Riunione LHCb-PD

Luca Giambastiani
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Z+jets differential cross section

Z->μμ only, only 2018 MagUp for the moment

Overview:

- Selection and plots
- Main backgrounds:
  - MisID of hadrons as muons
  - Semileptonic decays of heavy flavour
  - Z decays to τ
  - ZZ, ZW and tt
- Jet reconstruction efficiency, fakes correction and unfolding
- Next steps in detail

Data selection

Events with at least 1 μ^+, 1 μ^- and 2 jets

Muon requirements:

- Positive and negative muons with max energy
- At least one muon TOS wrt L0 and HLT1
  - L0MuonEWDecision
  - Hlt1SingleMuonHighPTDecision
- Muon isolation > 0.7 and muon IPχ^2 < 20 for both

Jets requirements:

- Reject jets with DeltaR(J, μ) < 0.5 wrt both selected muons
- Keep the 2 jets with max PT

Cuts:

- 20 GeV < PT(μ) < 150 GeV
- 2.0 < $\eta(\mu)$ < 4.5
- 60 GeV < M($\mu\mu$) < 120 GeV
- 20 GeV < PT(J1) < 100 GeV
- 20 GeV < PT(J2) < 40 GeV
- 2.2 < η(J) < 4.2

WARNING: Trigger, isolation and IPχ^2 requirements are not enforced on MC samples

Some detail: DaVinci option

Jets: StdHltJets with PT > 10 GeV

```
_jets = DataOnDemand(Location = 'Phys/StdHltJets/Particles')

firstZ =  CombineParticles(
    'Combine_Z1',
    DecayDescriptor='Z0 -> CELLjet CELLjet',
    MotherCut = "ALL"
)

firstZ.DaughtersCuts = { 'CELLjet': 'PT>10*GeV' }
```

Muons:
StdAllLooseMuons
with PT > 20 GeV

```
_muons = DataOnDemand(Location = 'EW/Phys/StdAllLooseMuons/Particles')

secondZ =  CombineParticles(
    'Combine_Z2',
    DecayDescriptor='Z0 -> mu+ mu-',
    MotherCut = "ALL"
)
secondZ.DaughtersCuts = { 'mu+': 'PT>20*GeV', 'mu-': 'PT>20*GeV' }
```

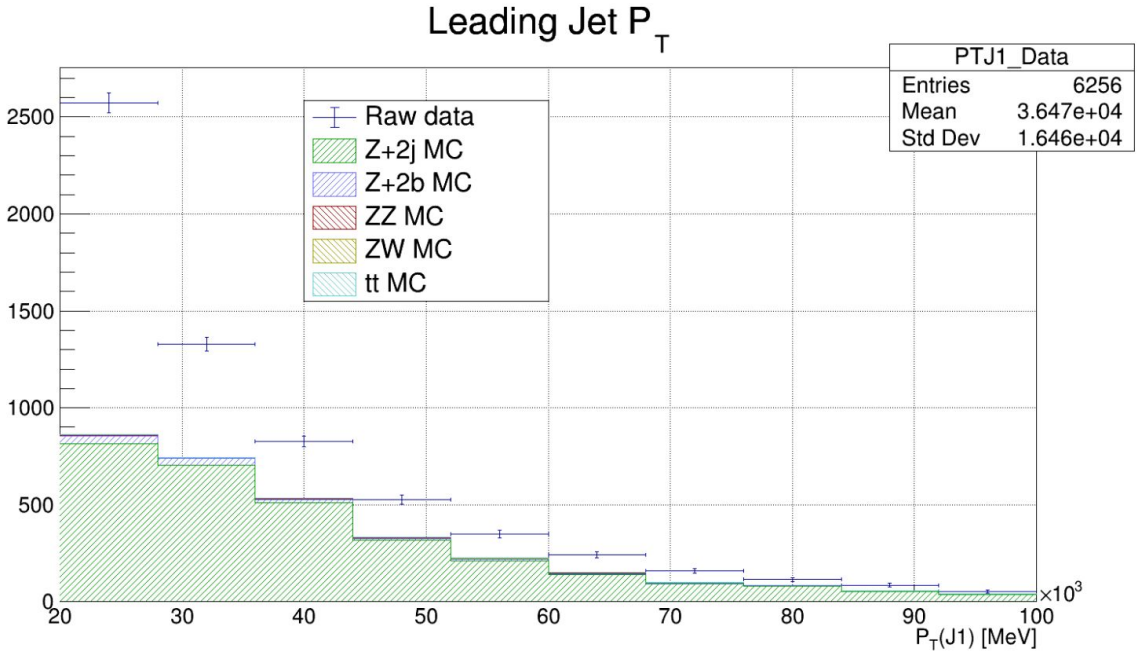
Trigger and stripping requirements in DaVinci: None
Required trigger lines in TupleToolTISTOS:

