Review of Recent MPI Results from the Tevatron

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MPI@LHC Glasgow 2010

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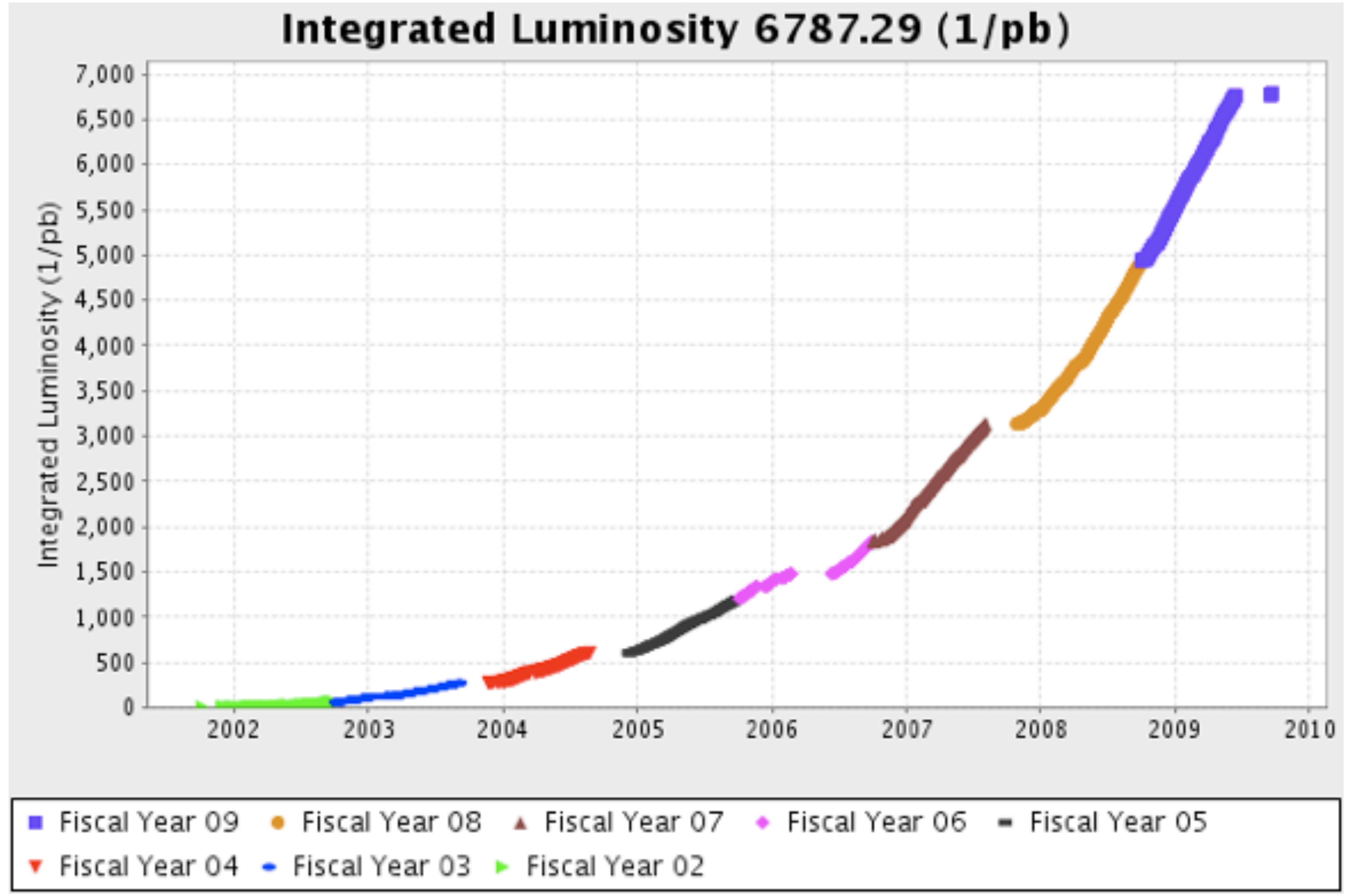
Overview

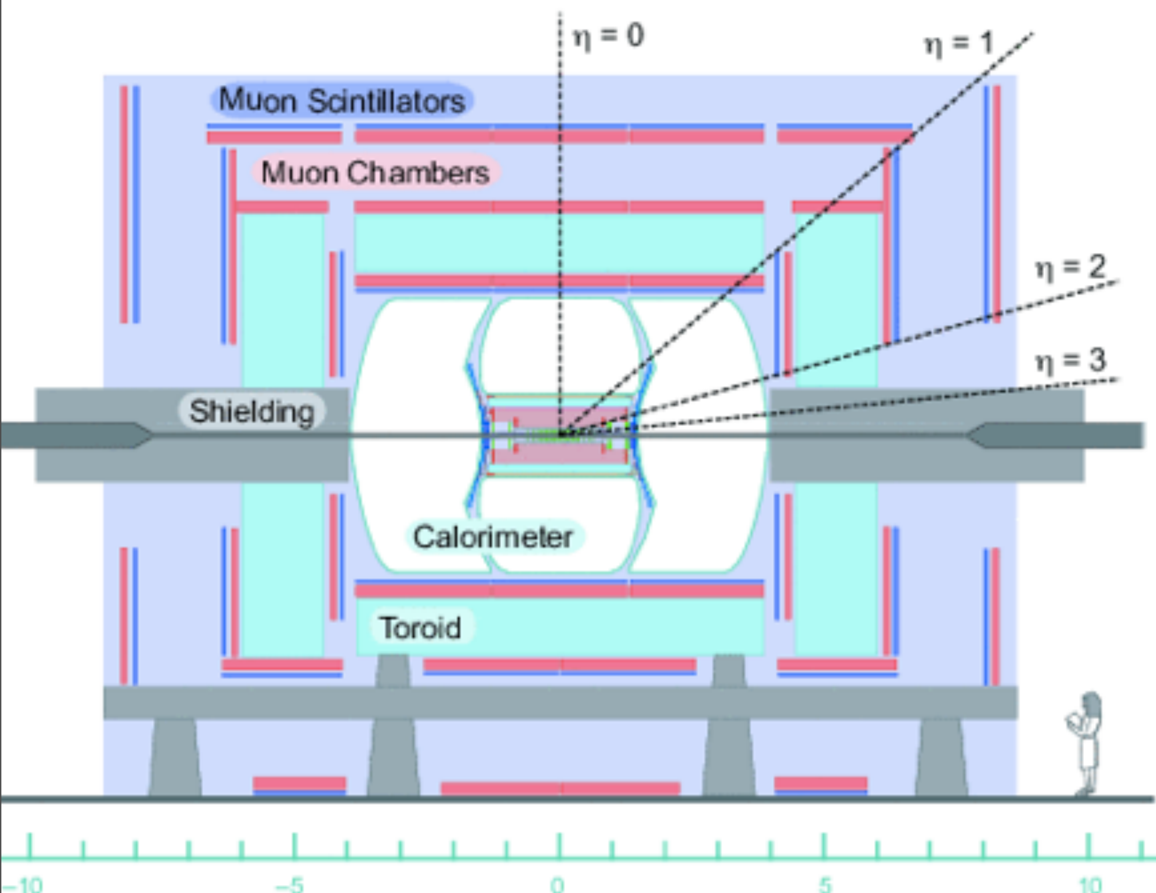
- Hyperons in minimum bias
- UE in Drell-Yan and incl. jet production
- Angular correlations in minimum bias
- k_t distributions of particles in jets
- DP events in γ + 3jets
- Upcoming: DP fractions in γ + 2(3)jets

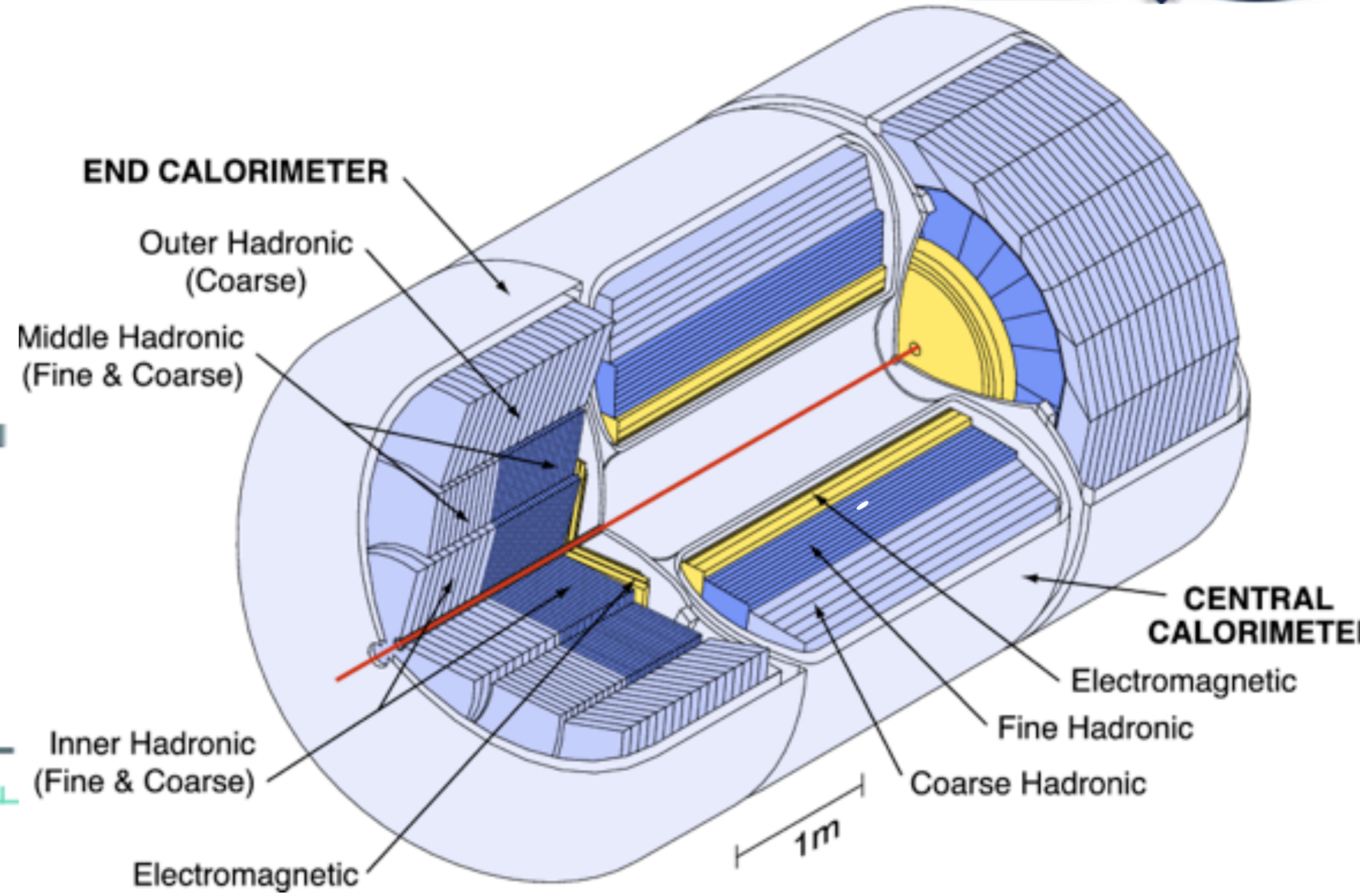
The Tevatron



- Fermilab's p-pbar collider at $\sqrt{s}$ = 1.98 TeV
  - Luminosity goal for end of 2011: 12 fb^{-1}
- Analysis in this presentation use 776 pb^{-1} to 3 fb^{-1}

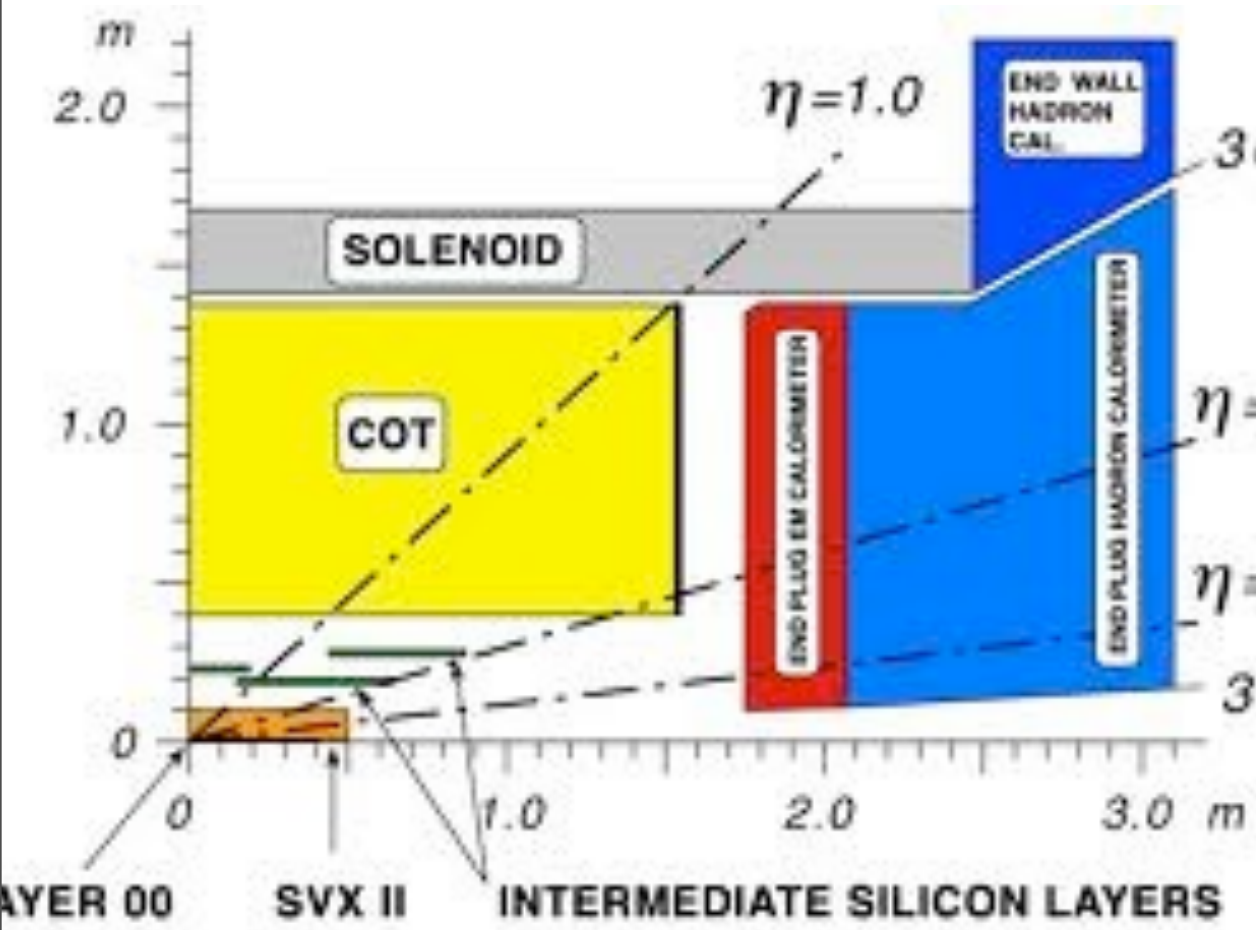
The DØ Detector

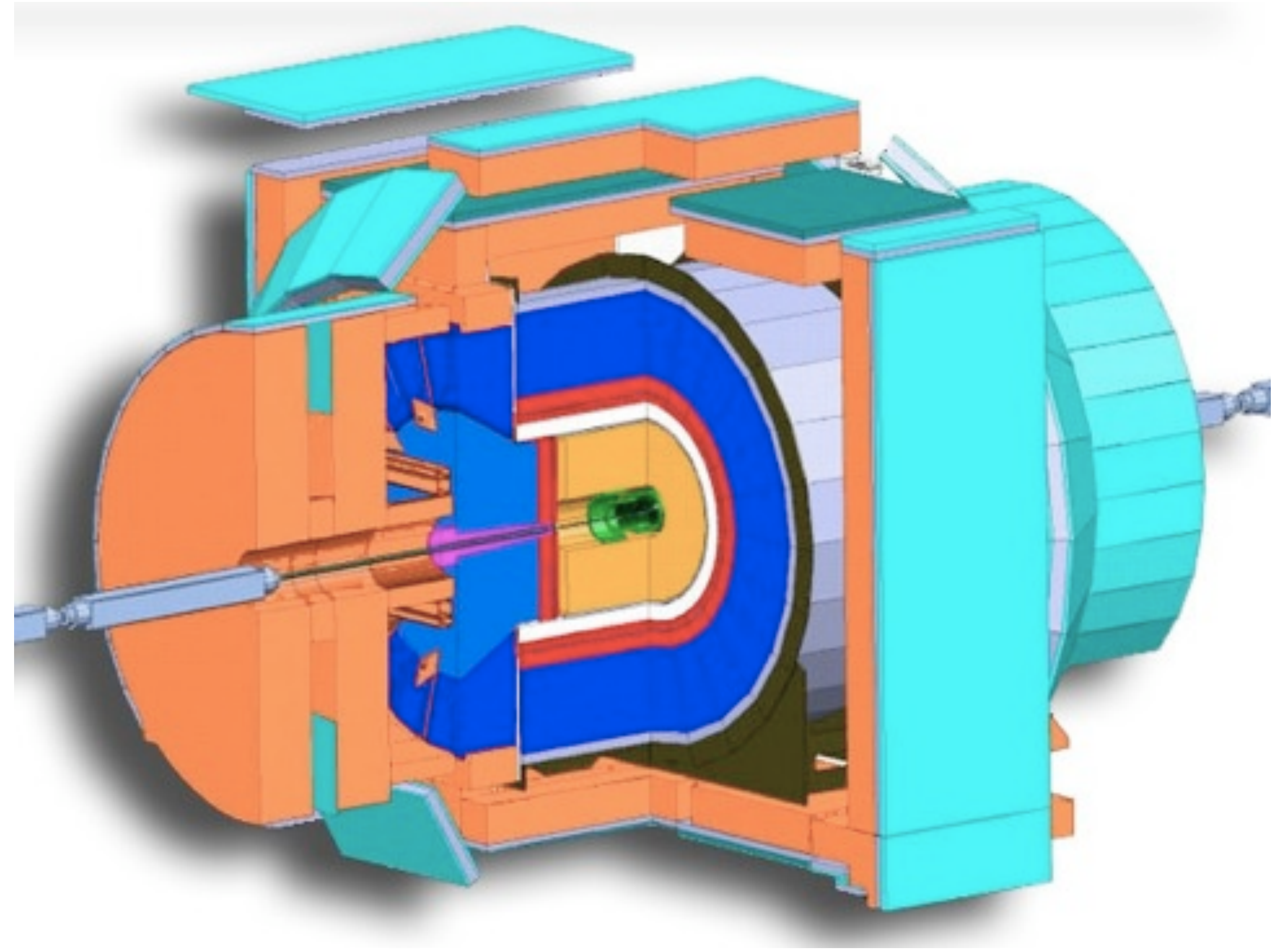




- Tracking using SMT and CFT |eta|<2, p_T>500(180) MeV
- Calorimetry |eta| < 4.2, Jet energy scale precision: 1-2%

The CDF Detector





- Tracking in SVX, Silicon, COT |eta| < 1, pT>300 MeV
- Calorimetry |eta| < 3.64, Jet energy scale precision: 2-3%

Hyperons in MinBias

- p_T dependent cross section of Hyperons (Λ, Ξ, Ω) in Minimum Bias events
  - Insight into particle production in collisions
  - e.g. QGP should enhance strange particle production
- 100 million MinBias events from CDF
  - Ample Λ statistics, good p_T reach
  - Also: Multiply strange Baryons ($\Xi^{\pm}$ and $\Omega^{\pm}$)

