Double-Parton scattering in γ + 3 jet final states

- Reminder of CDF analysis
- First steps with Pythia 8.086
- CMSSW analysis code in CVS

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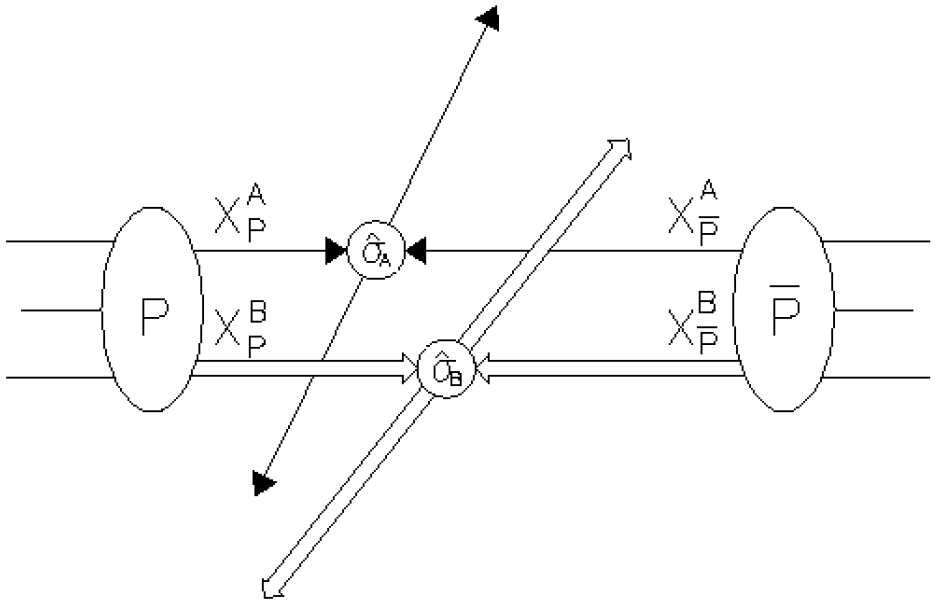
Concept

- **DPS – two *hard* parton-parton interactions in one proton-proton collision**
- **Important background to di-boson ($W^+ W^-$, etc.) and boson+jets production**
- **New research line within CMS inspired by CDF's "Photon + 3 jets"-measurement**

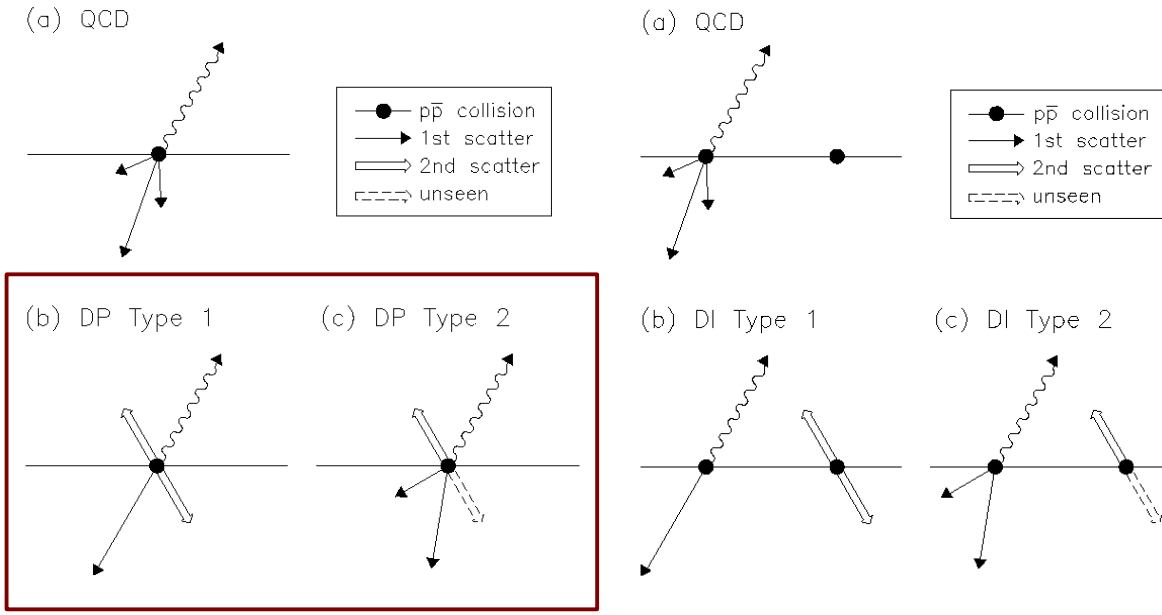
[see *Phys. Rev. D56,3811(1997)*]

schematic diagram:



two parton-parton interactions
in one proton-proton collision

one p pbar collision:



Double-Parton scattering processes

two p pbar collisions:

CDF Measurement of DPS

Choose γ + jet and dijet pairs by minimizing

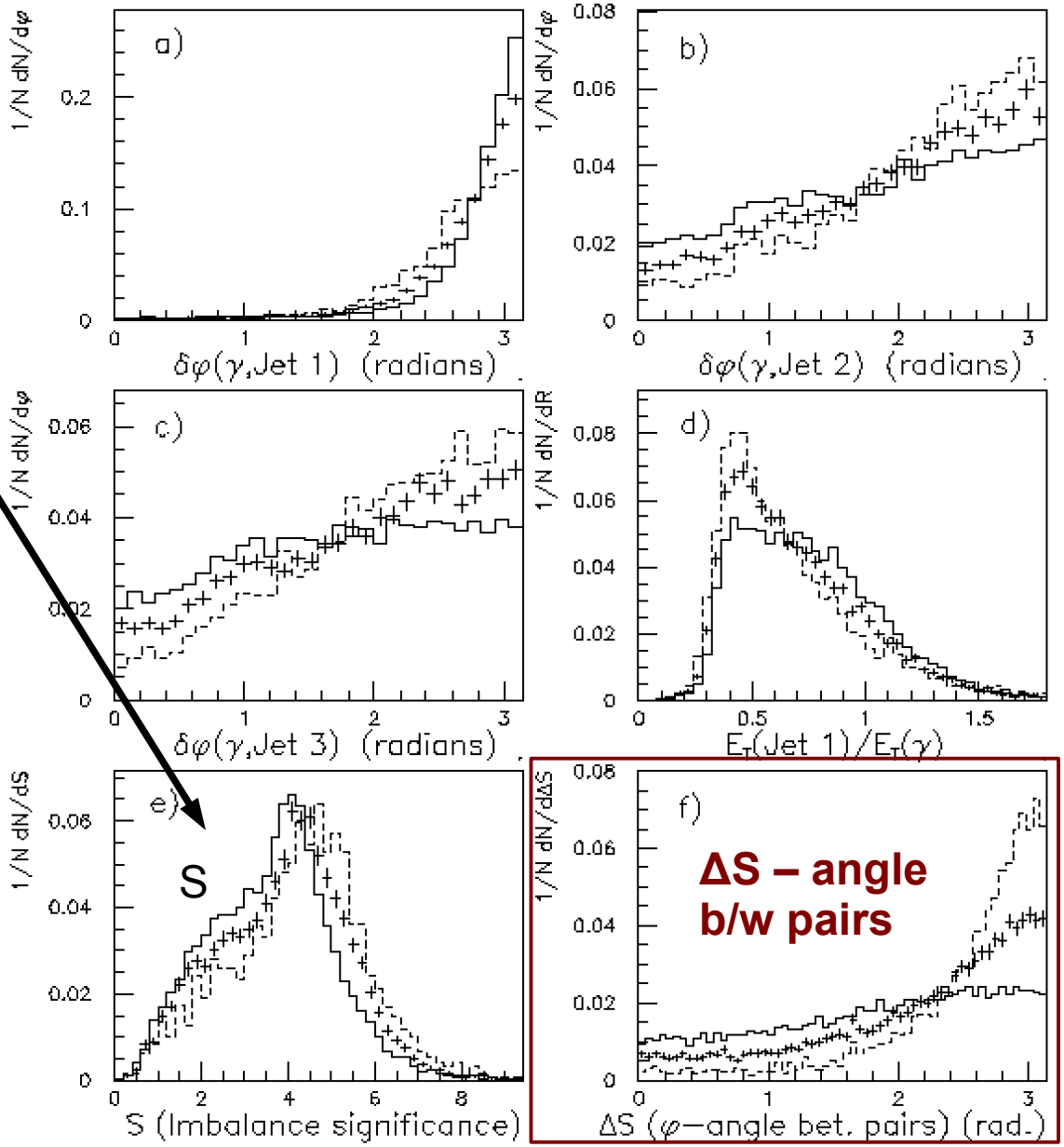
$$S = \frac{1}{\sqrt{2}}\sqrt{\left(\frac{|\vec{p}_T(\gamma,i)|}{\sqrt{p_T(\gamma)+p_T(i)}}\right)^2 + \left(\frac{|\vec{p}_T(j,k)|}{\sqrt{p_T(j)+p_T(k)}}\right)^2}$$

***MIXDP* model for Double Parton scattering:**

- Assumes two independent hard scatterings
- Obtained by mixing two CDF events (inclusive photon and minimum bias)
- → γ + jet incorporates underlying event contribution appropriate for single p pbar collisions