- L0MuonEWDecision
- Hlt1SingleMuonHighPTDecision
- Hlt2SingleMuonVHighPtDecision

A look at data

Signal MC:
Z+2j and Z+2b generated with MadGraph @NLO

Data:
Accepted 6256 events over 56680 (11.04%)
Z+2j:
Accepted 2815 events over 9882 (28.49%)
2959.69 norm
Z+2b:
Accepted 1106 events over 3891 (28.42%)
121.93 norm
tt:
Accepted 1614 events over 22585 (7.15%)
31.10 norm
ZZ:
Accepted 77 events over 256 (30.08%)
6.48 norm
ZW:
Accepted 88 events over 284 (30.99%)
5.52 norm



Luminosity of this dataset: 1037.54 pb
Cross sections from generator (MadGraph for Z+2j/b, Pythia8 all the others)

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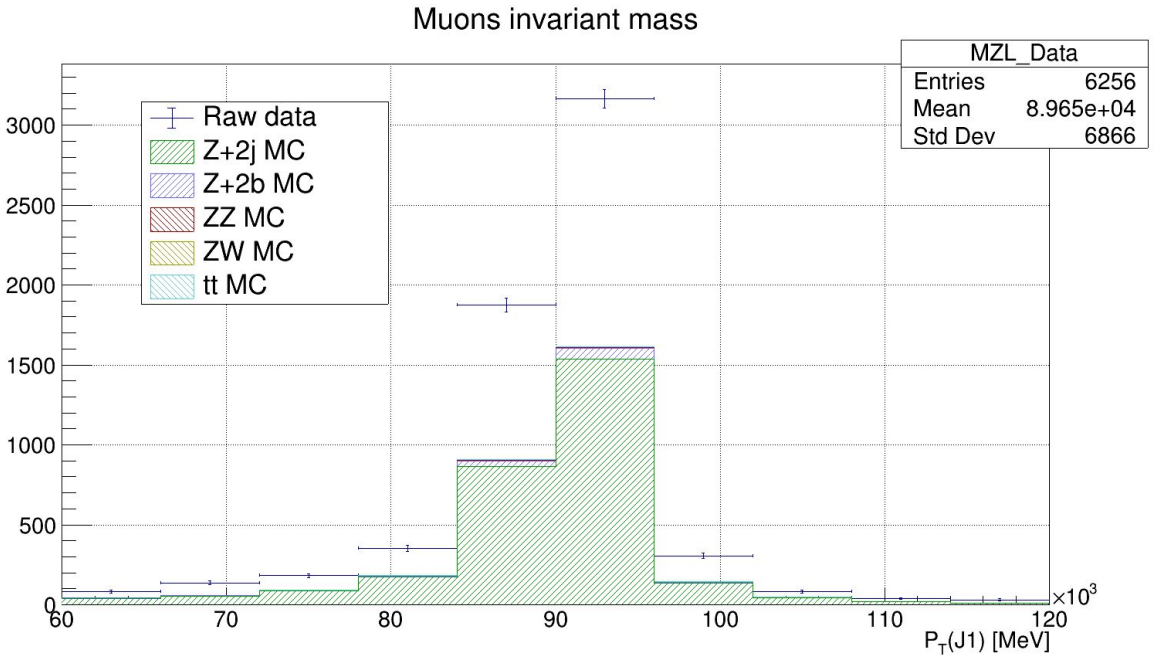