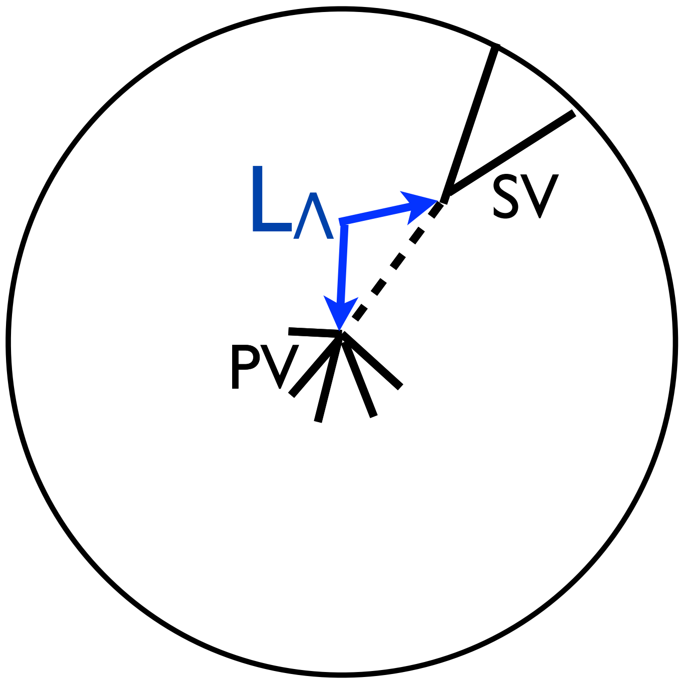
Using 3 fb^{-1}
Feb 2010

CDF note 10084

http://www-cdf.fnal.gov/physics/new/qcd/hyperons_10/HyperonWEBV2.htm

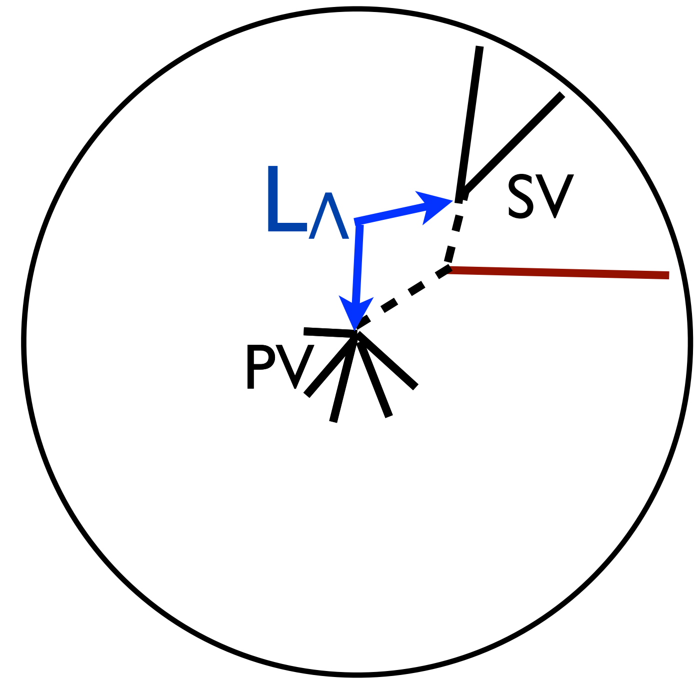
Λ, Ξ and Ω Selection

- Select best, isolated PV and good tracks
- Track $p_T > 0.325$ GeV, $|\eta| < 1.0$
- Lambda selection based on:
  - Transverse decay length $L_\Lambda > 2.5$ cm
  - Needs to point back to PV (d0, Δz)

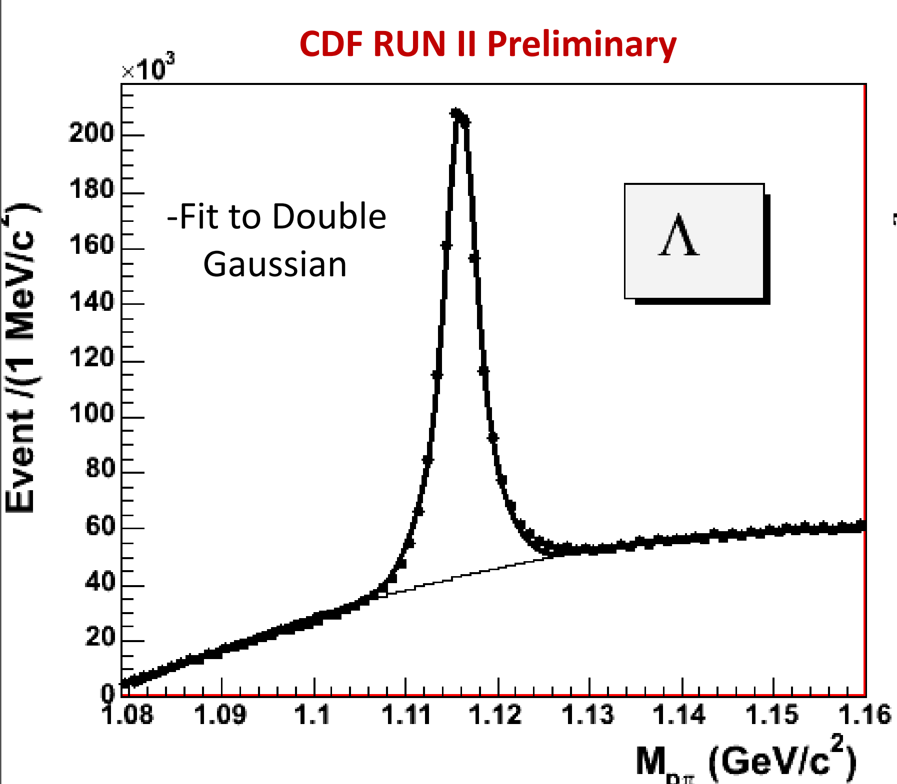


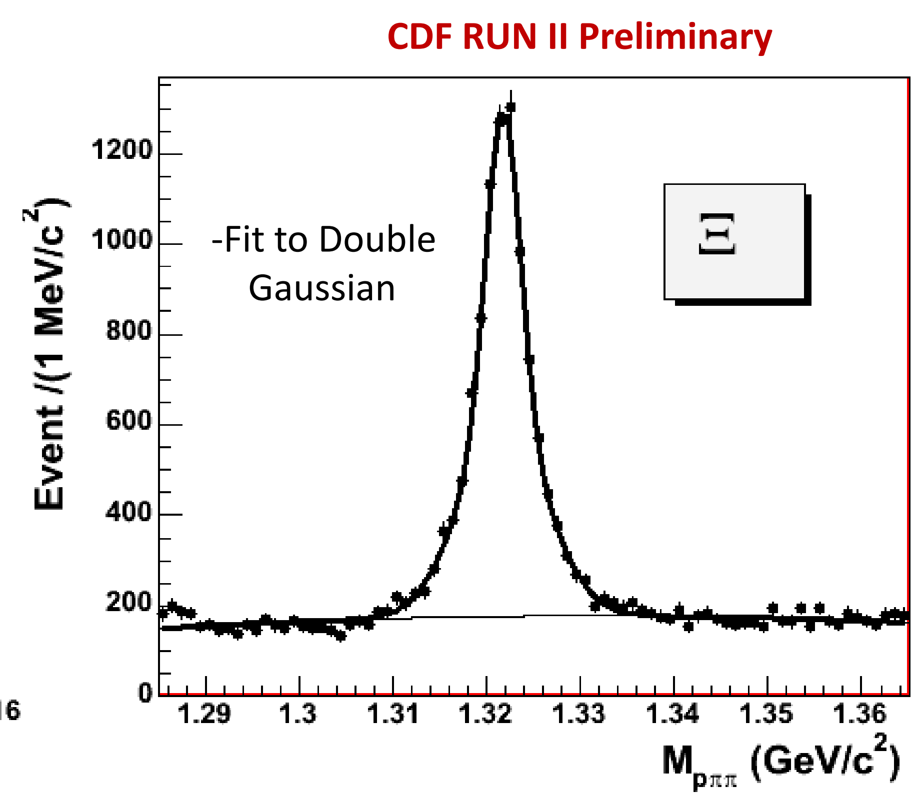
Λ, Ξ and Ω Selection

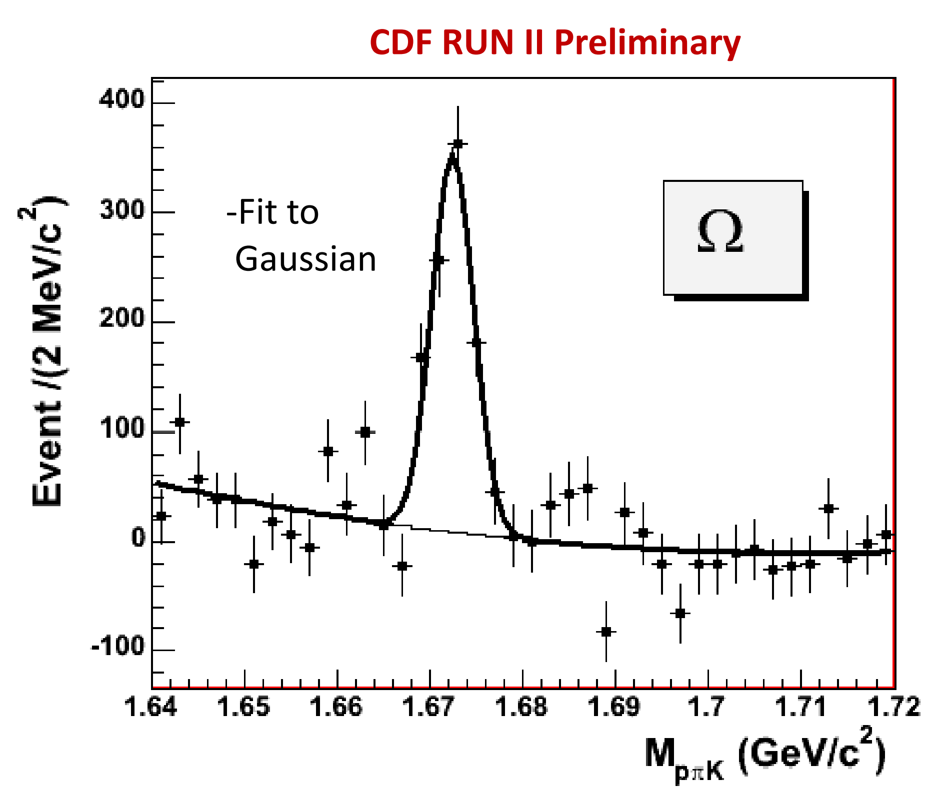
- Select best, isolated PV and good tracks
- Track p_T > 0.325 GeV, $|\eta|$ < 1.0
- Lambda selection based on:
  - Transverse decay length L_Λ > 2.5 cm
  - Needs to point back to PV (d0, Δz)



  - For Ξ/Ω add a track (π or K) “in between”



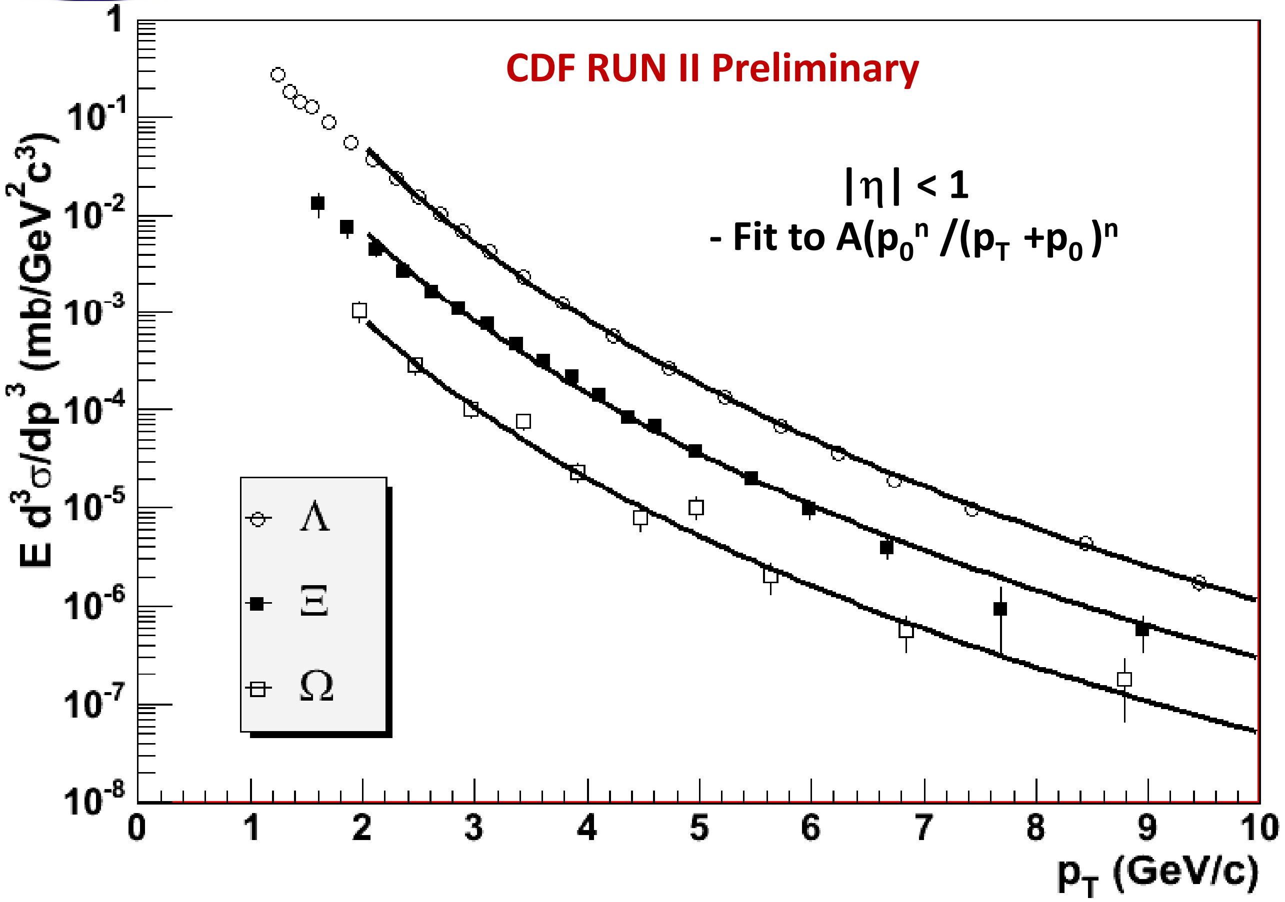




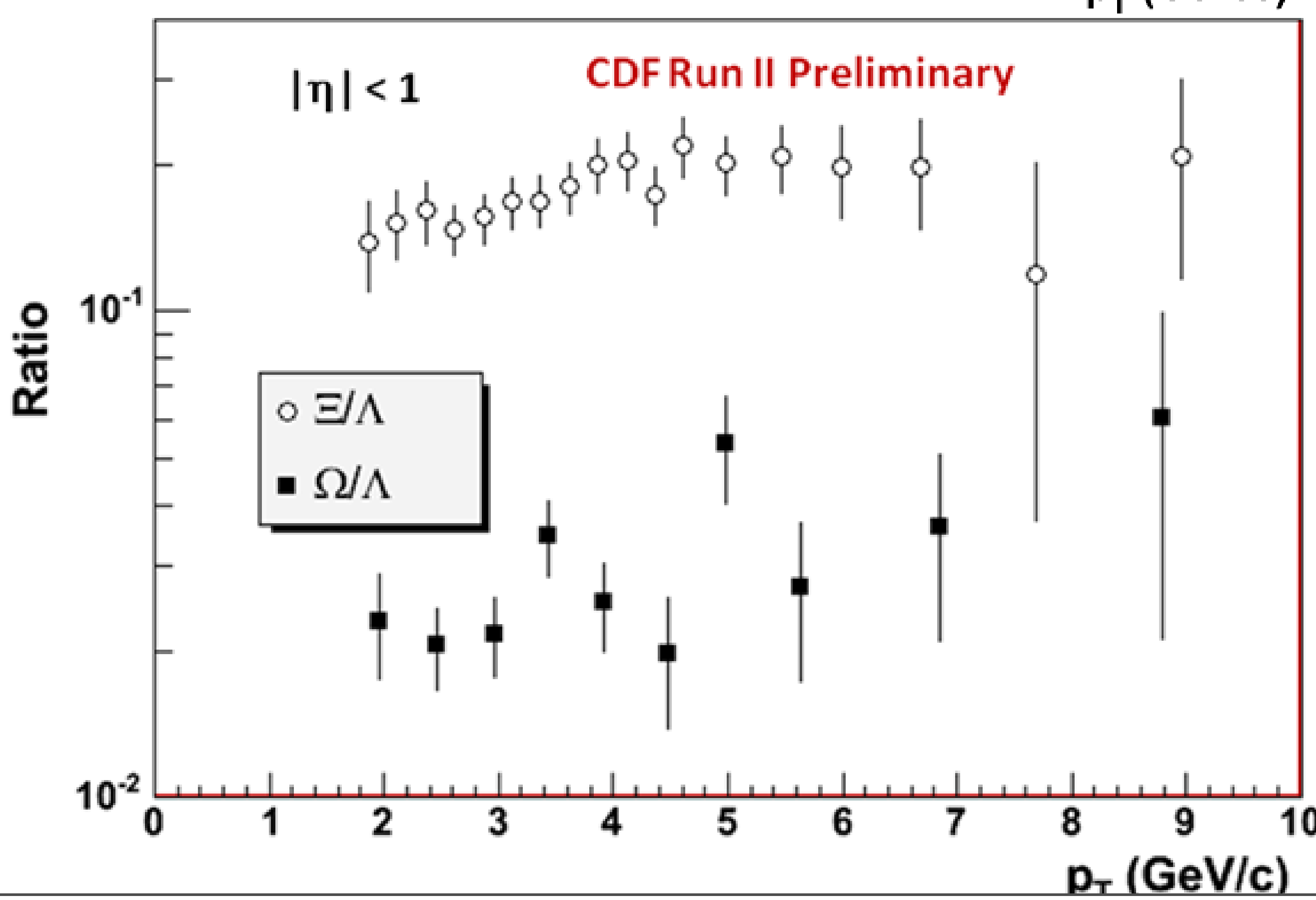
Main Systematics

- Luminosity
  - Cross section corresponding to MinBias trigger from Run I study (+1 mb for increase in energy): 44 ± 6 Mb
- Signal fit / background estimate
  - For low p_T bins (< 1.4 GeV), the background is rising steeply and cannot be fitted well.
- Acceptance calculation (from MC)
  - Calculated by varying all cut parameters and adding acceptance ratios in quadrature.

Hyperons in MinBias



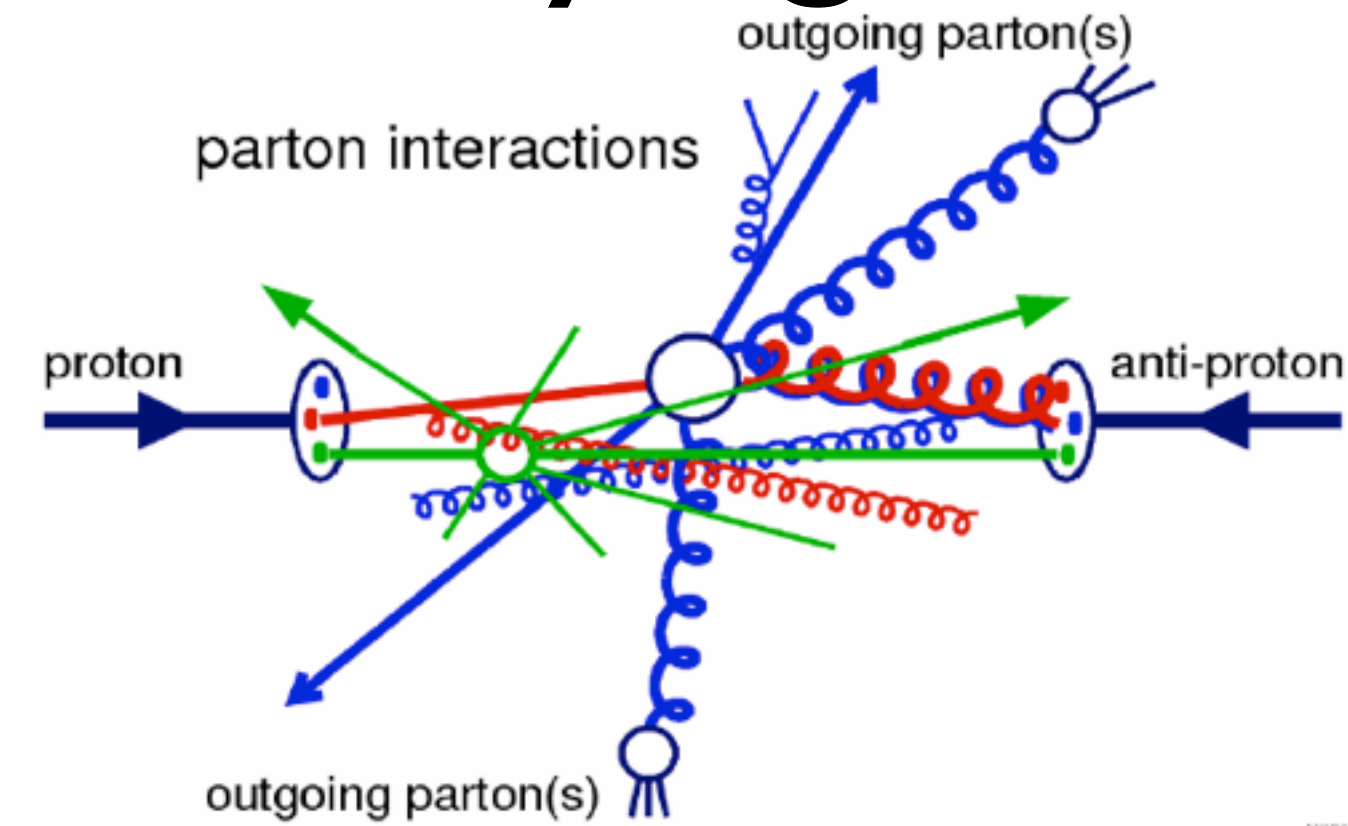
- Good fit using power law
  - Low p_T region better with exponential



- Ratios of Ξ/Ω over Λ are mostly flat after a gentle rise in low p_T region

(Λ sample includes Σ→Λγ also ca 50% of Λ from Ξ decays!)

