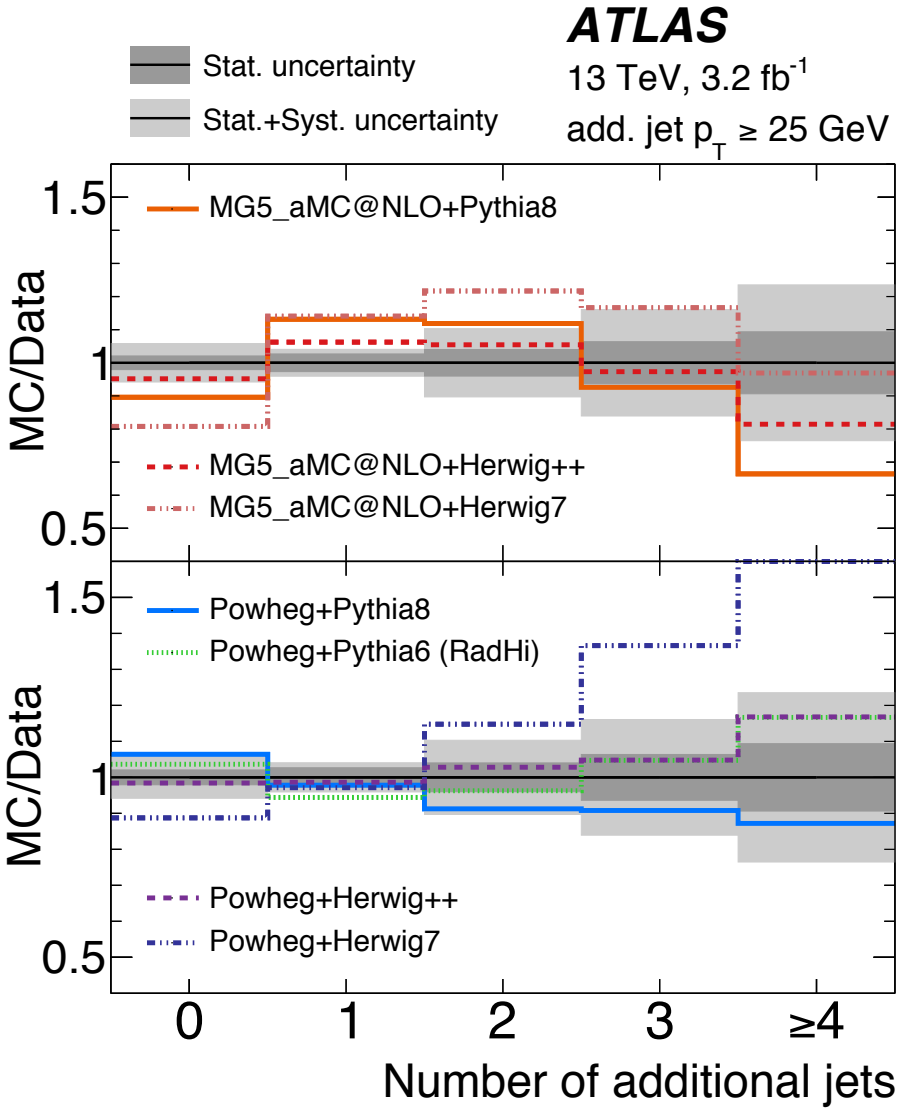
Powheg+Pythia8

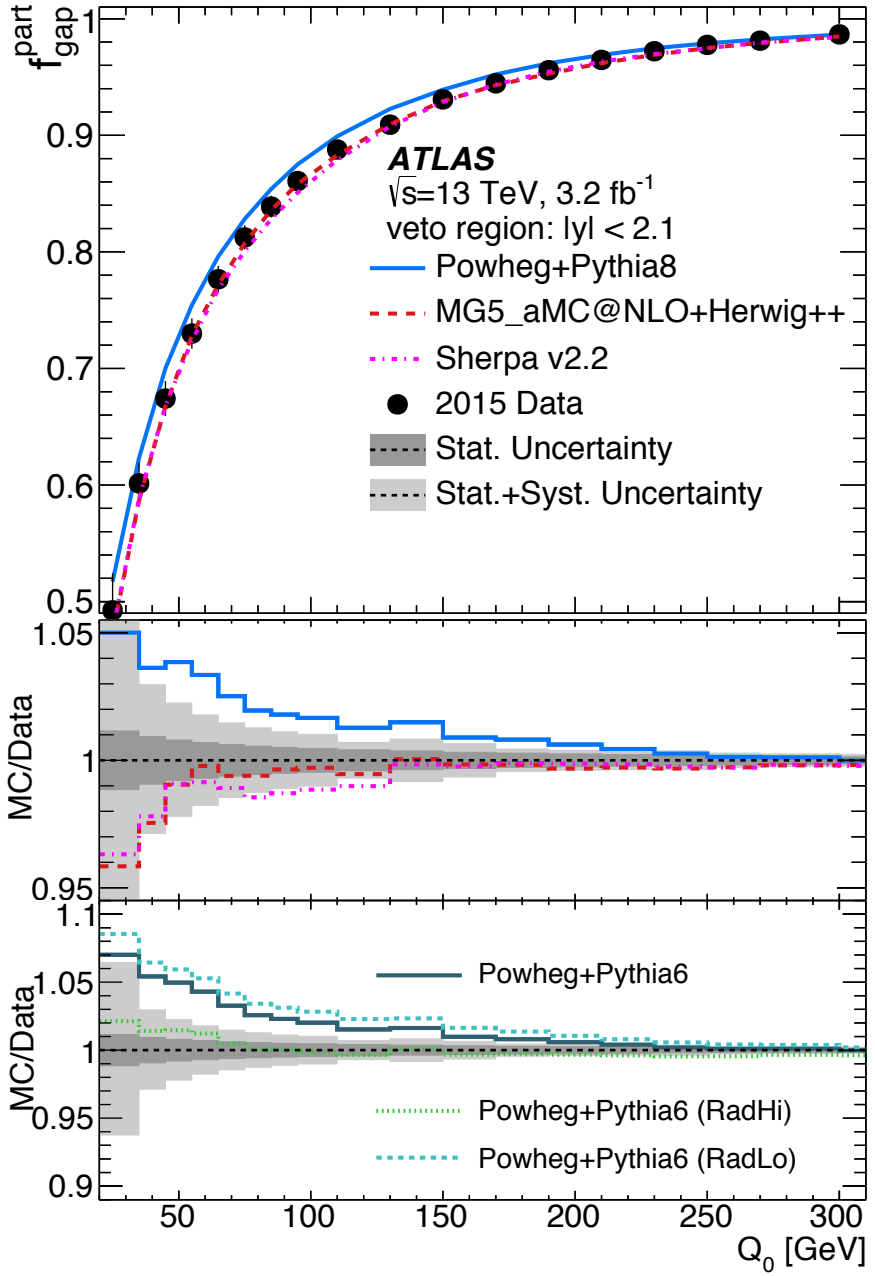
- Run 2 default simulator is Powheg+Pythia8 (TOP-17-002, TOP-17-007)
- PH+P8 good for tt+jet modeling (TOP-16-021); yet to be tested for JEC at CMS
- Good for AK4+AK7 inclusive jets (EPJC 76 (2016) 451); AK4/AK7 ratio sensitive to FSR
- Just missing quantitative uncertainty from comparisons to data





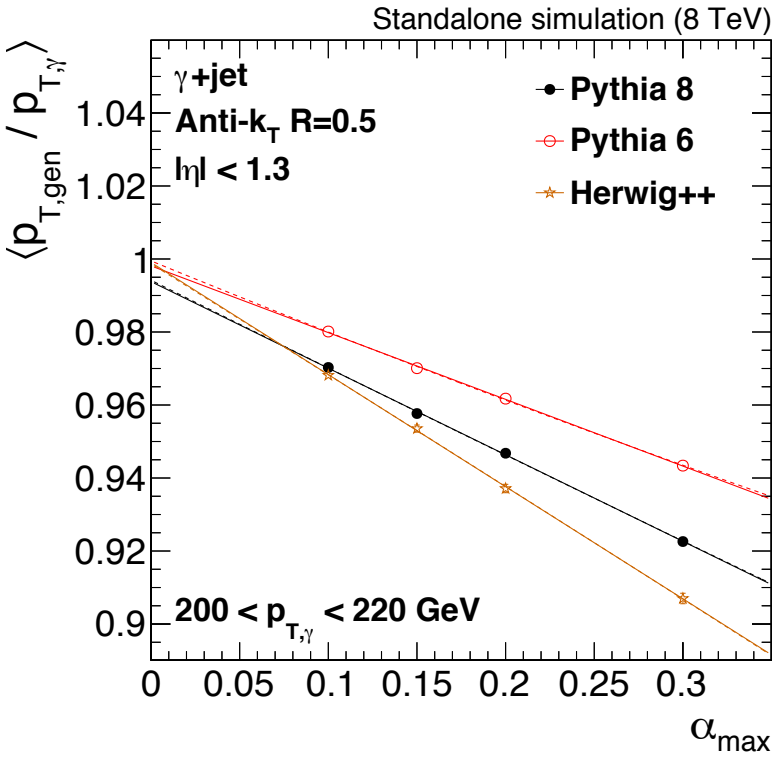
- N_{jet} and gap fraction from ATLAS (EPJ C77 (2017) 220)
- Sensitive to ISR and FSR, so no way to tell apart
- Plots like m_t^{kin} or $\langle p_{T,b}/p_{T,l} \rangle$ vs $p_{T,1stAdd}/p_{T,b}$ or Q_0?





Summary

- Used to have chronic mismodeling of light-jet FSR in simulation
  - Pythia6/MadGraph > data > Pythia8 > Herwig++
  - Tools of the trade: $\alpha = p_{T,2}/p_{T,\gamma}$ and p_T^{bal}/MPF
- NLO+PS (Powheg+Pythia8) now much better, although lack quantitative number
  - Could use standalone Z/γ+jet for estimate? Also need effective α_{max} in ttbar
- b-jet FSR consistent with light jets
  - Evidence so far supports consistency at O(0.5%) level



Backup

What happens in a jet, stays in jet

— rule of JEC