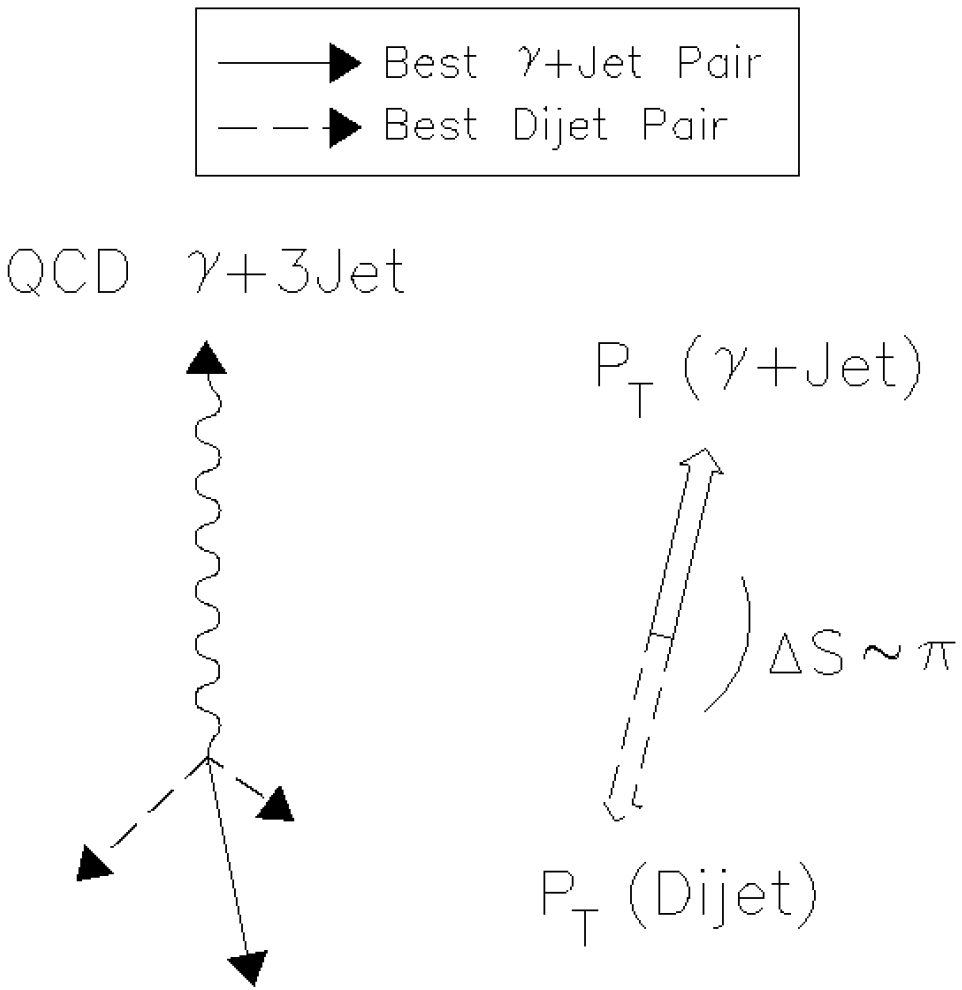
Plots compare shapes for

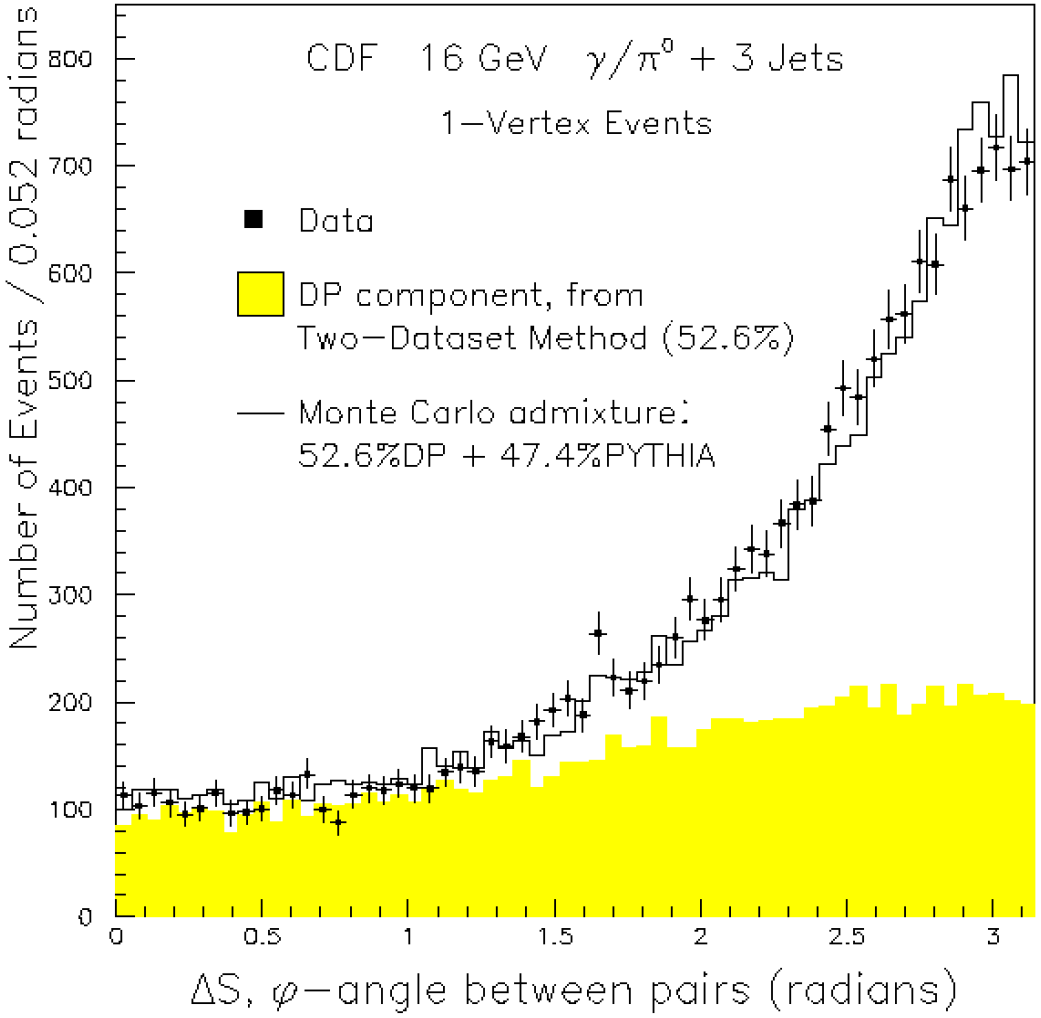
- 1-Vertex data (**+**)
- MIXDP prediction for Double Parton scattering (—)
- Pythia 5.702 prediction for single parton-parton scattering (– –)



Azimuthal angle between pairs

ΔS - azimuthal angle between the P_T-vectors of the two best-balancing pairs





→ Data (■) described by admixture (—) of Double Parton and Single Parton scattering

New model in Pythia 8.086

- **Pythia 8.086 allows a precise specification of a second hard process**
  - Relevant section in Pythia 8.086 manual: https://twiki.cern.ch/twiki/pub/CMS/MBUEFlorianBechtelLog/pyManual2ndHardProcess.ps
- **Limited set of prepackaged process collections for 2nd process**
  - QCD 2 → 2
  - Photon + jet
  - Two prompt photons
  - Single γ/Z: q qbar → γ/Z^0
  - Single W: q qbar → $W^{+/-}$
  - q qbar → b bbar, gg → b bbar **...beware of double-counting**
- **Selection rules**
  - **same selection rules** for process properties and phase space cuts **as first hard process**
  - In particular: P_T^{min}-cut for 2 → 2 **applied to both hard processes**

Pythia 8.086 tests

```
...
 |   |                                                                    |   |
 |   |   PPP   Y   Y  TTTTT  H   H  III    A      Welcome to the Lund Monte Carlo!   |   |
 |   |   P  P   Y Y     T    H   H   I    A A     This is PYTHIA version 8.086       |   |
 |   |   PPP     Y      T    HHHHH   I   AAAAA    Last date of change: 31 May 2007   |   |
 |   |   P       Y      T    H   H   I   A   A                                       |   |
 |   |   P       Y      T    H   H  III  A   A    Now is 13 Jul 2007 at 16:57:59     |   |
 |   |                                                                    |   |
...
```

Parameter settings for Double Parton scattering in γ + 3-jet final states:

"HardQCD:all = on",
"SecondHard:generate = on",
"SecondHard:PhotonAndJet = on",
"PhaseSpace:mHatMin = 40.",
"PhaseSpace:pTHatMin = 20."