Underlying Event



Using 2.2/2.7 fb^{-1}
Aug 2010

Phys. Rev. D82, 034001 (2010)

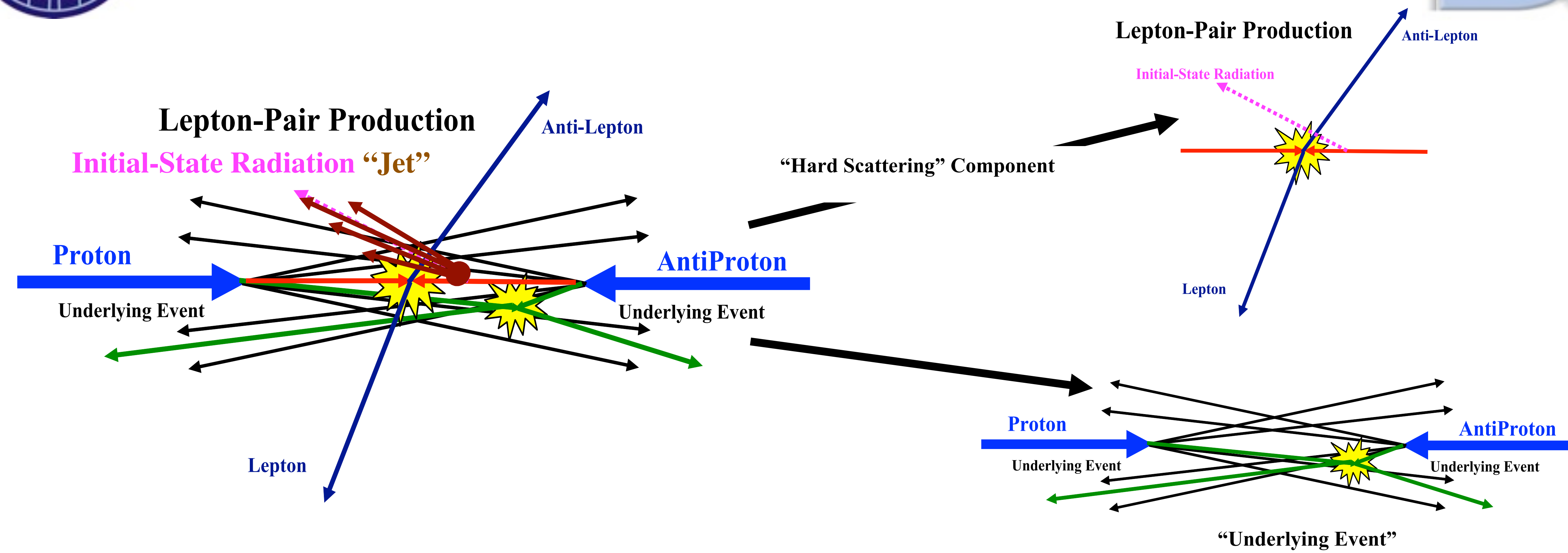
- Underlying Event (UE) is an unavoidable part of hadron collisions (besides ISR and FSR)

⇒ Thus forms a constant part of the background to all hard processes

⇒ At very least needs to be measured in order to tune event generators.

With MPI modelling being an important part to tune

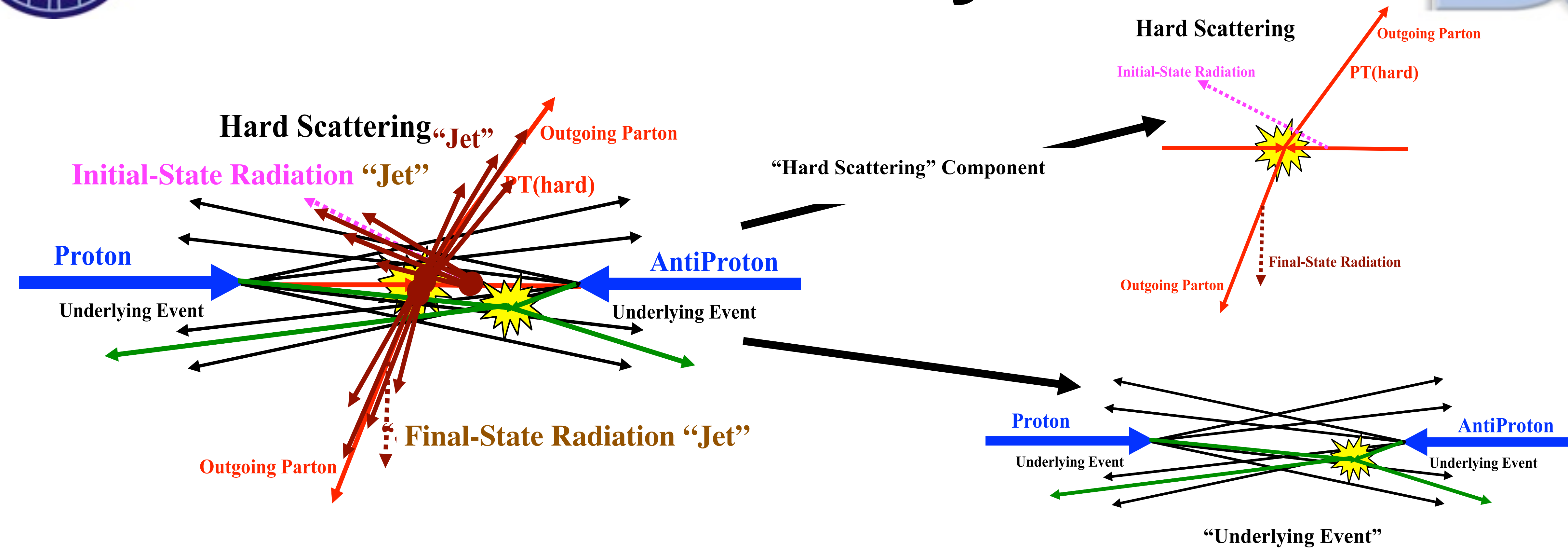
UE in Drell-Yan



- (Di-)Electron (Muon) triggers with $E_T(p_T)$ > 18 GeV
  - 2 identified electrons: E_T>20GeV, $|\eta|<1$

  or 2 identified Muons: p_T>20GeV, $|\eta|<1$
  - Leptons isolated within R < 0.4
  - Leptons from same PV and 70 < M_{ll}/GeV < 110

UE in inclusive Jets

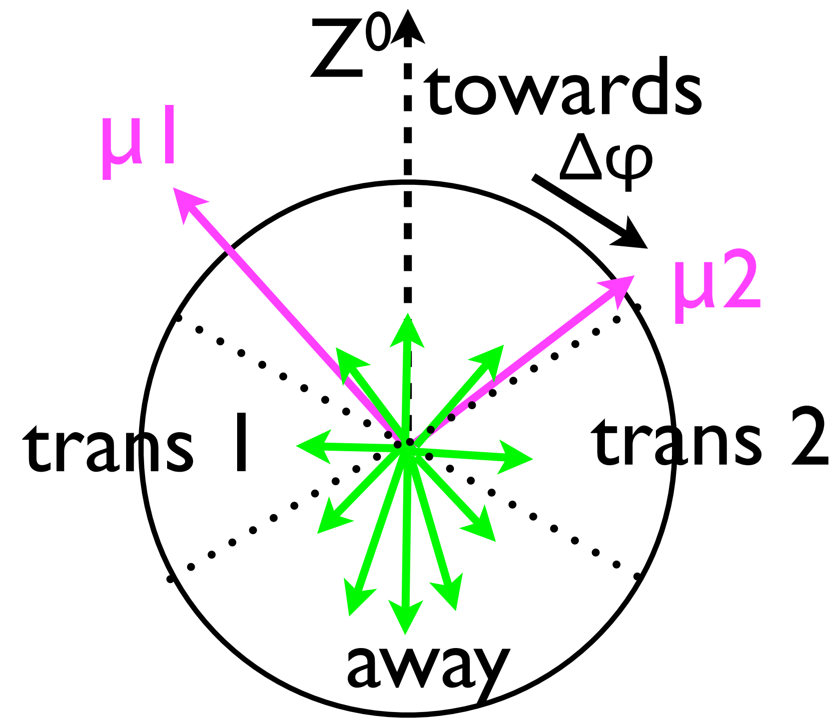


- Jets reconstructed by midpoint cone algorithm with $R_{cone} = 0.7$
- Highest p_T Jet must have $|\eta| < 2$

Underlying Event

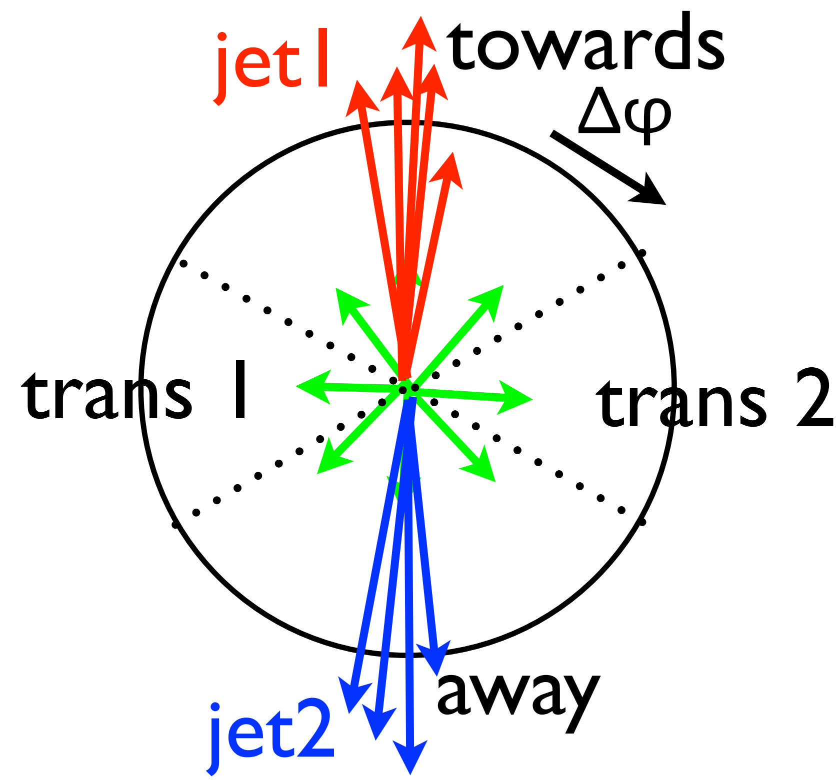
Drell-Yan events:

- Di-muon direction defines φ=0
- transverse and towards region most sensitive to UE
- recoil (ISR) of di-muon system in away region



Di-jet events:

- Leading jet axis defines φ=0
- Only transverse regions show UE characteristics
- Second jet dominates away region

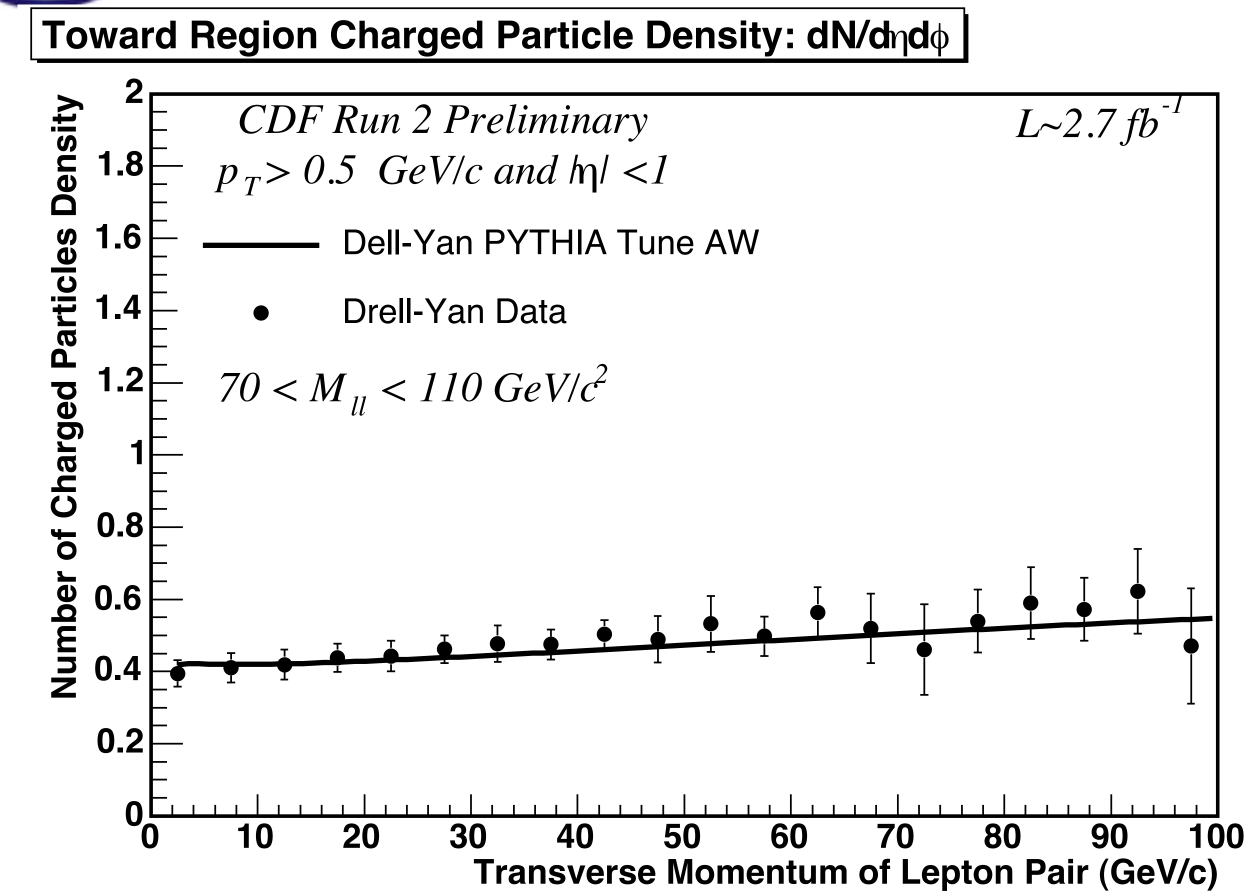


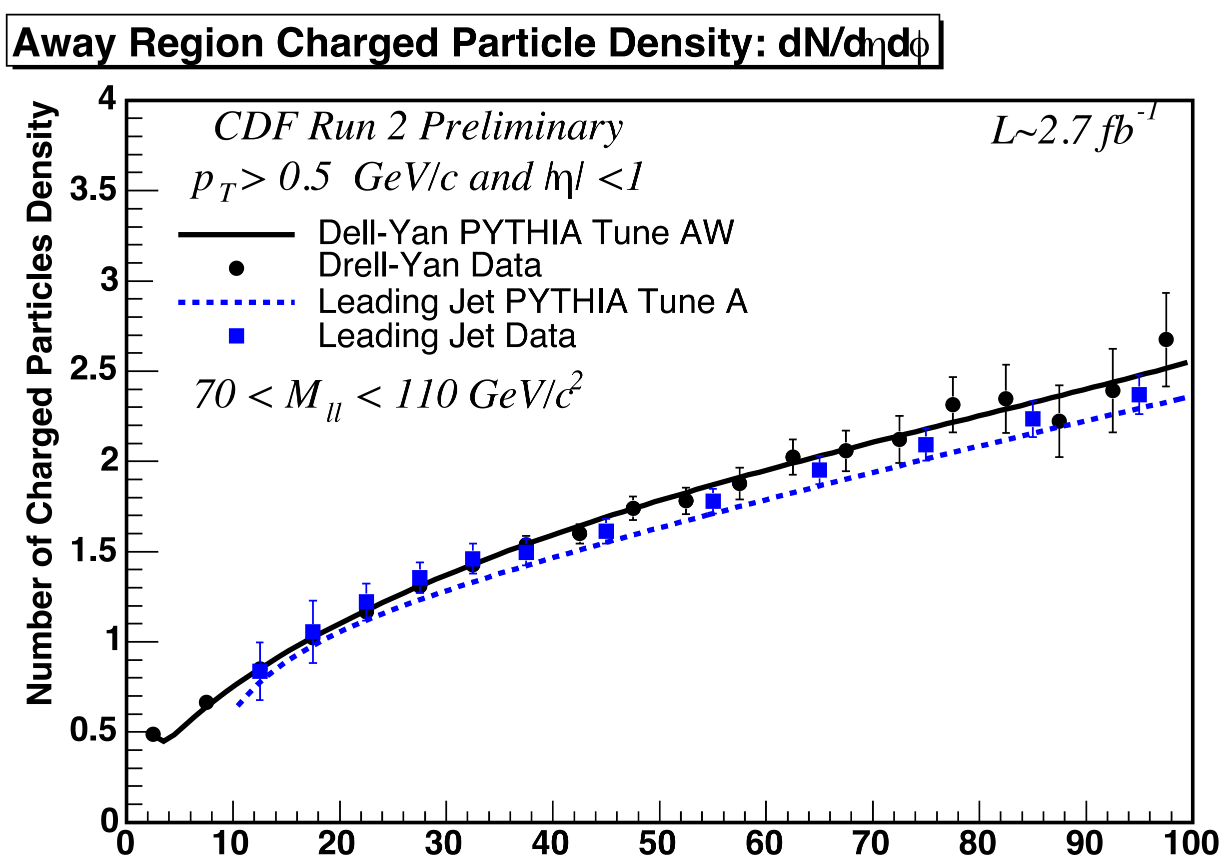
Observables in UE

- Select good tracks with
  - *$0.5 < p_T/GeV < 150$,* $|\eta| < 1$, exclude selected muons
  - *Vertexing cuts wrt PV* to guard against secondaries, conversions, etc.
- For away, transverse and towards region, measure:
  - ➡ Number of charged tracks
  - ➡ Scalar sum of track p_T (also average and maximum)
  - ➡ $\langle p_T \rangle$ as a function of number of tracks and vice-versa (Only for Drell-Yan)