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Some detail: Decfile

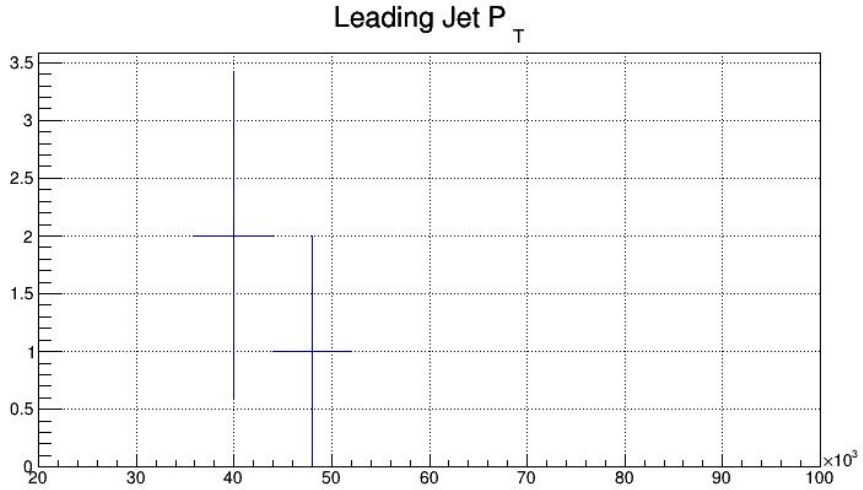
- Madgraph (matrix element) generate muons and 2 jets without specifying intermediate resonances
  - If I ask production of Z+2j, then Pythia would decay a Z with zero width
  - Invariant mass cut ensures there is only gamma/Z
- No cuts on kinematics
- Requirements in Gauss:
  - more than 1 muon in acceptance and PT > 5 GeV

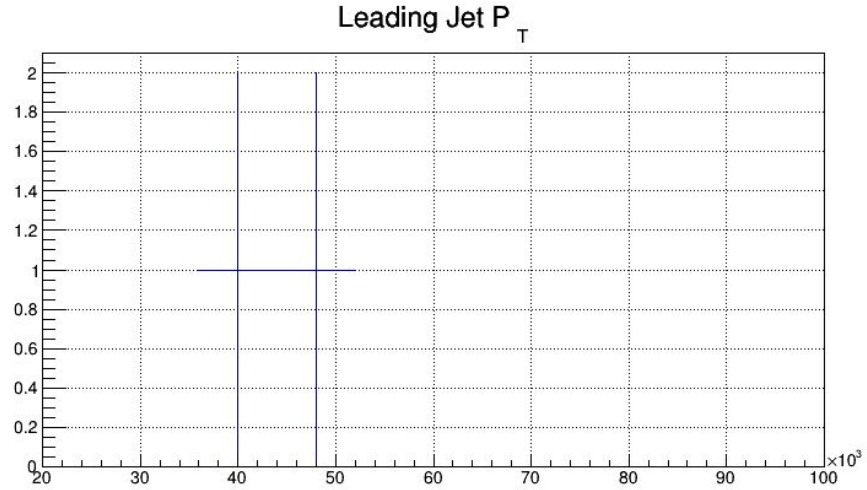
```
# Madgraph options.
from Configurables import Gauss
Gauss().SampleGenerationToolOptions = {
    "Commands": ["import model loop_sm-ckm",
                 "define p = u d s c u~ d~ s~ c~ g",
                 "define j = u d s c u~ d~ s~ c~ g",
                 "generate p p > mu+ mu- j j [QCD]",
                 " set mll_sf 40.0",
    ],
    "DecEff": 0.003
}
```

```
tracksInAcc = Generation().HiggsTypeCut
tracksInAcc.Code = " ( (count ( isGoodMuonZ ) > 0 ) ) "
tracksInAcc.Preambulo += [
        "from GaudiKernel.SystemOfUnits import  GeV, mrad",
        "isGoodMuonZ = (GNINTREE( (GABSID == 13) & ( GTHETA < 400.0*mrad ) & (GPT > 5*GeV), 1) > 1 )"
]
```