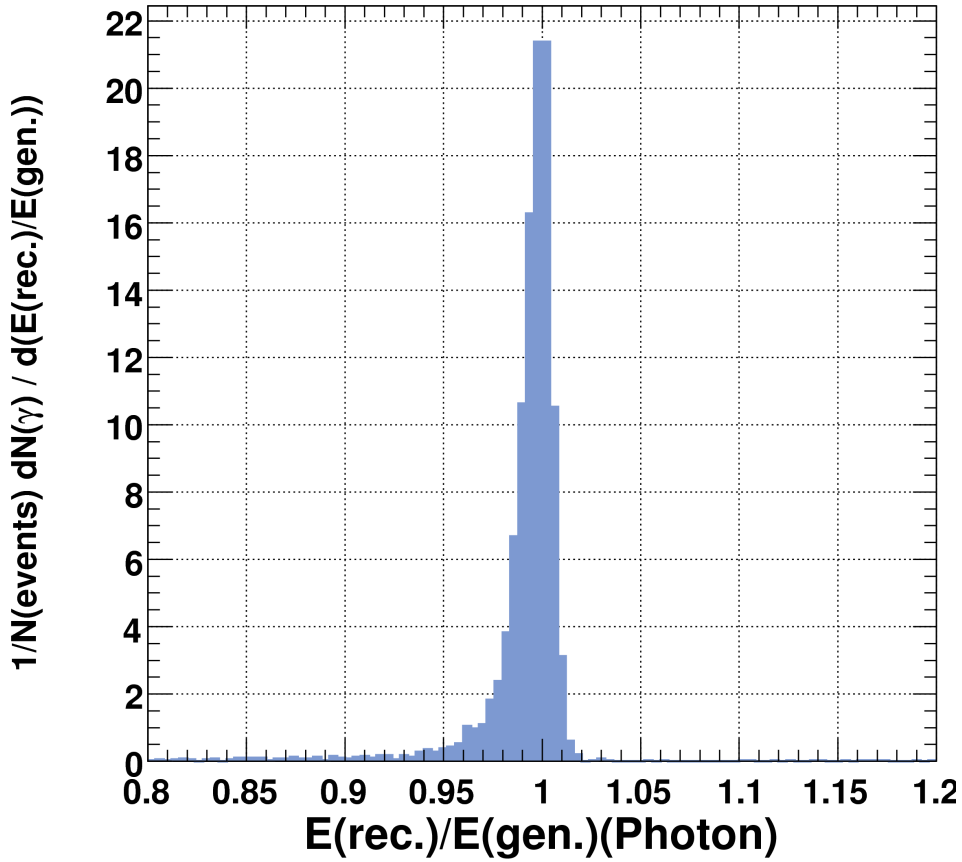
generated 1000 events without crashing

CMSSW interface to Pythia 8

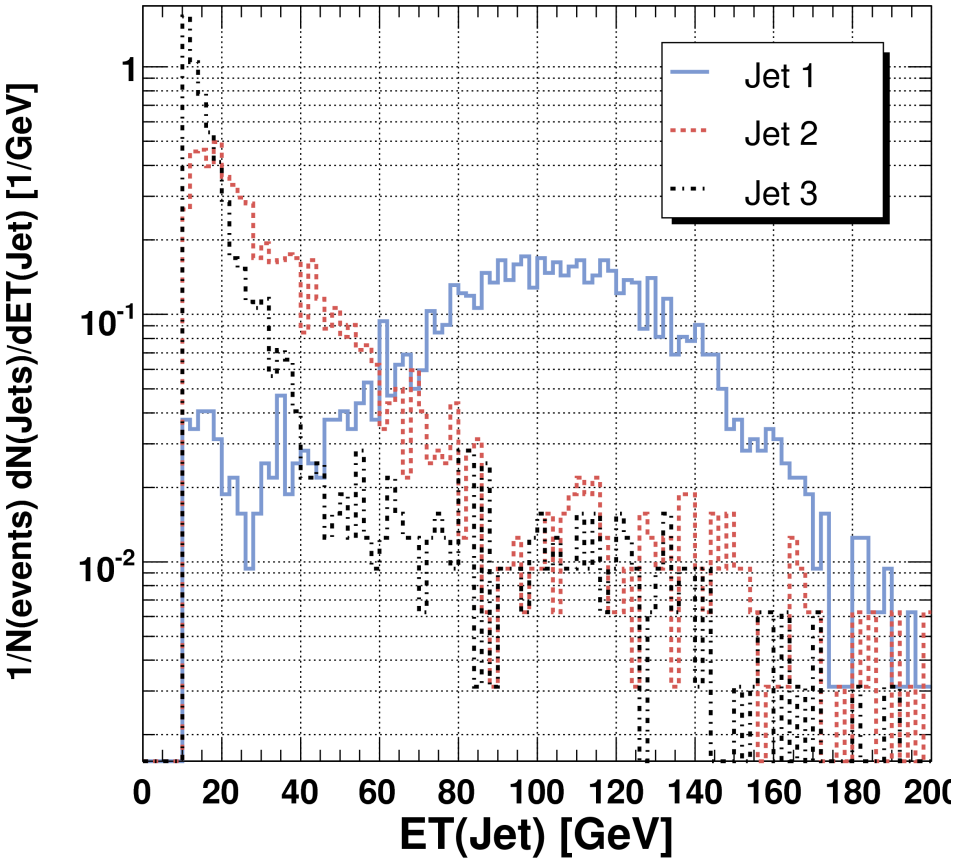
- **Pythia 8.086 not yet available in Genser repository**
  - Installation described in http://www.thep.lu.se/~torbjorn/pythiaaux/future.html
  - Official example: main41.cc
  - local installation in /rdata2/uhh-cms013/data/bechtel/Pythia8/pythia8086
- **CMSSW interface provided by Mikhail Kirsanov**
  - GeneratorInterface/Pythia8Interface
  - Usage (i.e. setup environment for a specific installation area) described in https://twiki.cern.ch/twiki/bin/view/CMS/Pythia8Interface
- **Production of test sample ongoing**
  - Code development on γ + jet sample /Photon_Jets_pt_120_170/CMSSW_1_3_1-Spring07-1361/GEN-SIM-DIGI-RECO
  - Analysis code available for CMSSW_1_4_3: UserCode/FlorianBechtel/GammaThreeJets/GTJAnalyzer