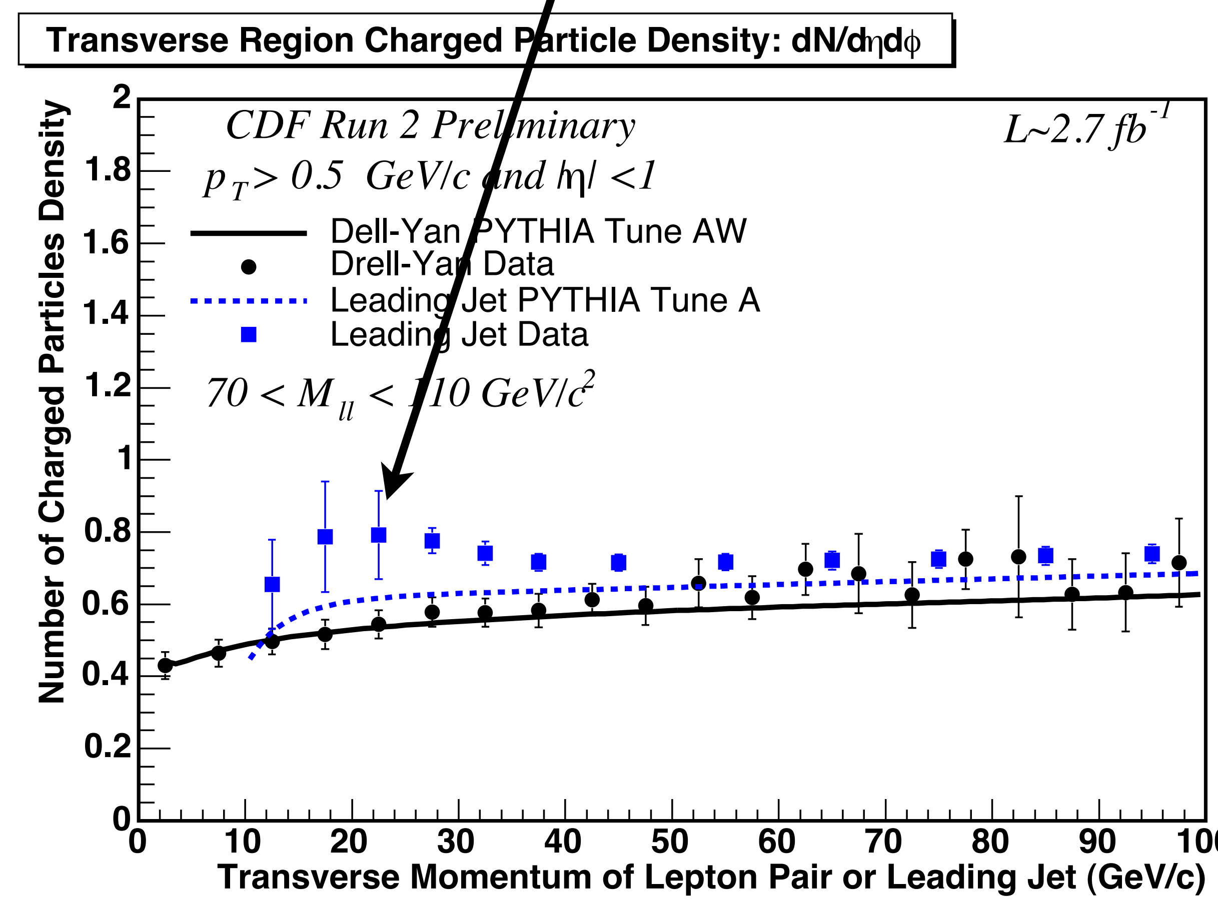
(All quantities shown corrected to particle level.)

Number of Particles



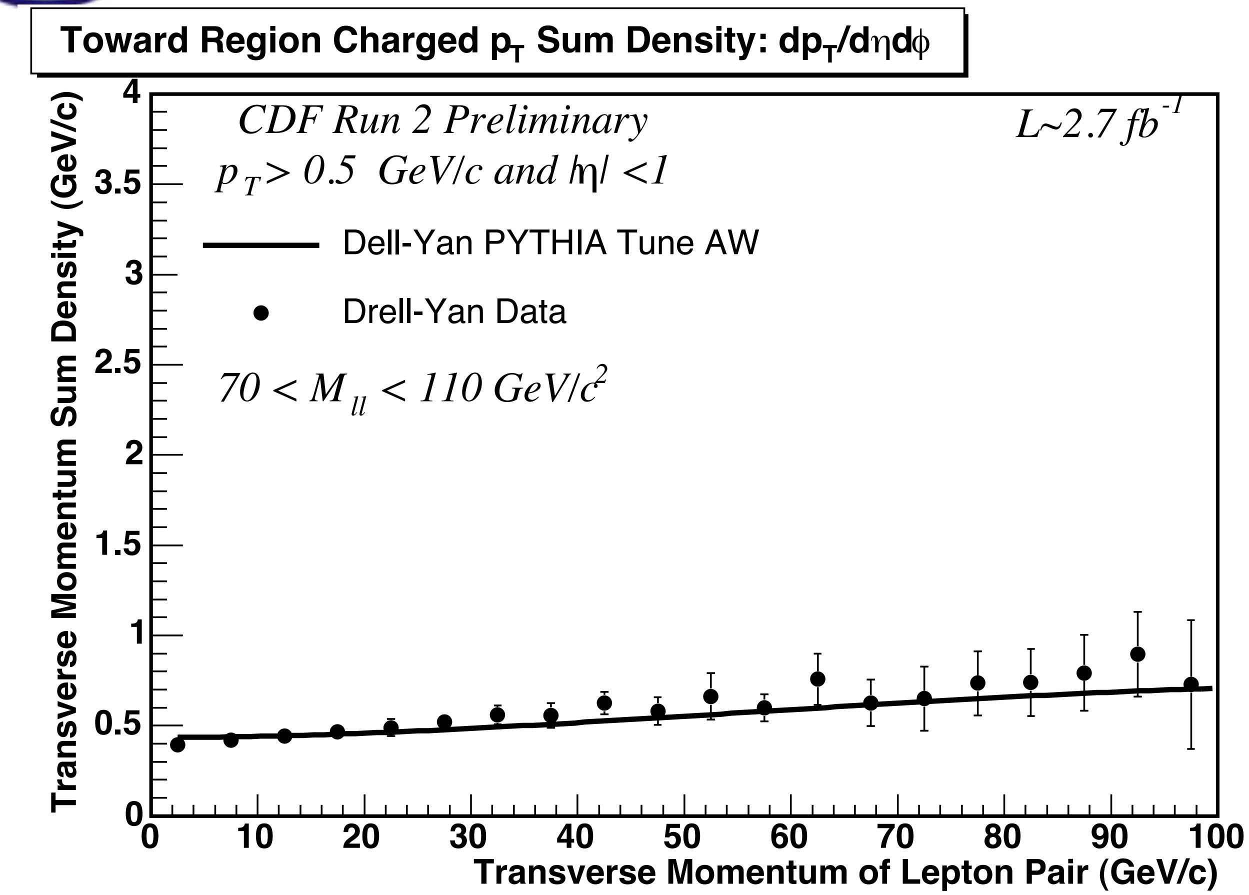


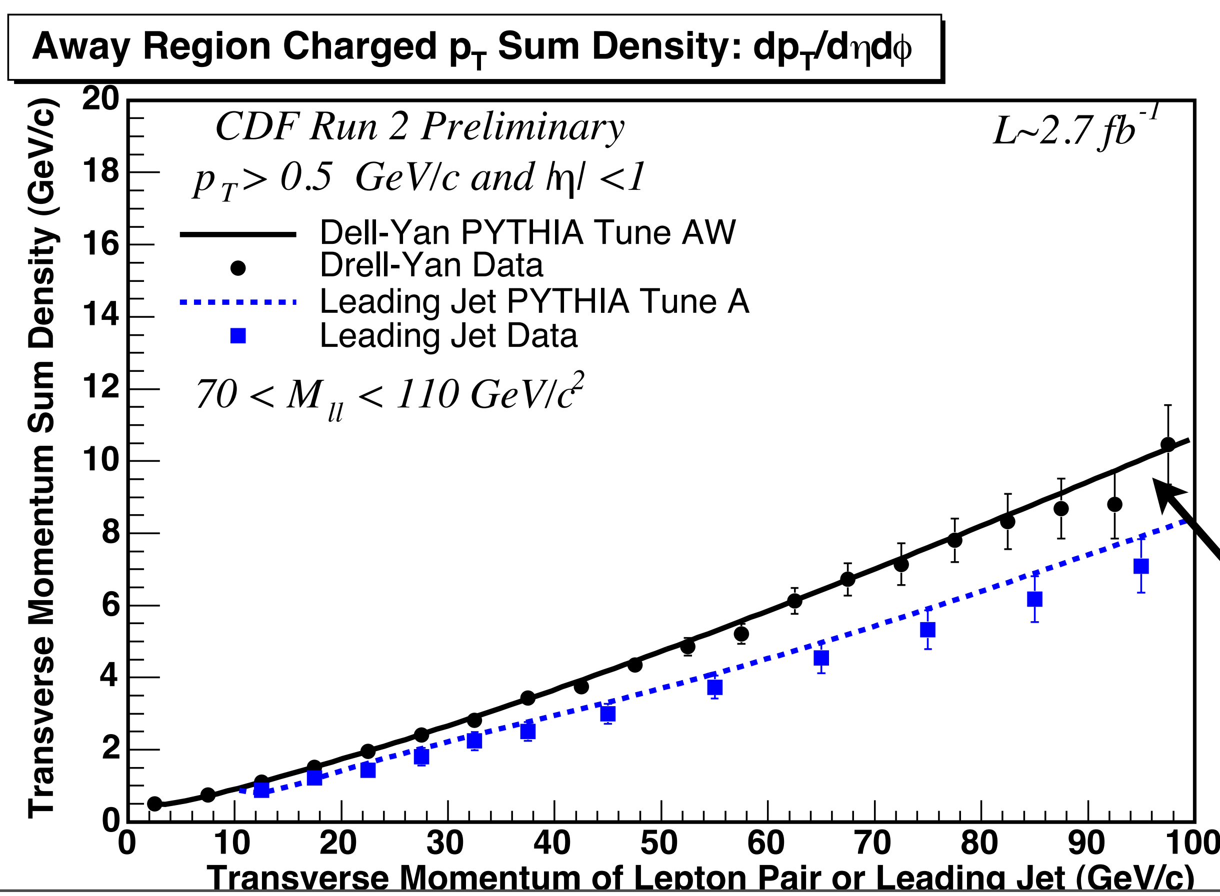
Low p_T leading jet not always leading parton



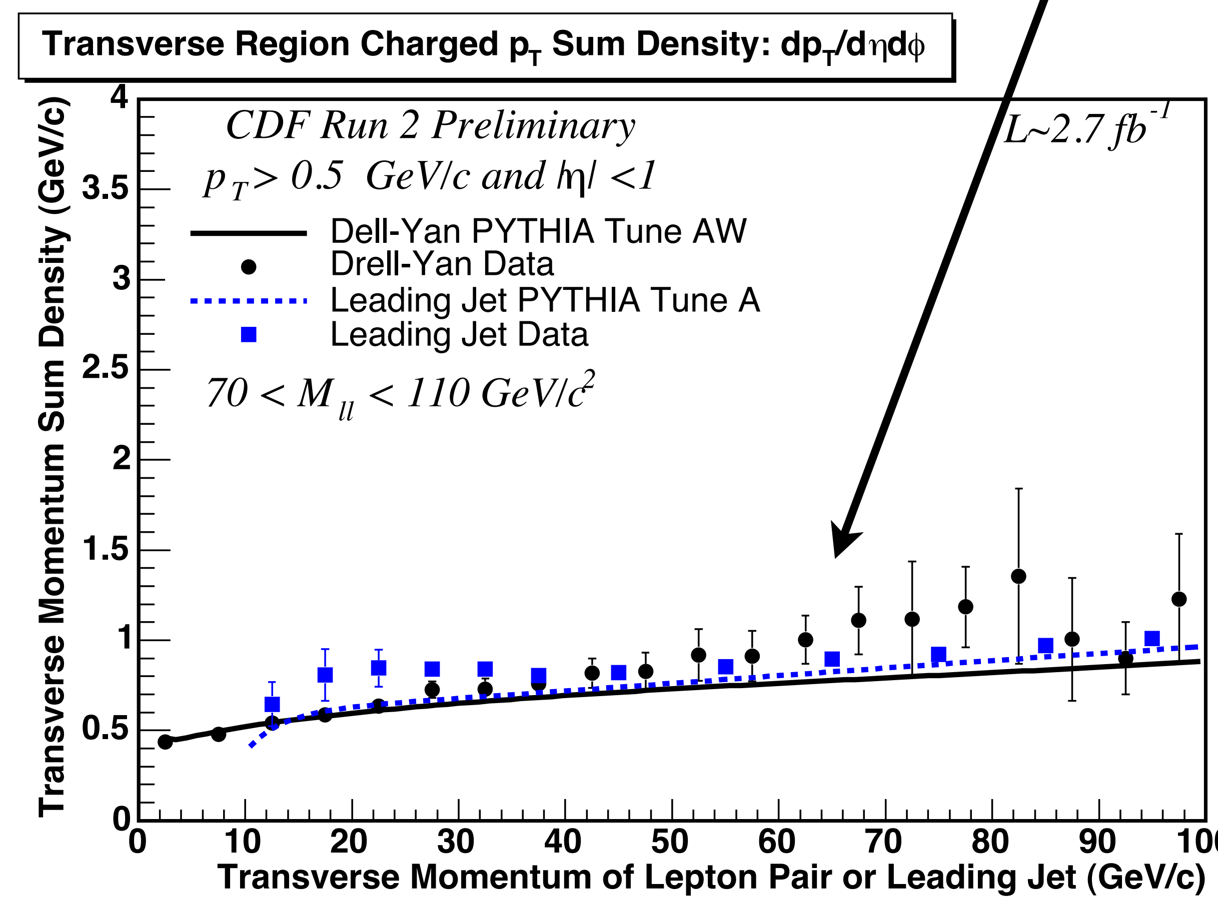
Similar charge particle densities between DY and Di-Jet

Sum of pT



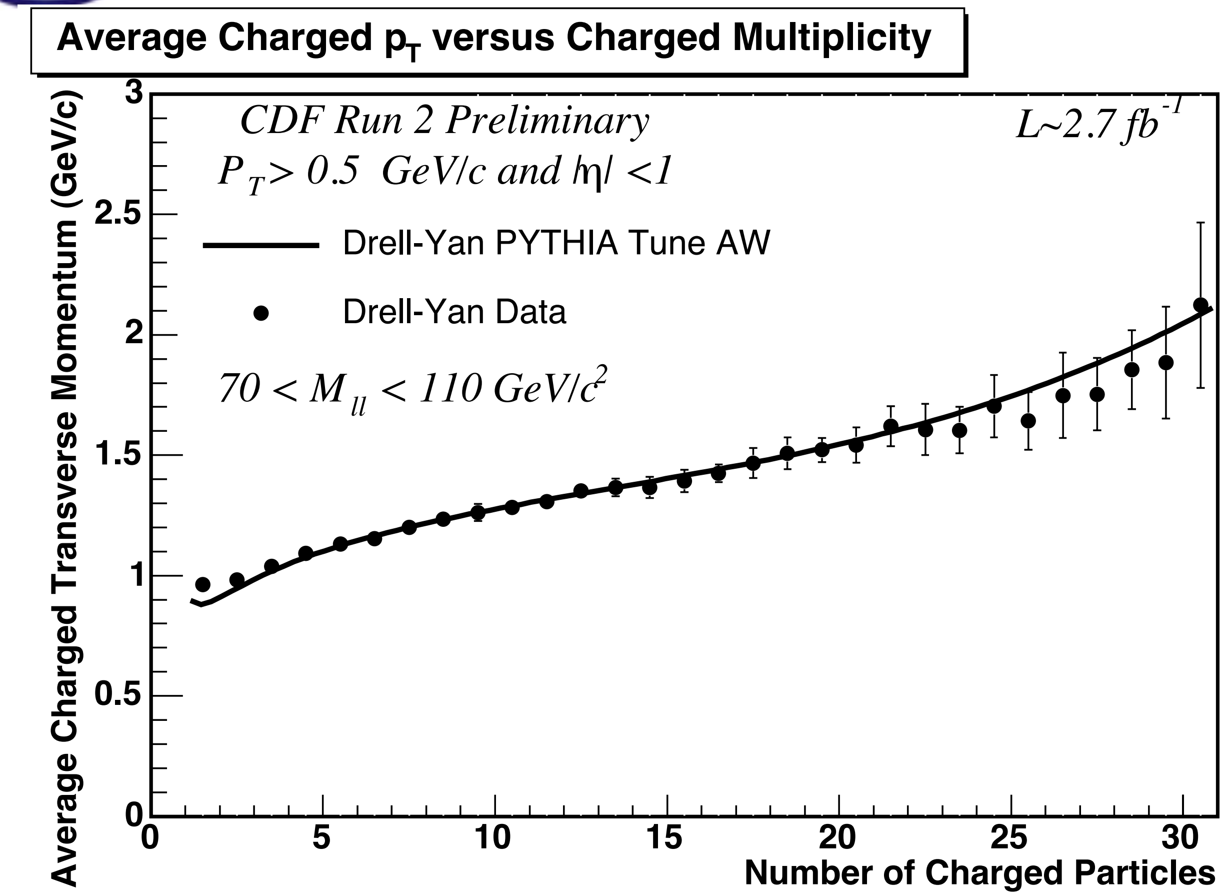


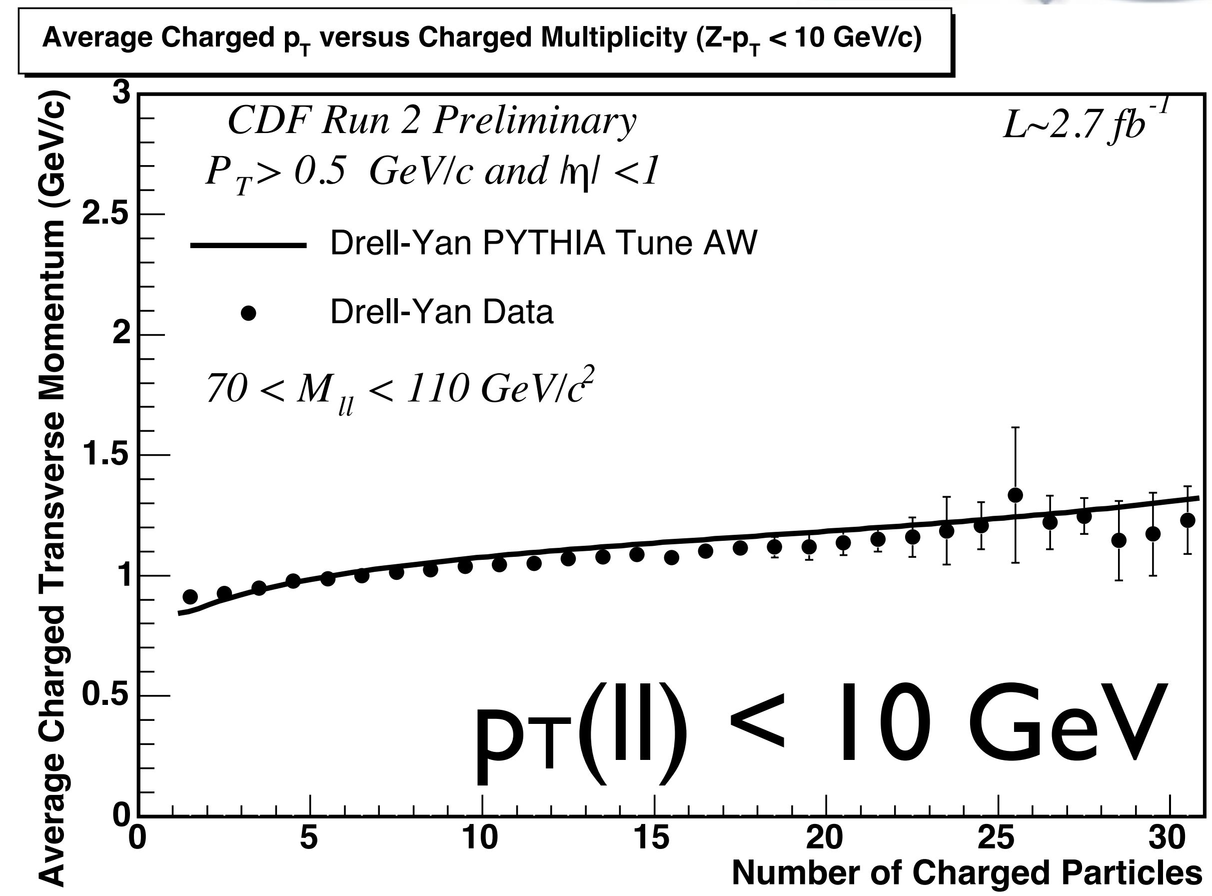
Transverse region very similar and well modelled