Same sign background

MisID of hadrons as muons: same sign sample
Subtracted from data

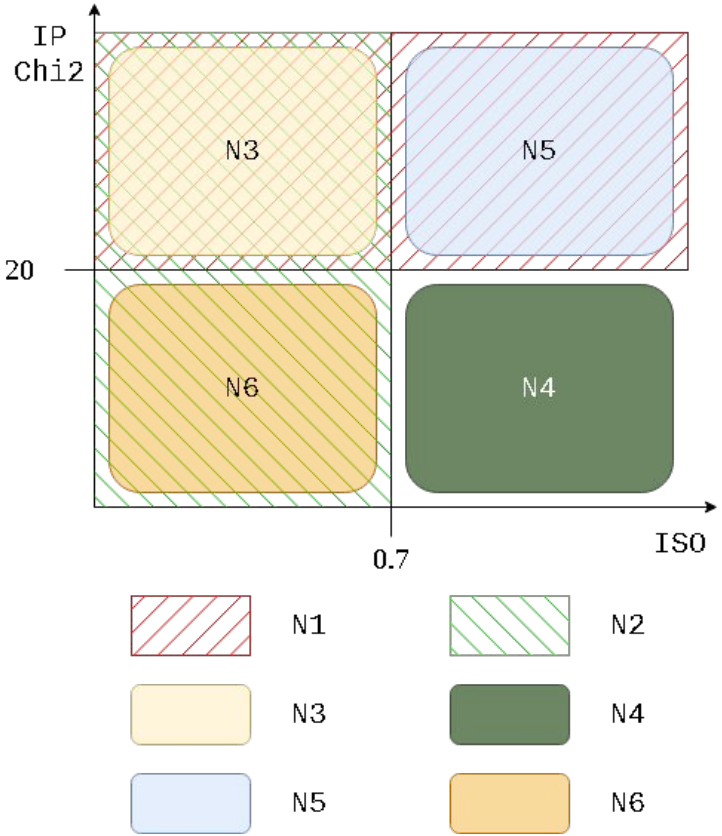




Data ++:
Accepted 3 events over 13500 (0.02%)

Data --:
Accepted 2 events over 9605 (0.02%)

Heavy flavour decays to muons



$$\frac{N_3}{N_1} = \epsilon(iso < 0.7)$$

$$\frac{N_3}{N_2} = \epsilon(\chi^2 > 20)$$

$$\frac{N_5}{N_1} = \epsilon(iso > 0.7)$$

$$\frac{N_6}{N_2} = \epsilon(\chi^2 < 20)$$

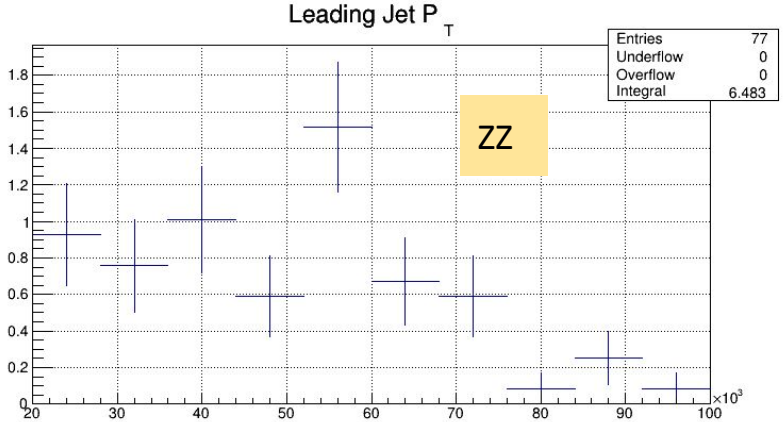
$$N_4 = N_{ALL} \times \epsilon(\chi^2 < 20) \times \epsilon(iso > 0.7)$$