Selection cuts

- choose photon with largest E_T
- $E_T(\gamma) > 10$ GeV
- R9(γ) = E(3x3 crystals)/E(Super-Cluster) > 0.95
  - effective in distinguishing photon conversions in the material of the tracker
  - large R9: photon candidate either did not convert or converted late in the tracker



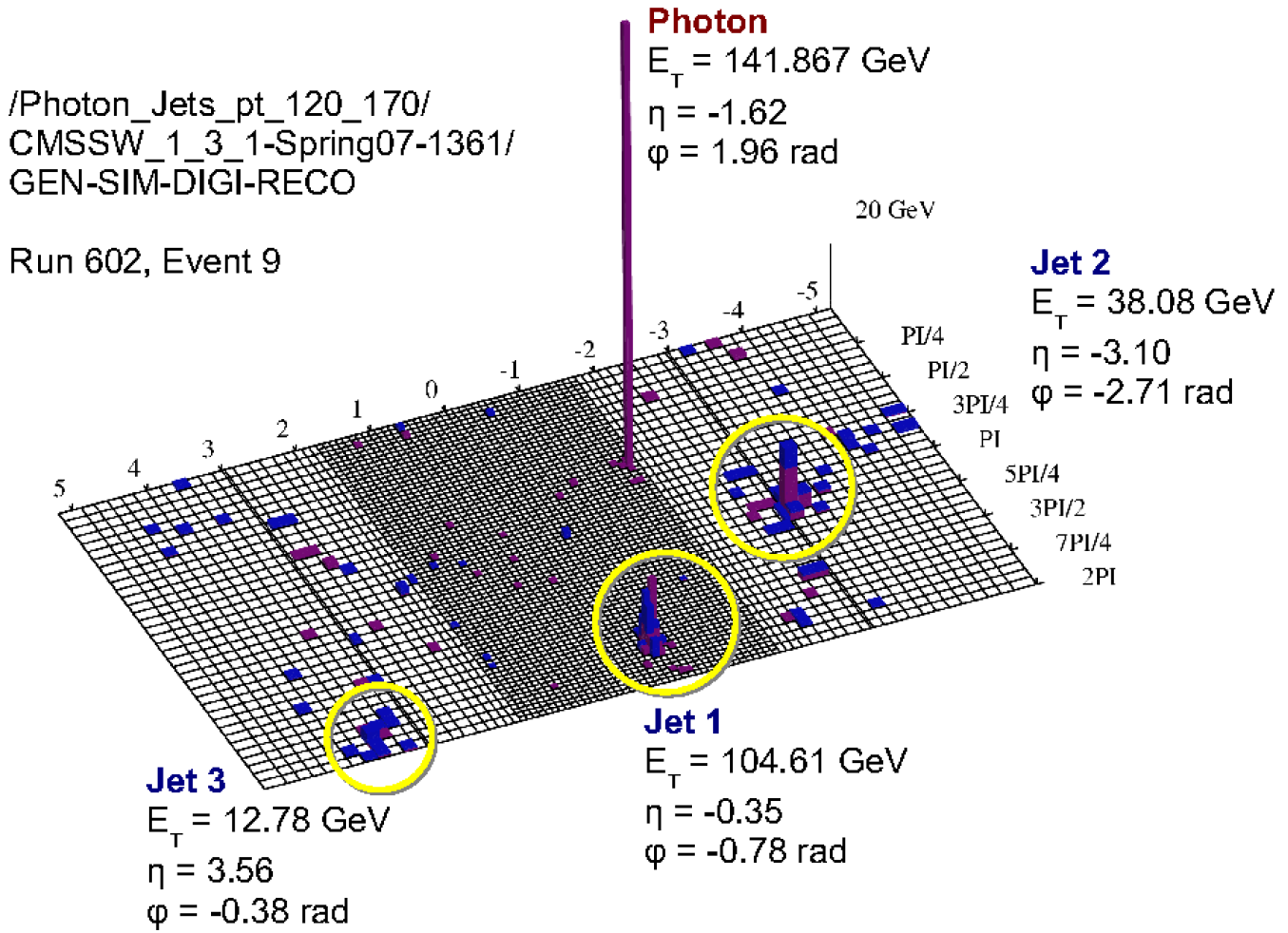
- exactly one event vertex
- E_T(Jet) > 10 GeV
- $\Delta R(\gamma, \text{Jet}) > 0.8$
  - choose three jets with largest E_T
- midPointCone7CaloJets
- Jet 1 combined with γ