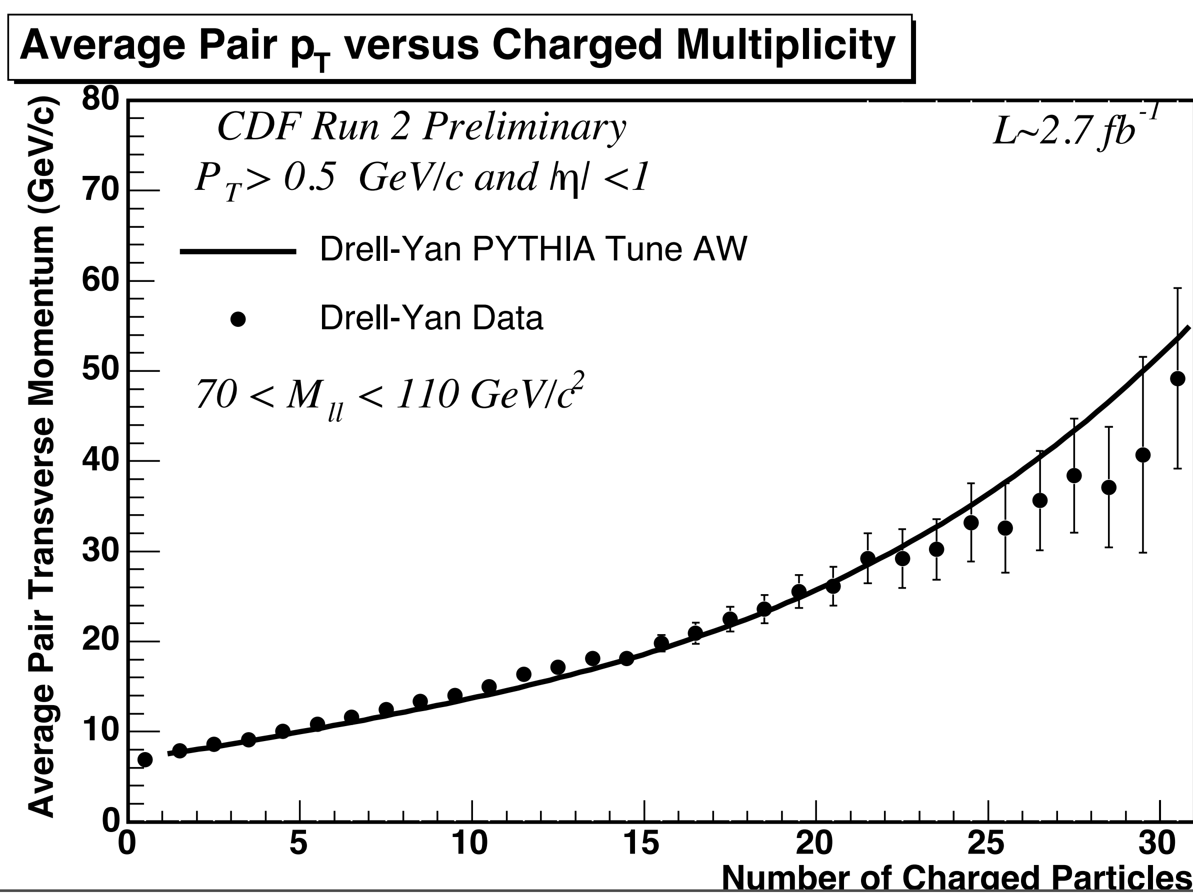


Sum of pT differs, but well described by AW

Correlation Plots

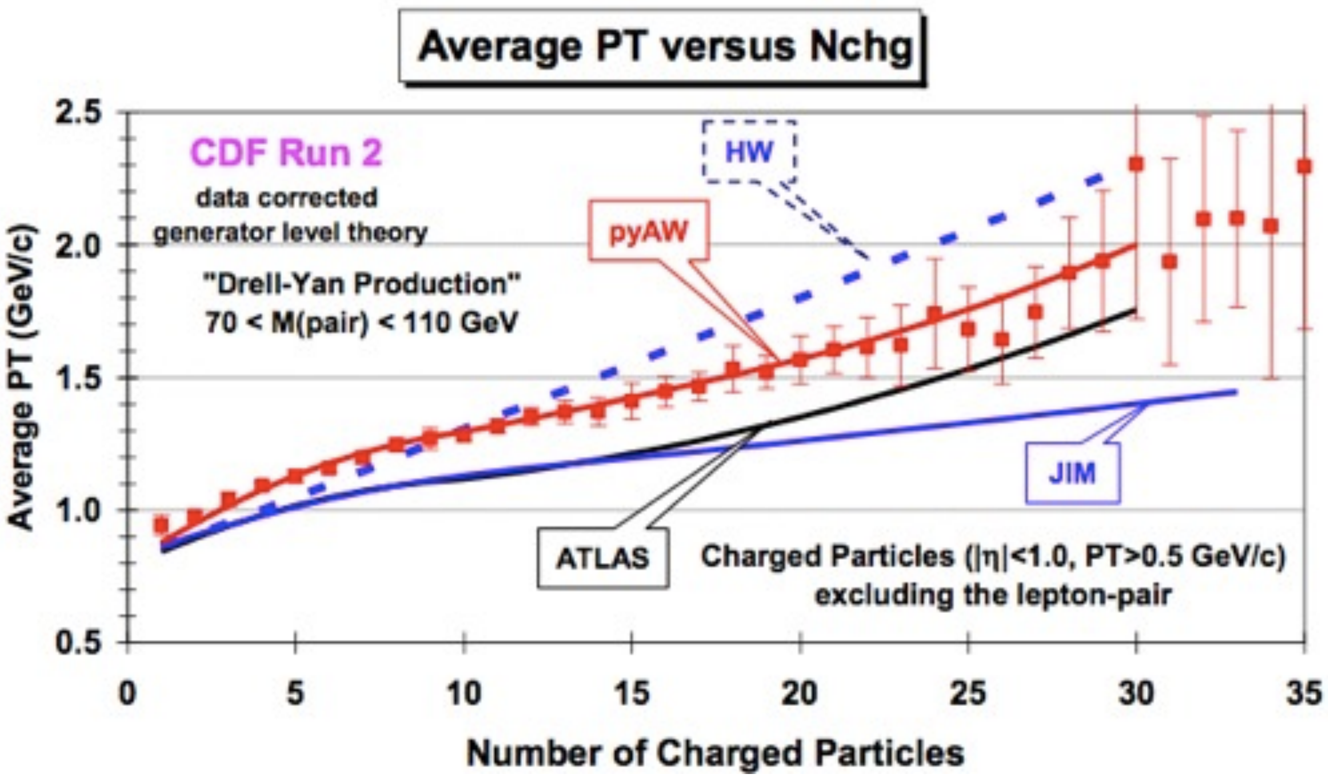


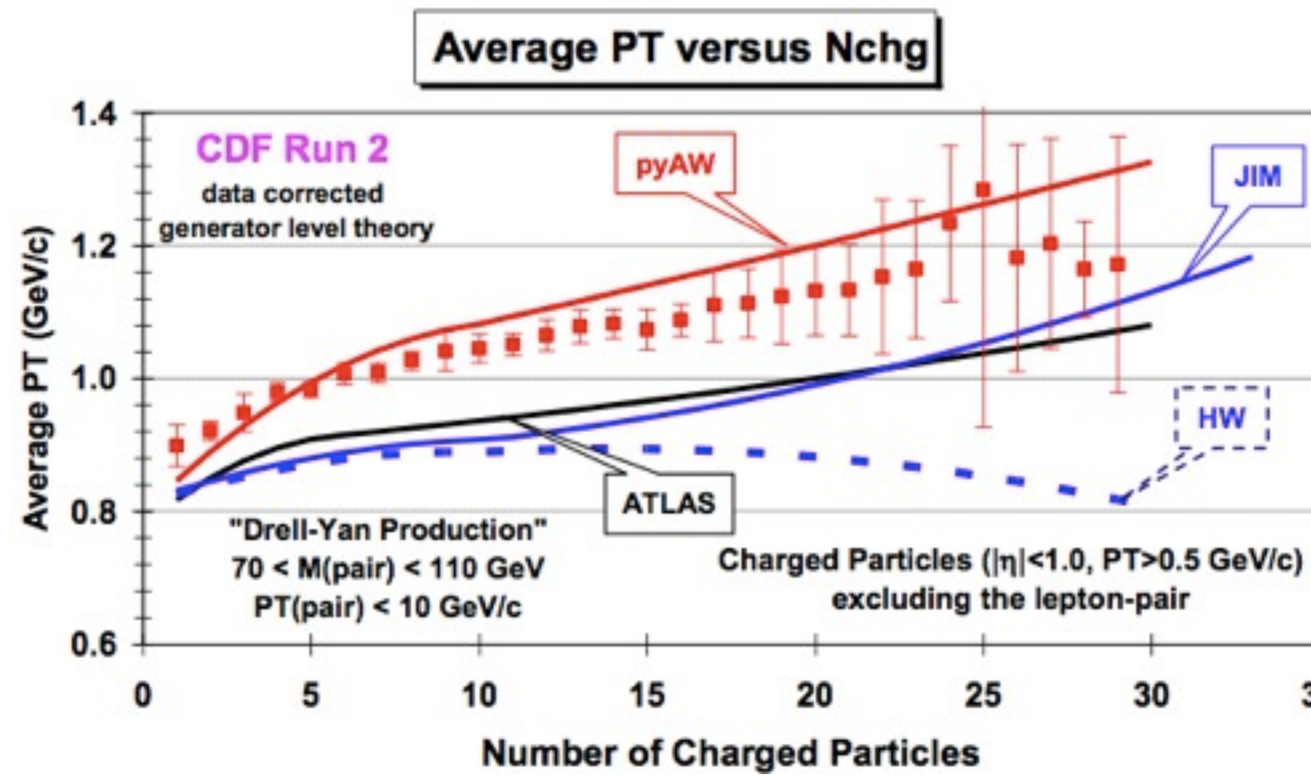


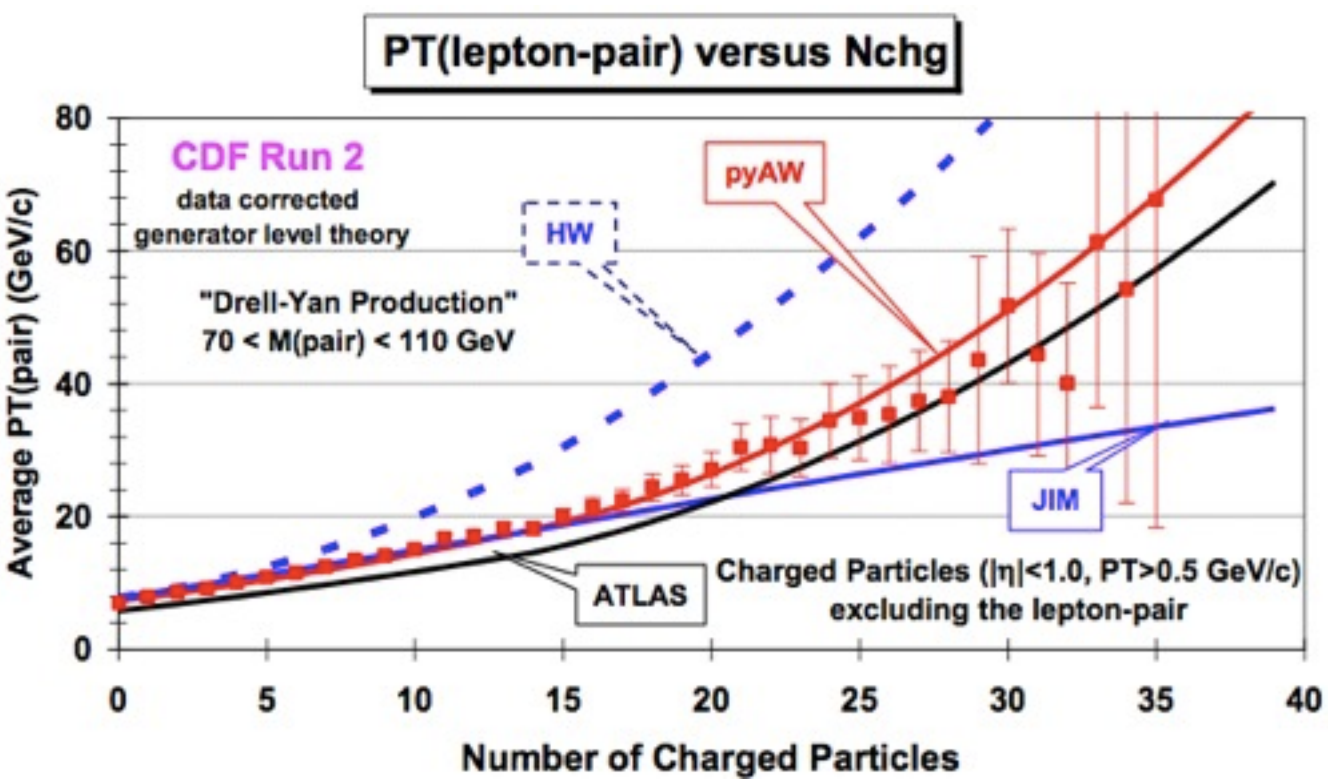


- Tune AW not perfect, but very close to all these distributions
- Furthermore, in comparison...

Correlation Plots







...Tune A performs best

- Herwig w/o MPI very poor
- Jimmy remedies this only partially

Drell-Yan p_T distribution

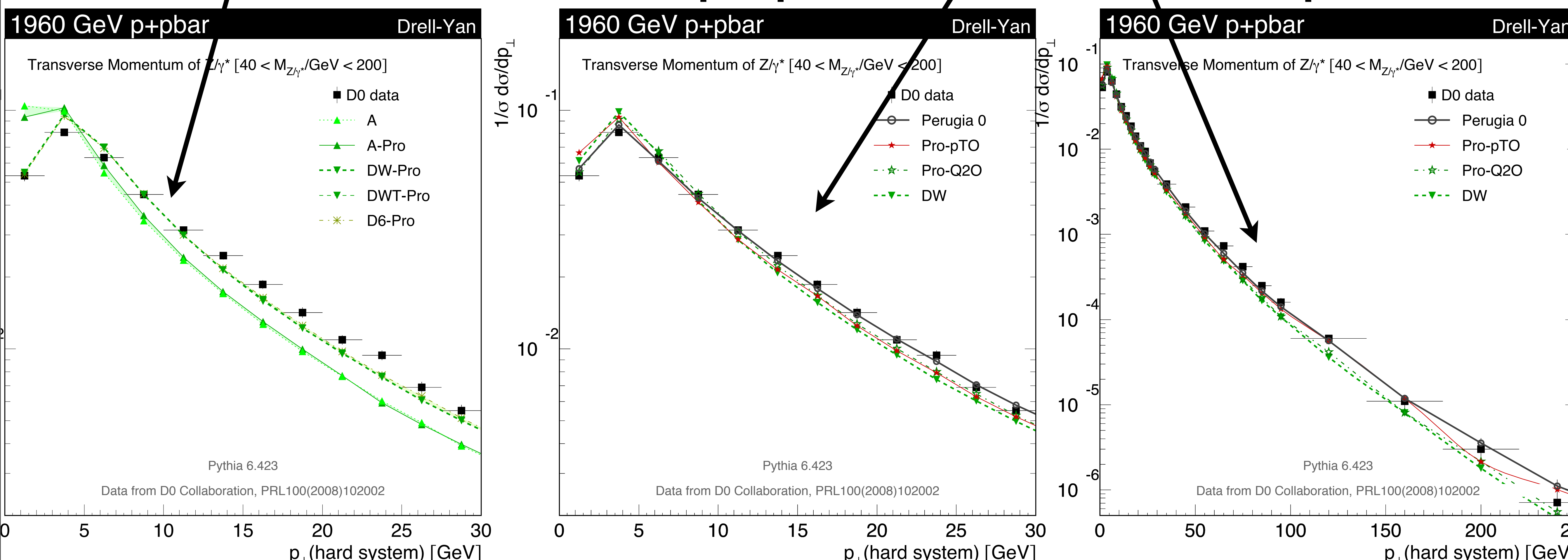
Di-muon p_T spectrum measured at DØ compared to:

A, DW-Pro, DWT-Pro, ...

P0, Pro-pT0, Pro-Q20, DW

p_T peak

p_T tail



Data: PRL 100(2008)102002

Plots from Peter Skands' homepage

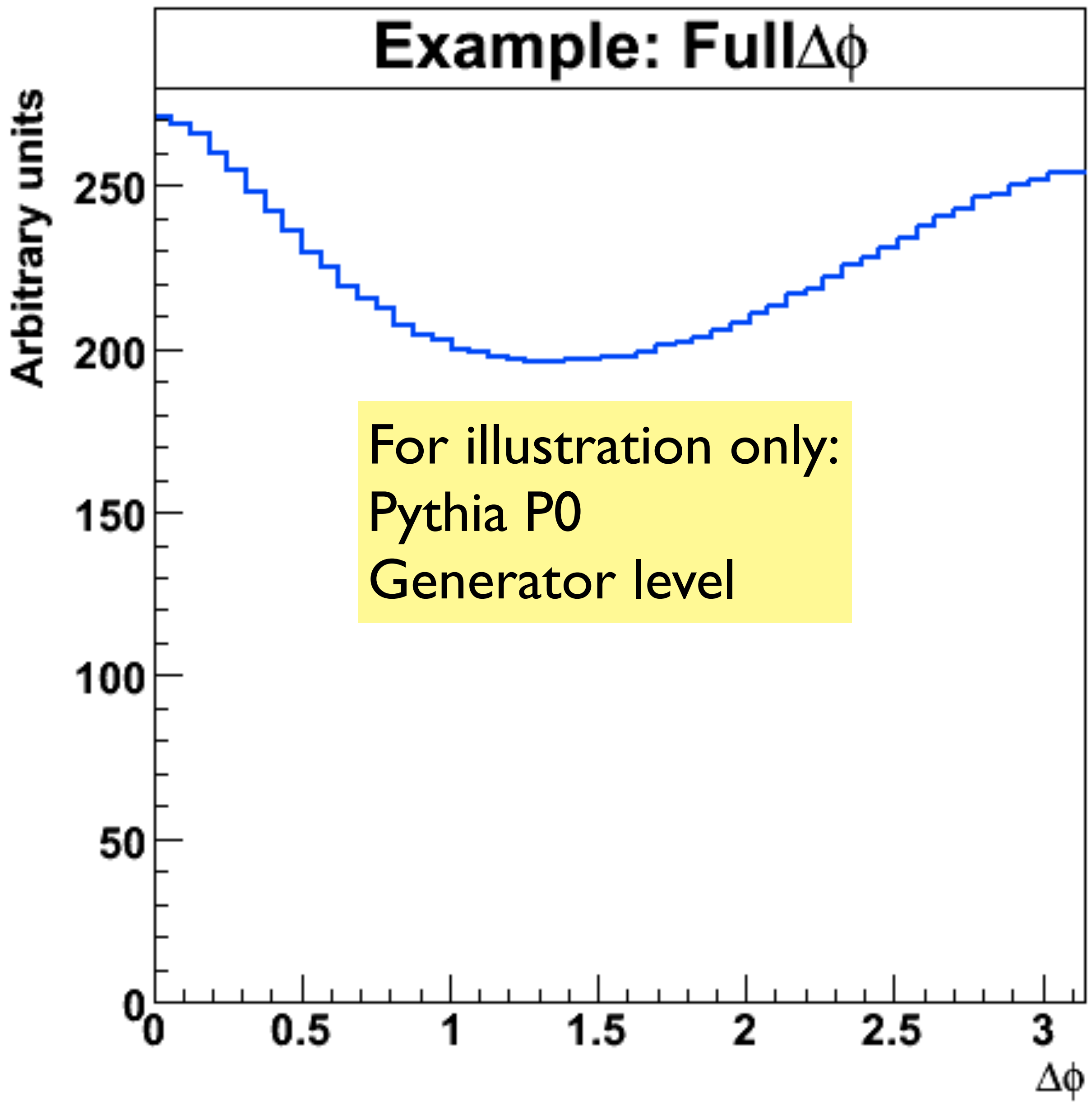
Δφ in Minimum Bias

- Minimum Bias: All events that deposit any energy in the acceptance.
  - Essentially very soft QCD and diffraction
  - Exhibits formation of very soft jets
  - ➡ Test if shape of these (in φ) is well modelled
  - ➡ Test for rapidity correlations
- Using only the tracker
  - good tracks p_T > .5GeV and $|\eta| < 2$
  - Use χ^2 to PV to suppress long lived contribution