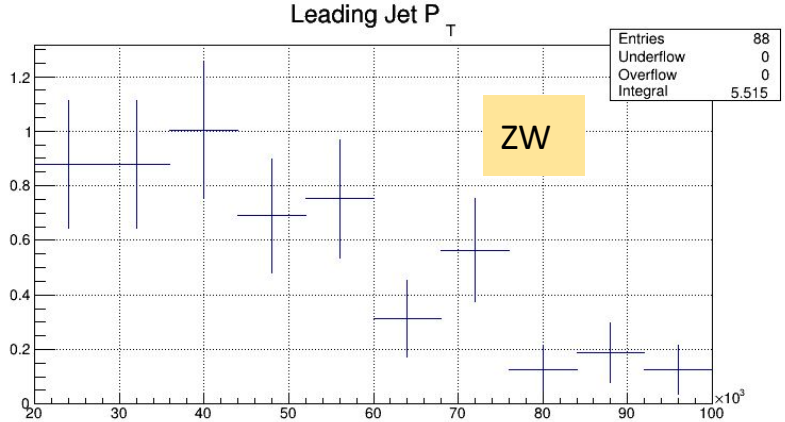
$$N_{ALL} = N_1/\epsilon(\chi^2 > 20) = N_2/\epsilon(iso < 0.7)$$

$$N_4 = N_1 \frac{N_2}{N_3}\frac{N_6}{N_2}\frac{N_5}{N_1} = \boxed{\frac{N_5 N_6}{N_3}}$$