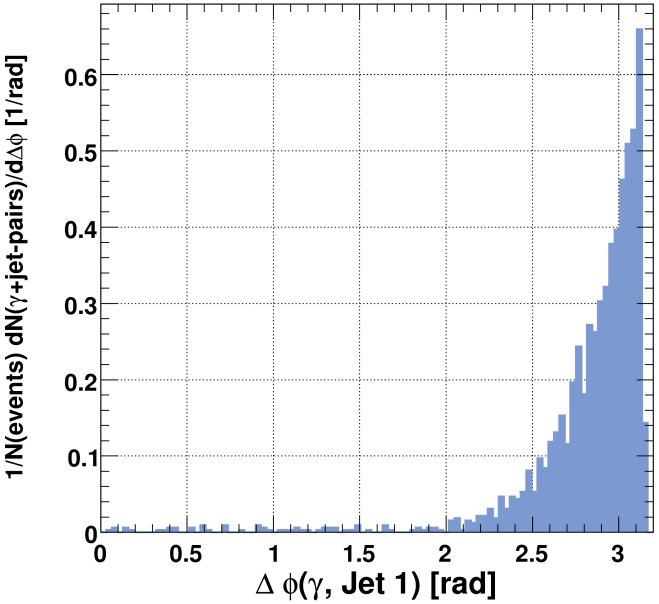
Pair selection

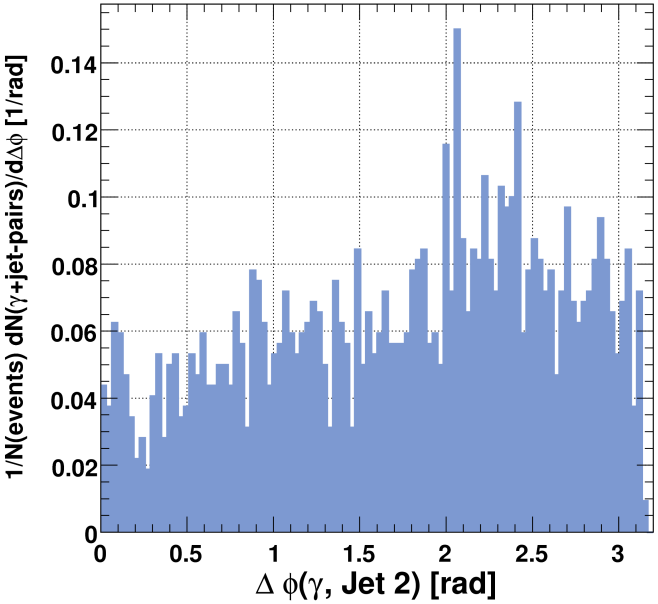
Choose γ + jet and dijet pairs by minimizing

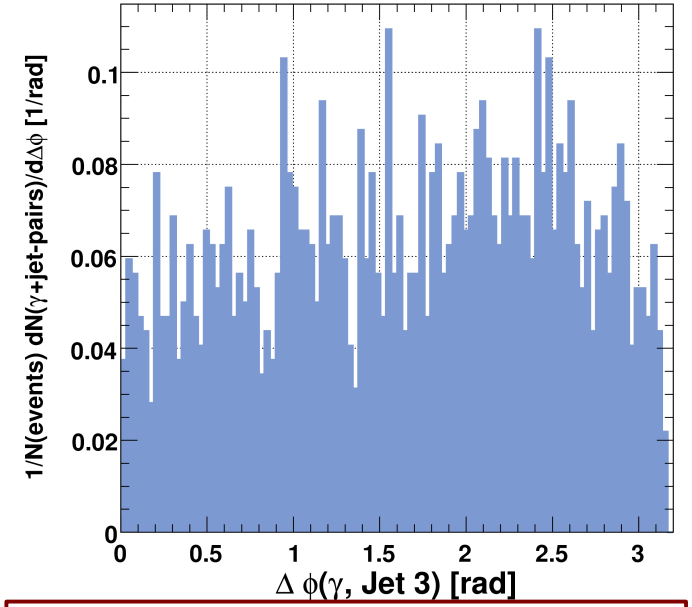
$$S = \frac{1}{\sqrt{2}}\sqrt{\left(\frac{|\vec{p}_T(\gamma,i)|}{\sqrt{p_T(\gamma)+p_T(i)}}\right)^2 + \left(\frac{|\vec{p}_T(j,k)|}{\sqrt{p_T(j)+p_T(k)}}\right)^2}$$