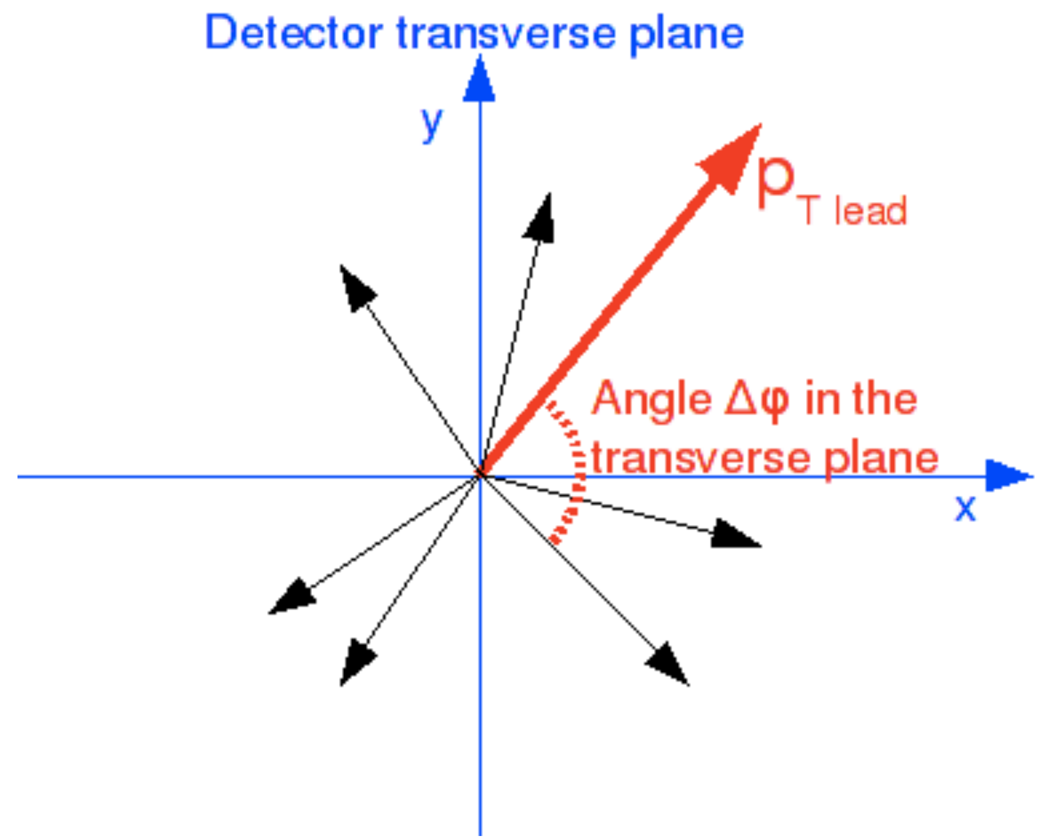
Using 1.3 fb^{-1}
Apr 2010

D0 Note 6054-CONF

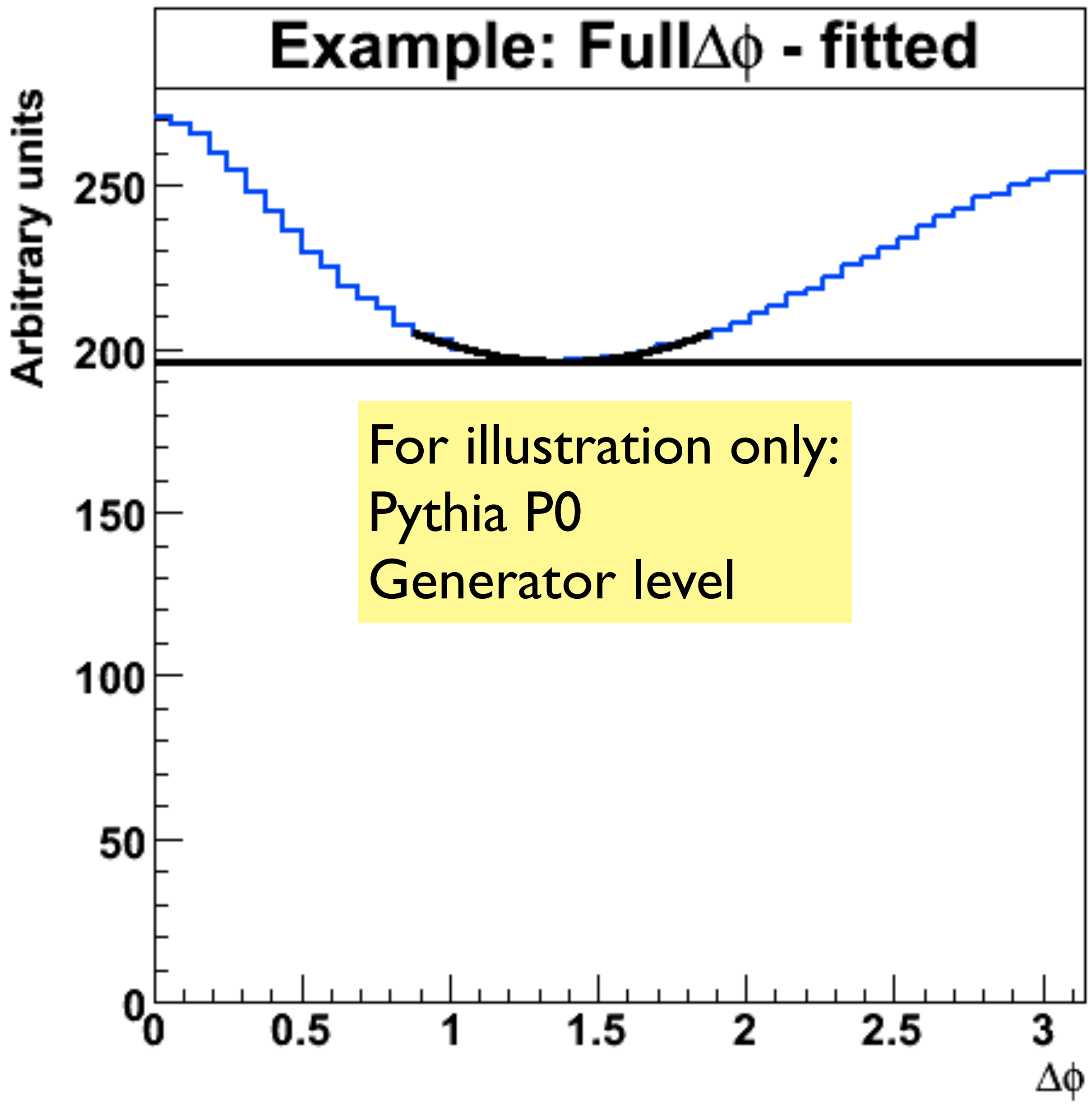
Δφ Crest Shape



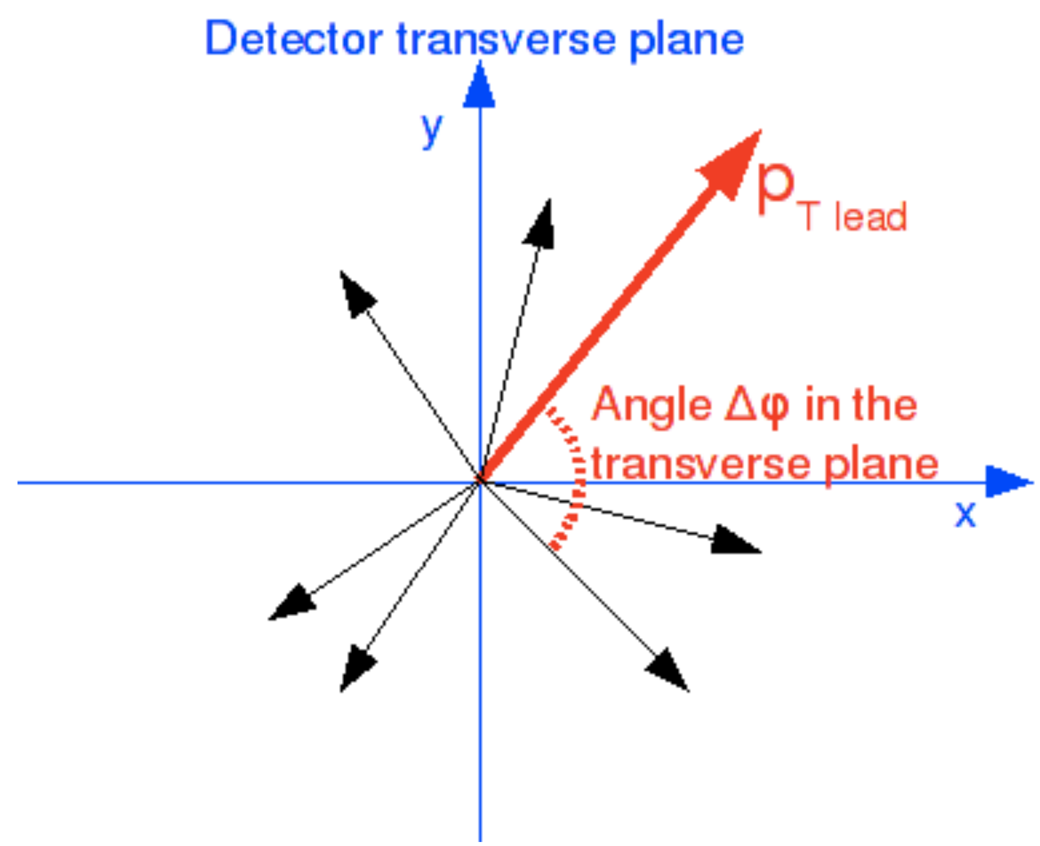
- Plot distance in φ between the leading track and all other selected tracks.



Δφ Crest shape

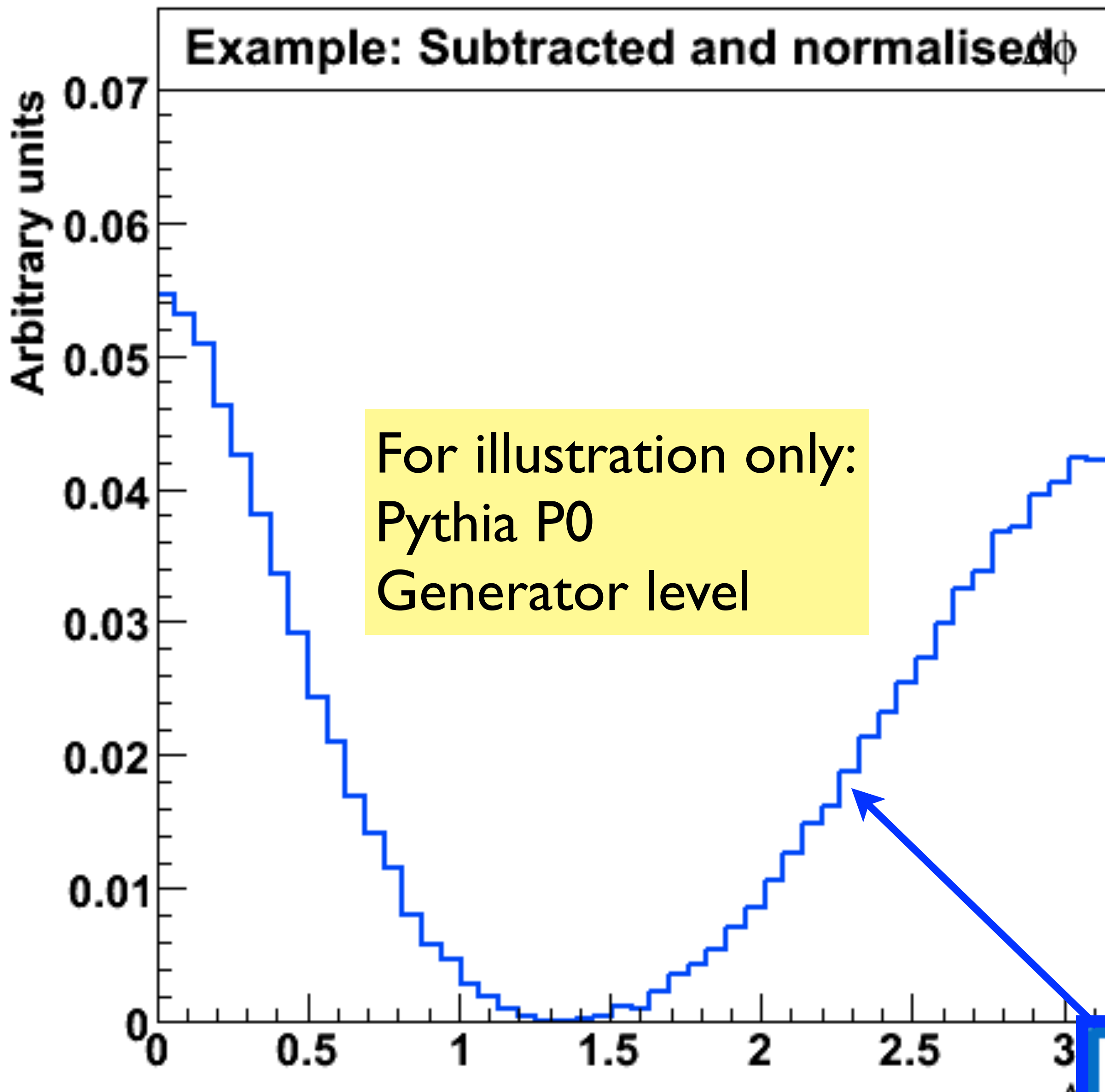


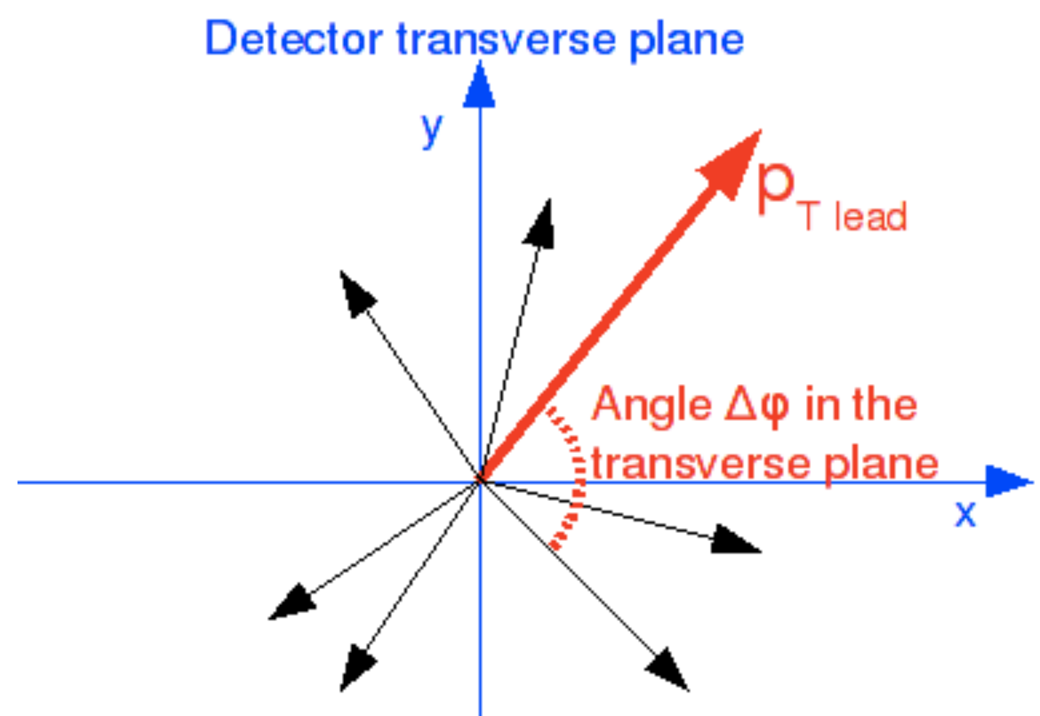
- Fit 2nd order polynomial to region around distribution minimum