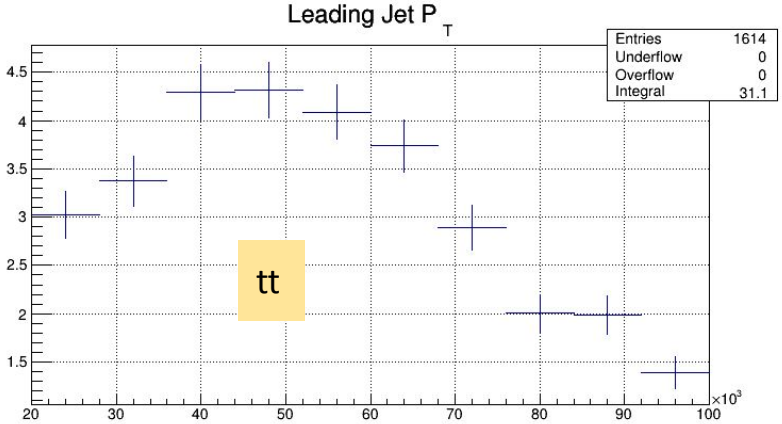
Est. 14 events

EW decays





Subtracted from data

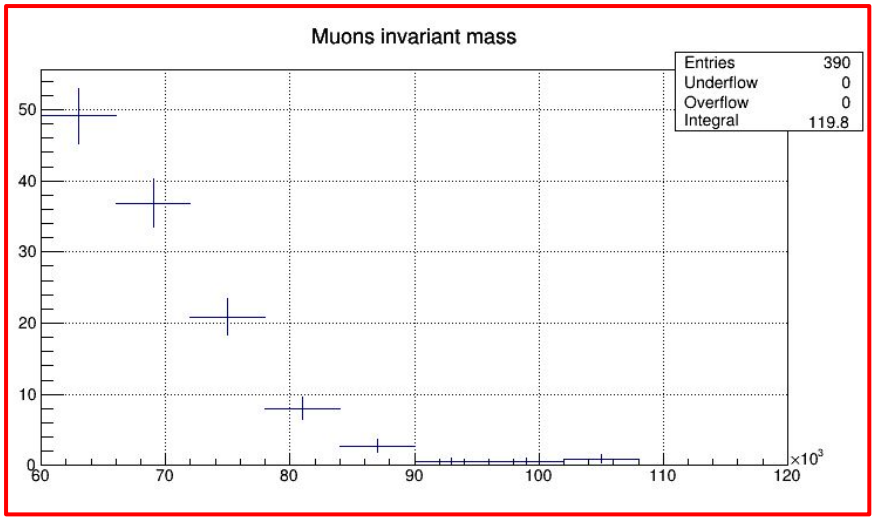


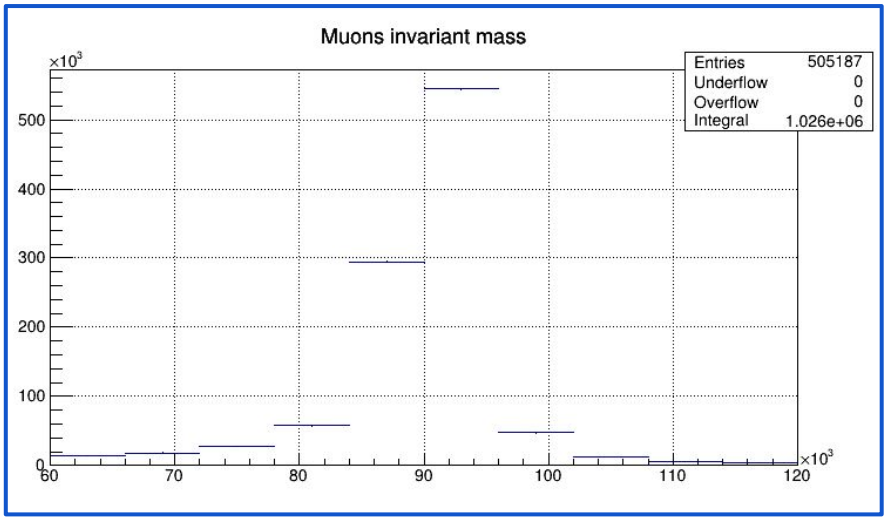
Z -> ττ background

Data after backgrounds subtraction

$$(Z \to \tau\tau)jj \simeq (Z \to \mu\mu)jj \times \frac{Z \to \tau\tau}{Z \to \mu\mu}$$

Est. 4.8 events





Unfolding et al.

$$U = \frac{P_T(MC) \in [\alpha, \beta] \text{ and } \eta(MC) \in [\gamma, \delta] \text{ and } P_T(RC) > 12.5 \text{ GeV}}{P_T(RC) \in [\alpha, \beta] \text{ and } \eta(RC) \in [\gamma, \delta] \text{ and } P_T(MC) > 12.5 \text{ GeV}}$$

Response matrix

$$\epsilon = \frac{P_T(MC) \in [\alpha, \beta] \text{ and } \eta(MC) \in [\gamma, \delta] \text{ and } P_T(RC) > 12.5 \text{ GeV}}{P_T(MC) \in [\alpha, \beta] \text{ and } \eta(MC) \in [\gamma, \delta]}$$

Jet reco efficiency

$$\rho = \frac{P_T(RC) \in [\alpha, \beta] \text{ and } \eta(RC) \in [\gamma, \delta] \text{ and } P_T(MC) > 12.5 \text{ GeV}}{P_T(RC) \in [\alpha, \beta] \text{ and } \eta(RC) \in [\gamma, \delta]}$$

Purity in rejecting fake jets

α = 20 GeV and β = +inf, or define the PT(j) bin if plotting jet PT distribution
γ = 2.2 and δ = 4.2, or define the η(j) bin if plotting jet eta distribution
PT threshold for matching is 12.5 GeV, smaller than 20 GeV to account for jet migrations

To obtain true events from reco: $N(MC) = N(RC) \cdot \frac{U \cdot \rho}{\epsilon}$