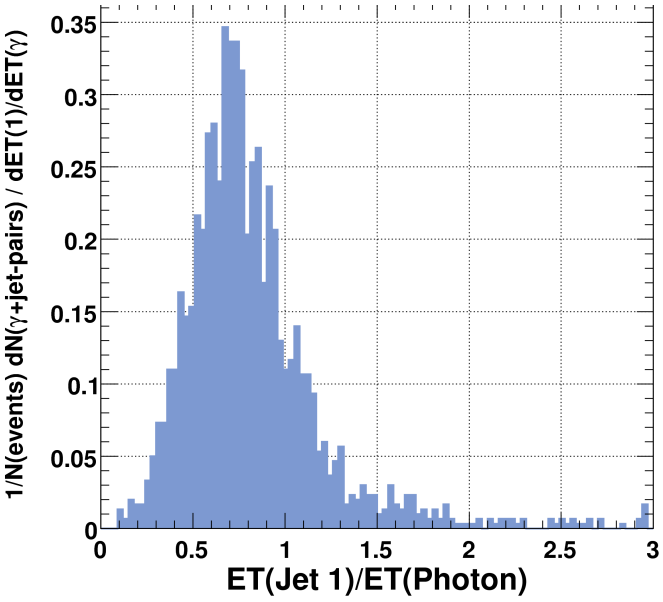


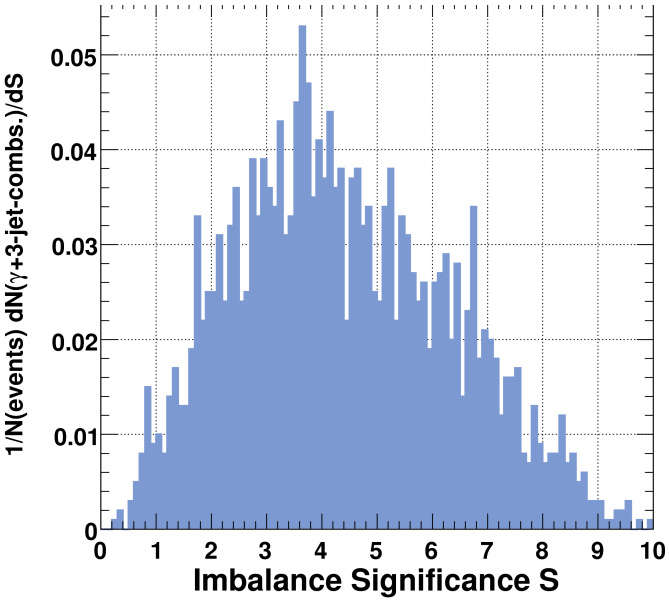
Code validation: Kinematic variables

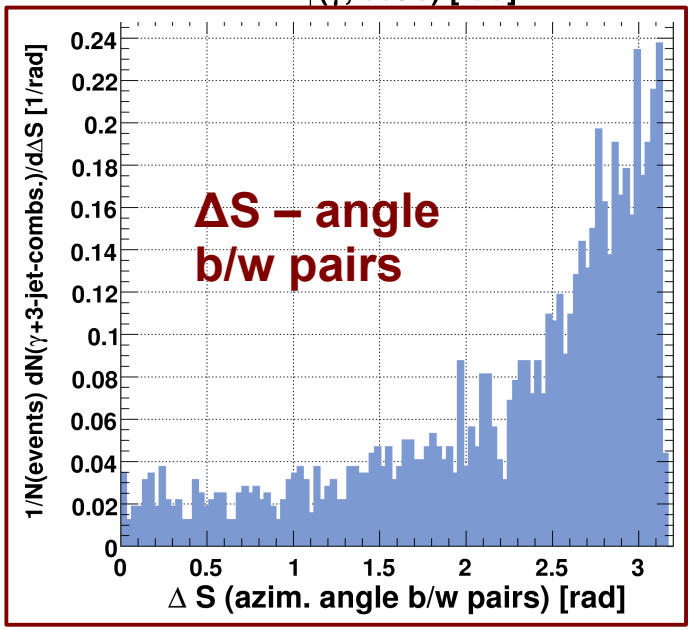












What's next?

- **Produce test samples**
  - Single Parton scattering:
    - γ + jets (Pythia) and γ + n-jets (Alpgen) from official production
  - Double Parton scattering:
    - Grid production: GEN files already quite large (probably not feasible to send them via input sandbox)
    - Batch farm: Access to local disk (/rdata2/uhh-cms013/data/bechtel/Pythia8/pythia8086) needed...
    - Workgroup servers: Slow and/or tedious

- **Code development**
  - implement charged jets (i.e. jets from tracks → better azimuthal resolution, can go to lower P_T)

Backup

Photon reconstruction efficiency

in 10000 events 3879 good matched photons
on average 1.6 photons with ET > 25 GeV
on average 3.4 photons with R9 > 0.95