Δφ Crest shape

- Subtract fitted minimum value from each bin and normalise to unit area

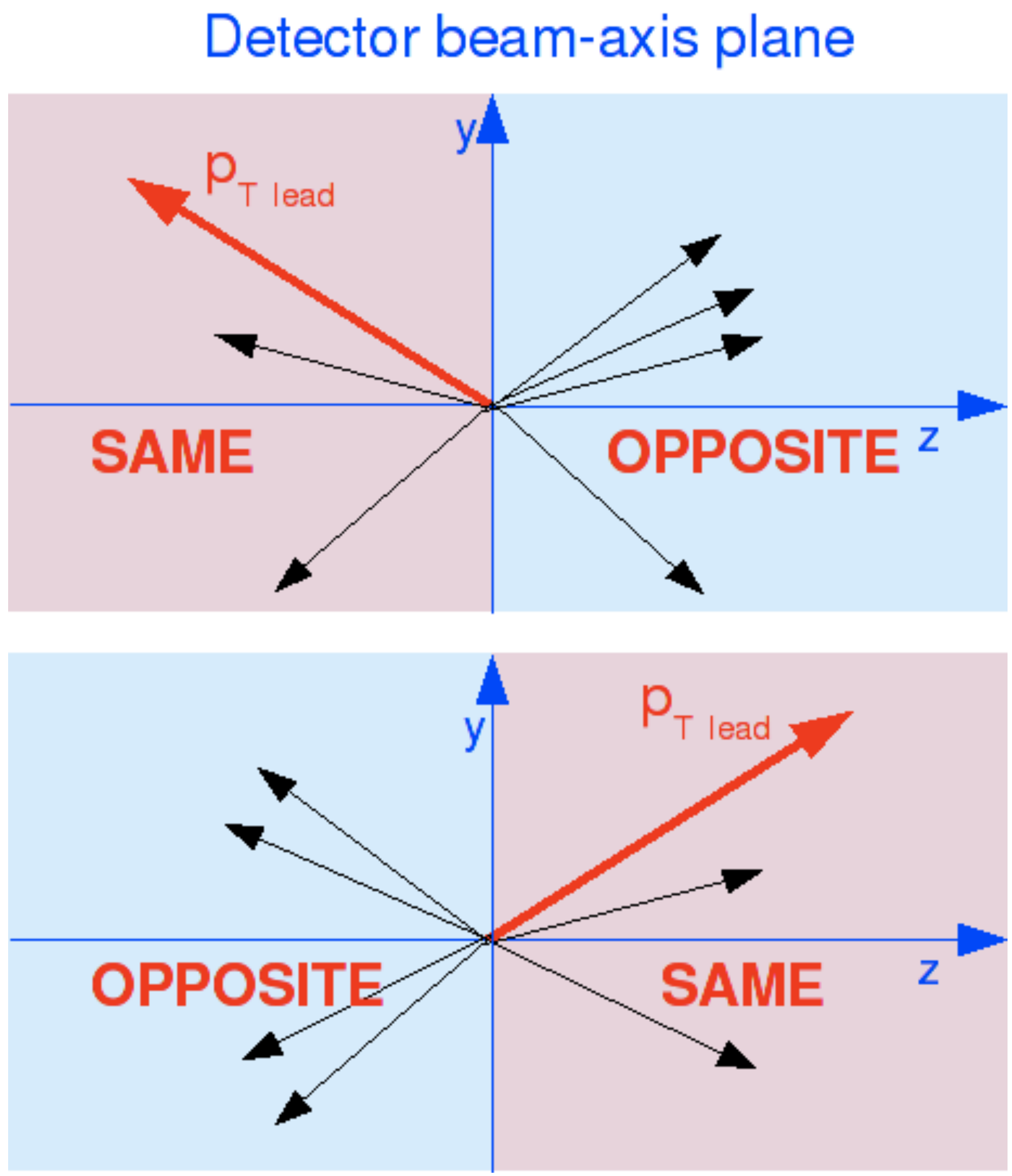




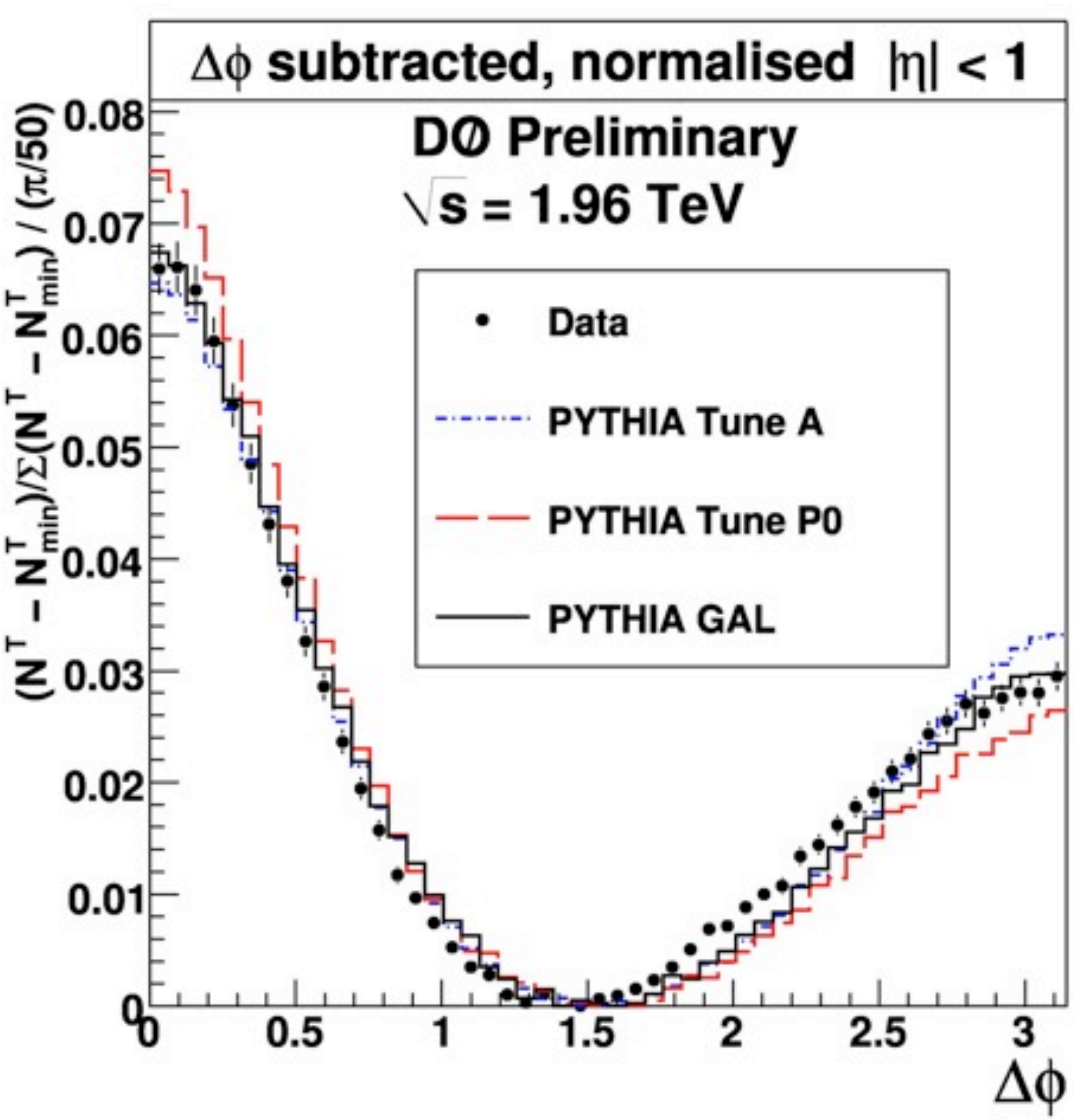
Measured crest shape characteristics: peak widths, relative heights, position of minimum

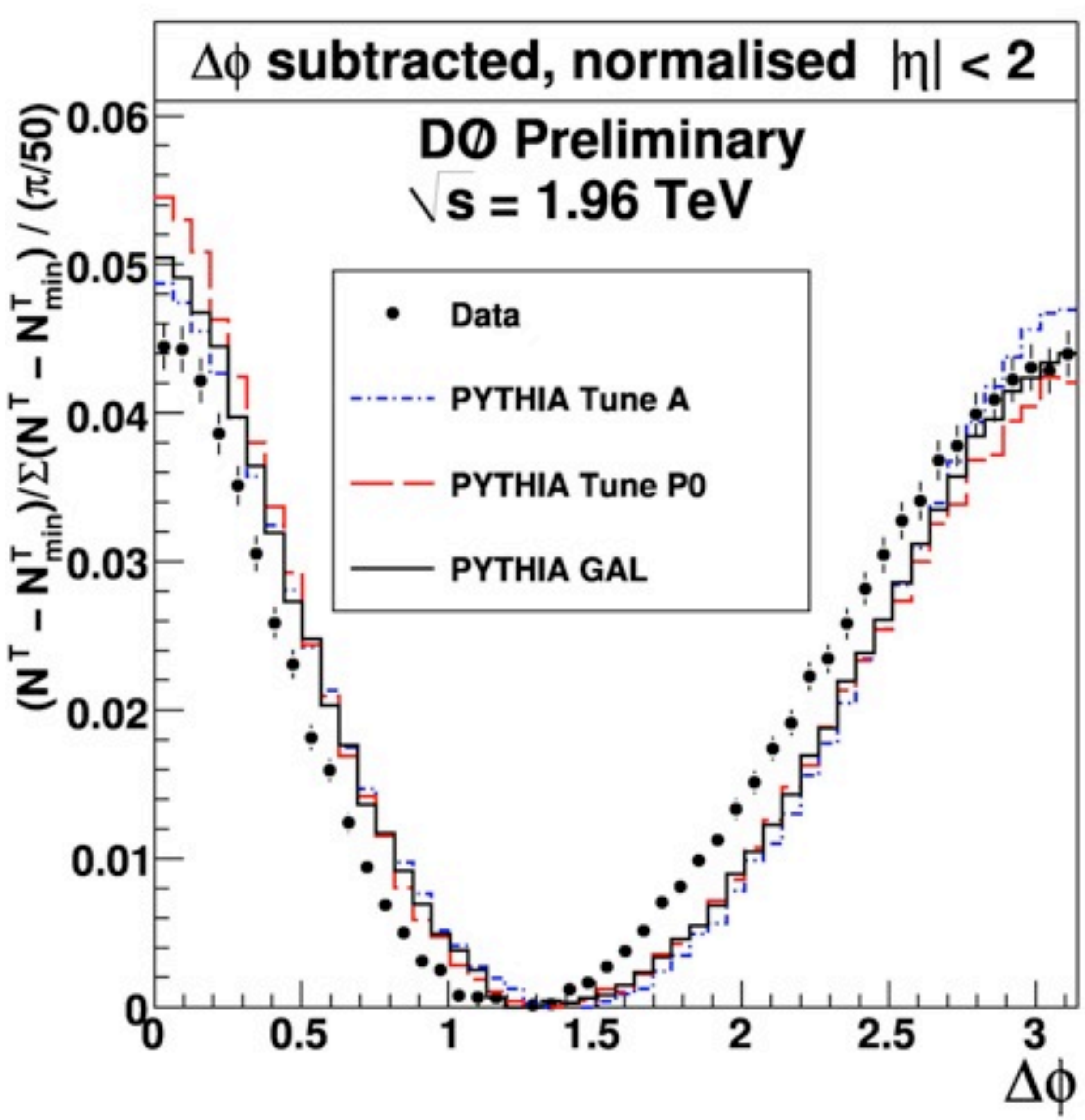
Same minus Opposite

- Event-by-event, define 2 detector regions based on η location of leading track
- Assign other tracks to "same" or "opposite" region according to their position in η
- Subtract "opposite" distribution from "same" and normalise
- Sensitive to η correlations



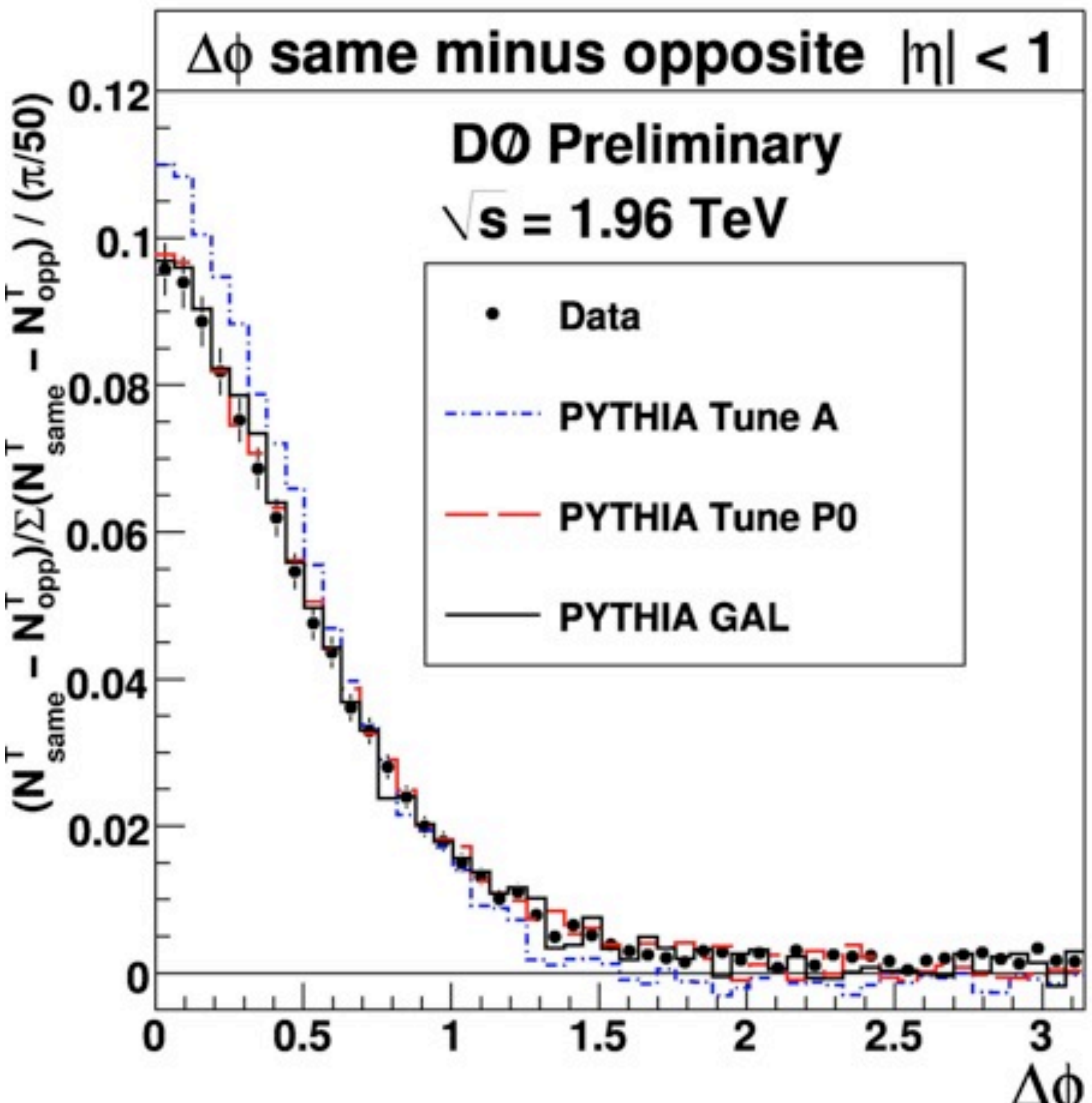
Crest Shape Results

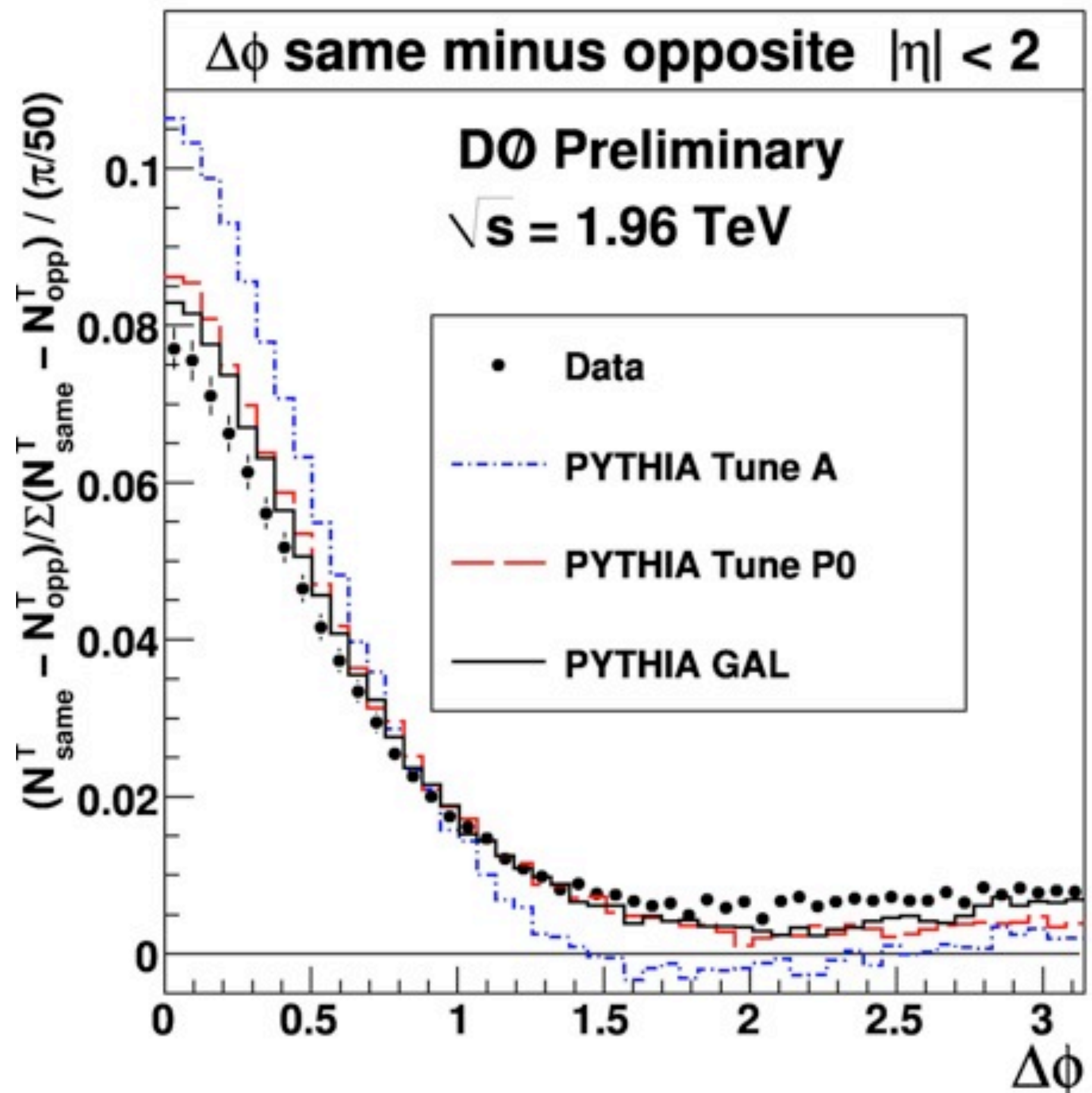




- Tune A and GAL describe data well for $|\eta|<1$
- All models are worse when widening to $|\eta|<2$