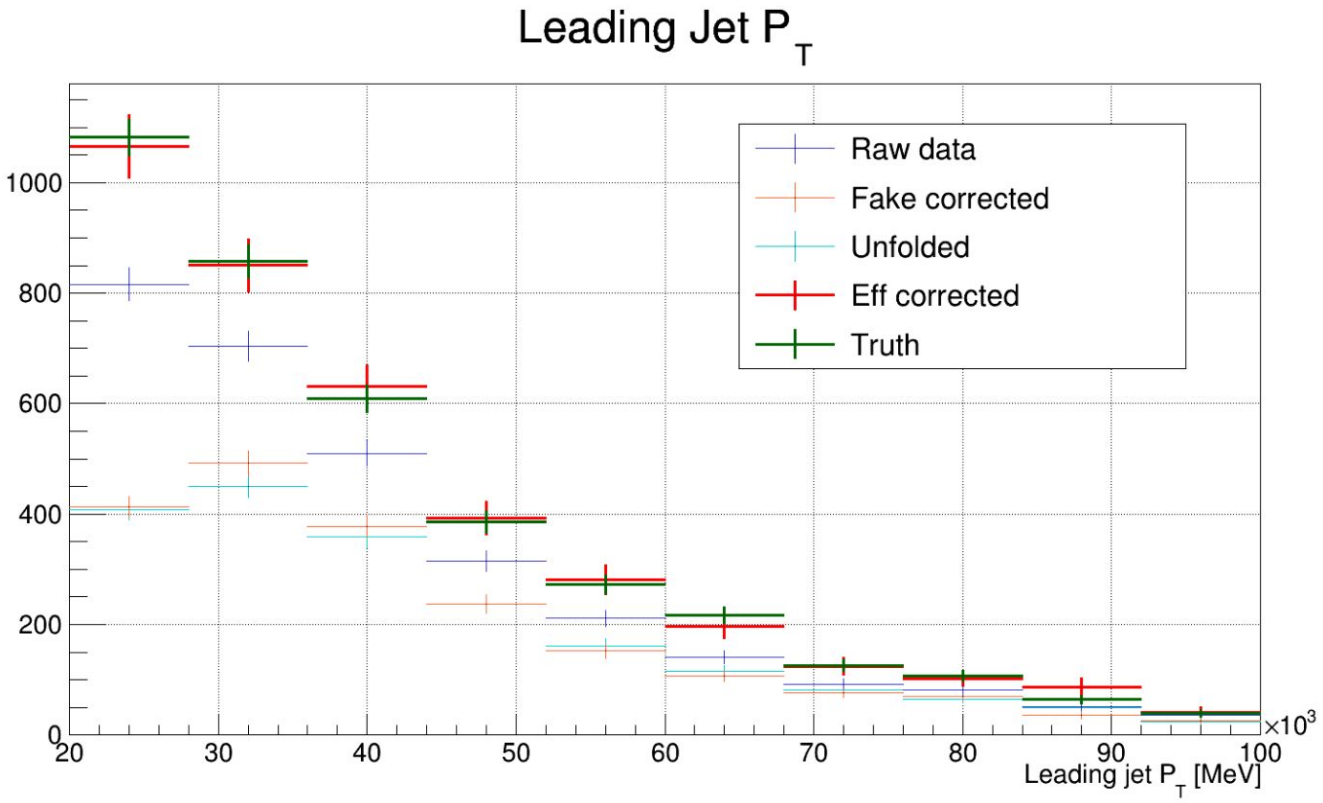
Closure test successful by definition

Unfolding et al.

Test on Z+2j@NLO simulated sample

Red and green distributions are compatible: Kolmogorov *p-value* = 100%

Bin-by-bin unfolding by RooUnfold



Conclusions

Simulated signal Z+2j @NLO does not reproduce well data

- Processes with smaller jet multiplicity at matrix element level, then additional jets come out from showering
- Also processes with larger jet multiplicity at ME but with some jets outside of acceptance
- NLO is really required?

Unfolding successful with PT(J1) variable

- Tested with “wrong” simulated signal, but I expect it will work well anyway

Missing:

- Production of all MC samples
  - Define signal process
  - EW bkgs with central production
- Production of MC and data for different years and polarity
- Z+j analysis
  - Requires minimal changes in all my programs, need to run DaVinci again
  - Production of signal MC (decfile already exists)

Timetable

- Definition of signal process for Z+2j: Aug week 1-2
  - Requires lots of generator level samples
- Run centrally all simulations for Z+2j: after first step, ~ Aug week 3 to Sept week 2
- Simulation for Z+1j (only signal)
  - Already done with Sim09l for Run2, Sim10 only for 2016
  - New simulations must be done with Sim10: is mixing versions a problem?
- Set up Z+1j analysis: ~ Aug week 3-4
- Make plots as function of different variables: Aug week 3-4
- Verify analysis chain (particularly unfolding) with new MC signal: ~ Sept week 3
- Systematics: from ~Sept week 2

- Set limit on ZZ
- Repeat analysis with Z->ee

First thoughts on systematics

- Backgrounds
  - Muons from heavy flavour: Change cuts in muons isolation and vertex
  - Z->ττ and EW: Poisson fluctuation of estimated events
- Efficiency, fake correction and unfolding:
  - Their statistical precisions
  - Others?
- Jet energy scale and resolution
- Jet identification: change id requirements comparing data and simulation