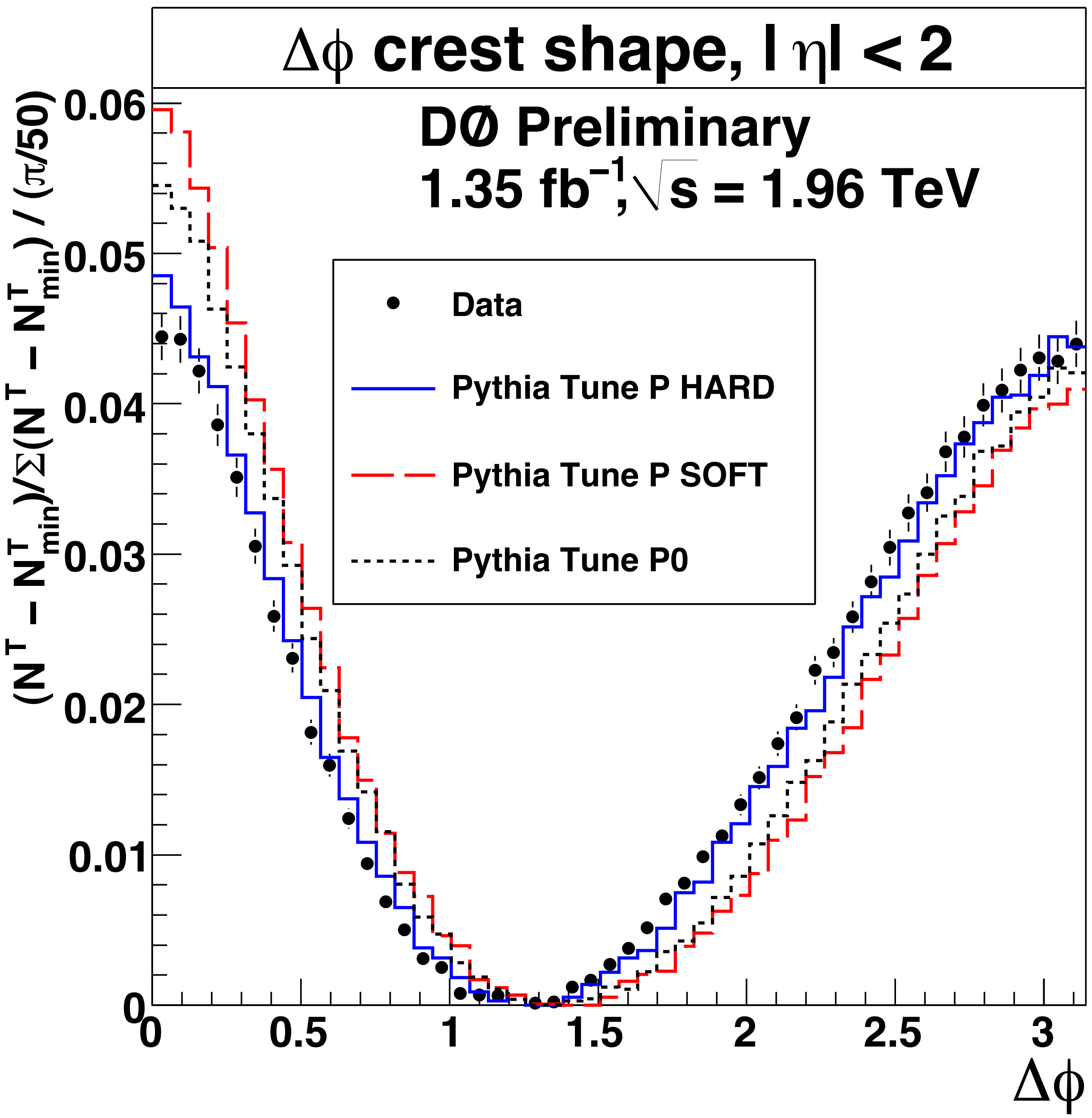
Same minus Opposite

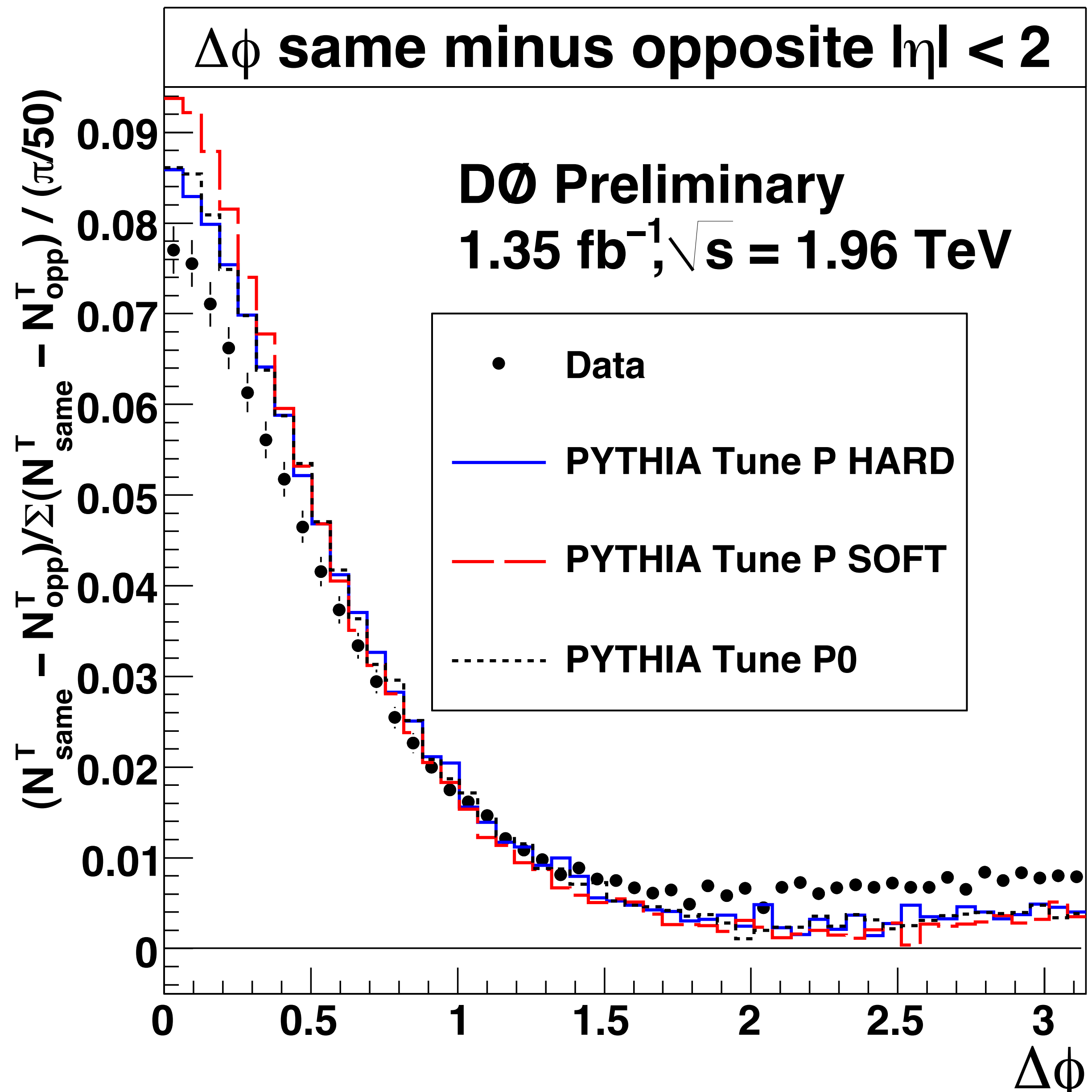




- Data shows *correlation of UE/recoil in* η with leading track
  - apparently *almost uniform* in Δφ
  - Q^2 ordered tunes behave completely different! (GAL closest)

P HARD and P SOFT





- Crest shape much better described by P HARD !

  (but no improvement in same minus opposite)

k_t Distribution in Jets

k_T : Transverse momentum of tracks wrt to jet axis

- Compare to MLLA, NMLLA (+LPHD)
- Pythia Tune A, Herwig 6.5

- Measure k_T distribution in bins of dijet invariant mass: m(jj) = 66 - 737 GeV and correct back to particle level.
  - Compare shape only by normalising to most reliable bin: $-0.2<\ln(k_T)/\mathrm{GeV}<0.0$

Using 774 pb^{-1}
Jun 2009

PhysRevLett.102.232002

k_t Distribution in Jets

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Perturbative calculation by resummation of leading logs

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"Translates" parton level distribution to hadron level

Perturbative calculation by resummation of leading logs

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Non-perturbative modelling of hadronisation

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Using 774 pb^{-1}
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k_t Distribution in Jets

- Jets reconstructed using the calorimeter and R = 1
  - only two more (soft) jets allowed
    $E_T < 5.5$ GeV + 0.065 $(E_T^1+E_T^2)$

=> ~250.000 Jets

- Plot k_T of tracks with
  - $p_T>0.325$ GeV and $|\eta| < 1$
  - in a cone of 0.5 radians around Jet axis
  - apply vertexing cuts to suppress secondaries
- Subtract UE by approximating it with tracks in similar cones at same polar angle θ but perpendicular in φ to di-jet plane

k_t Distrib. Systematics

- Jet Energy Scale know to 3%

  Affects the binning of distributions by di-jet mass

- Contamination from long lived particles, secondaries, conversions, etc: 3%

  Using selection efficiency of those in detector MC

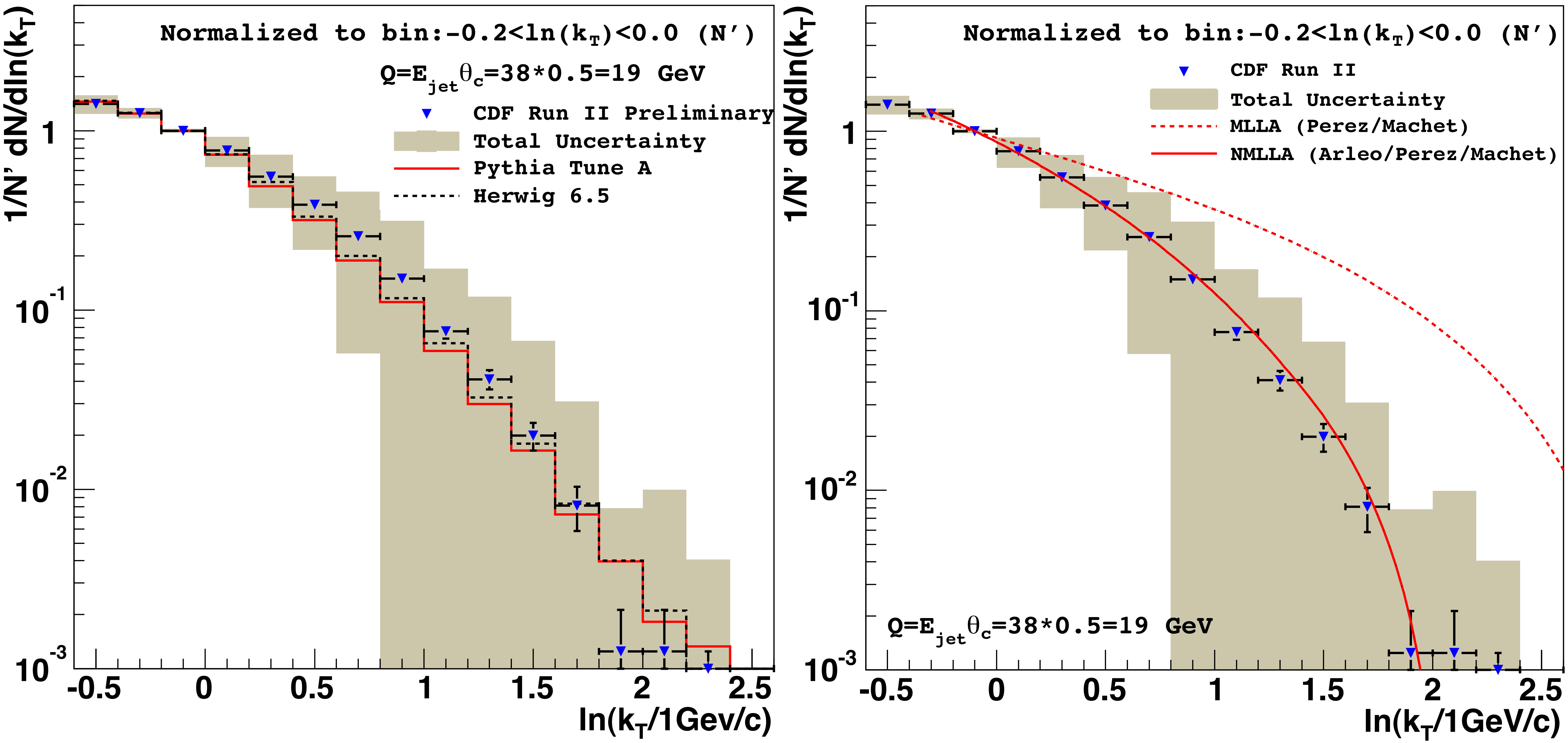
- Choice of jet reconstruction cone radius: 1%

  By varying cone radius in reconstruction

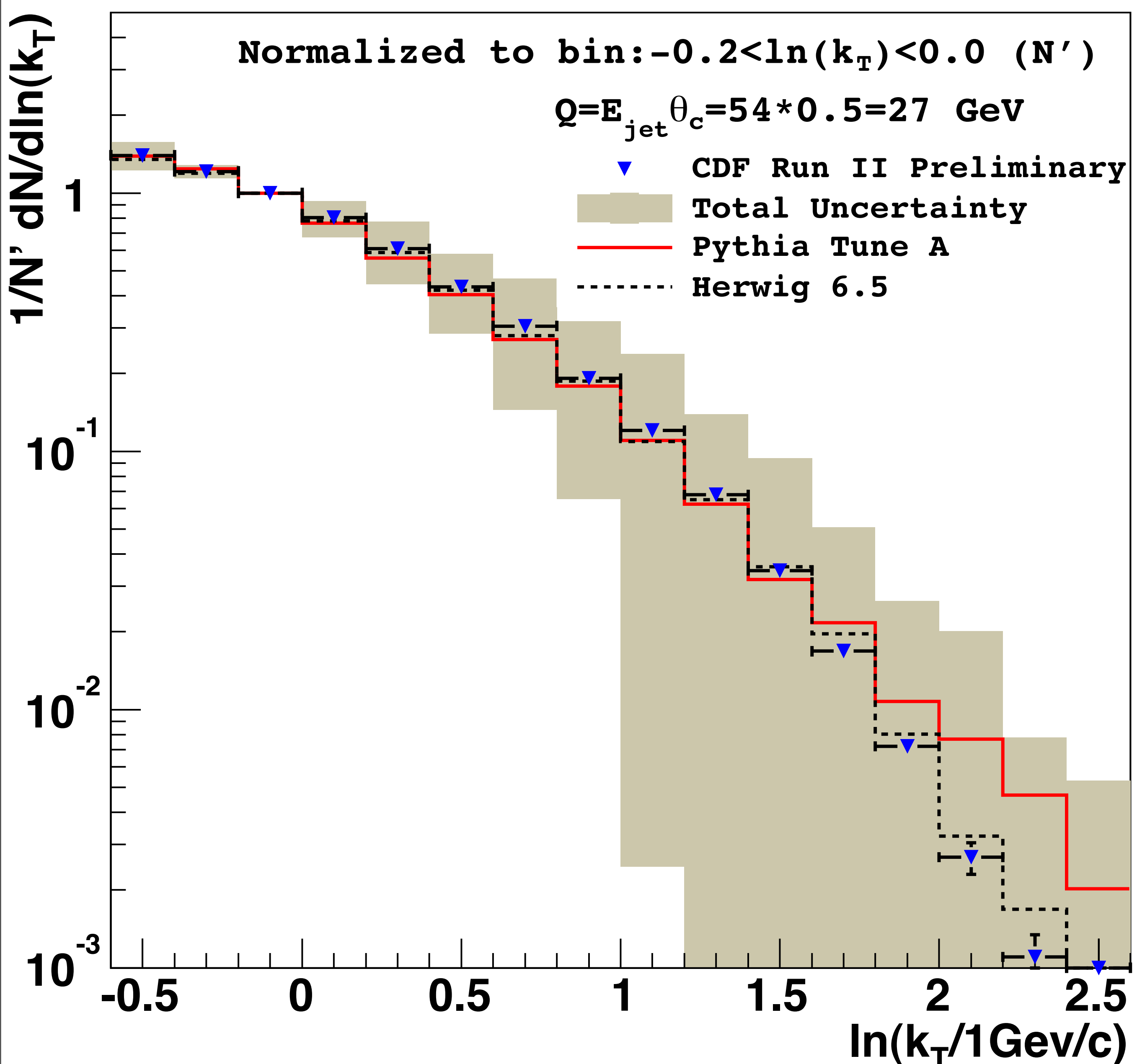
- Error on gluon fraction: < 1%

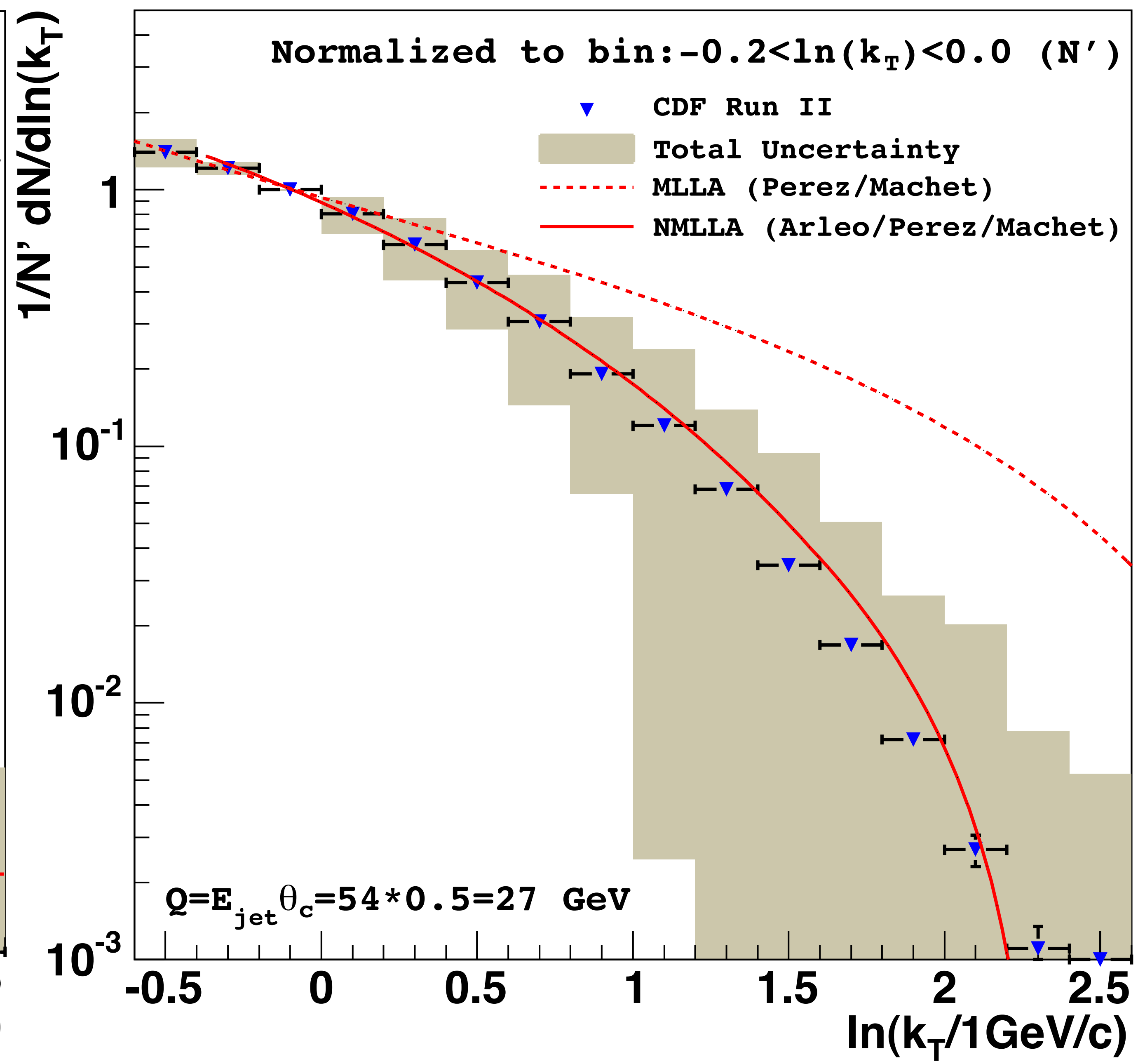
  done by comparing CTEQ5L and CTEQ6.1

k_t Distribution in Jets

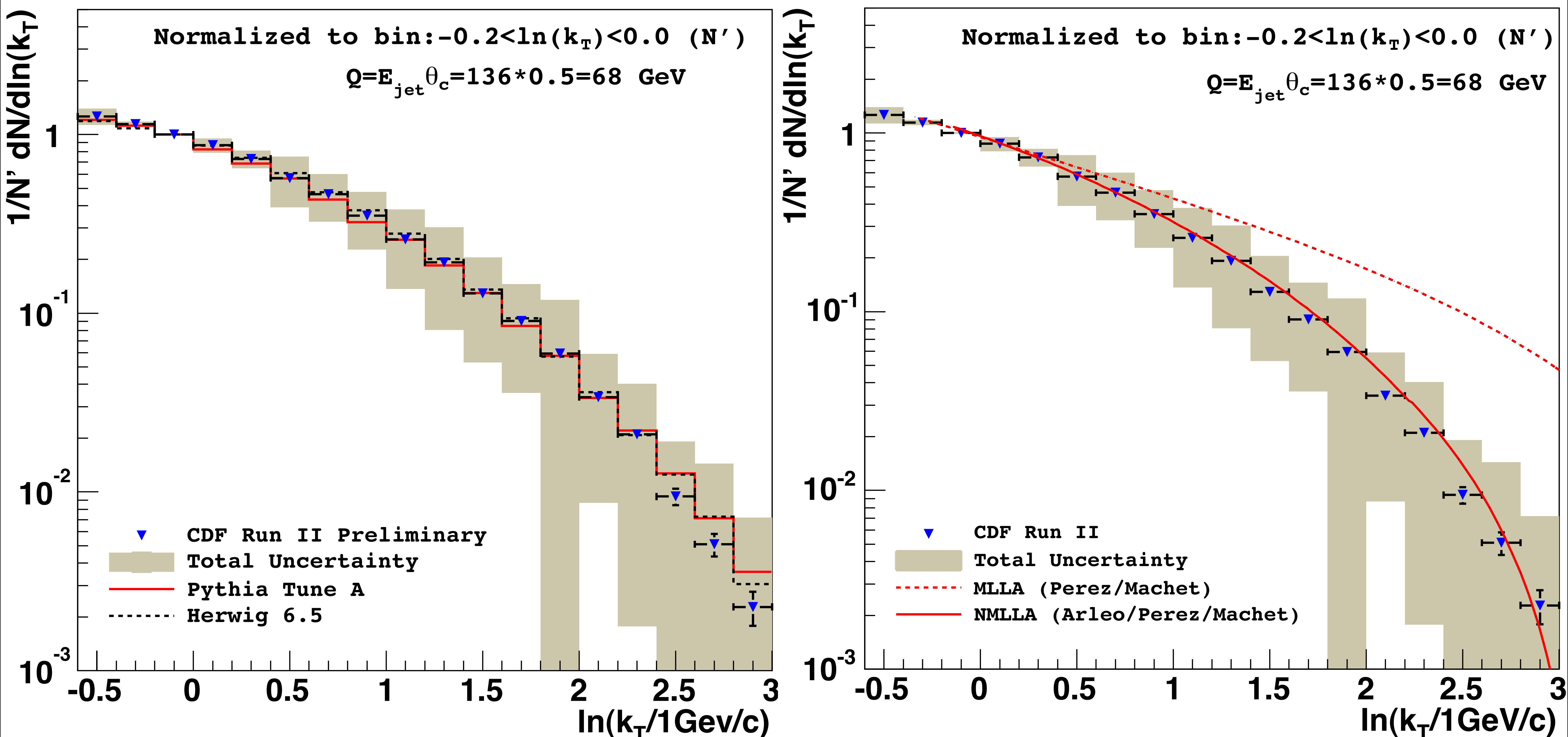


k_t Distribution in Jets

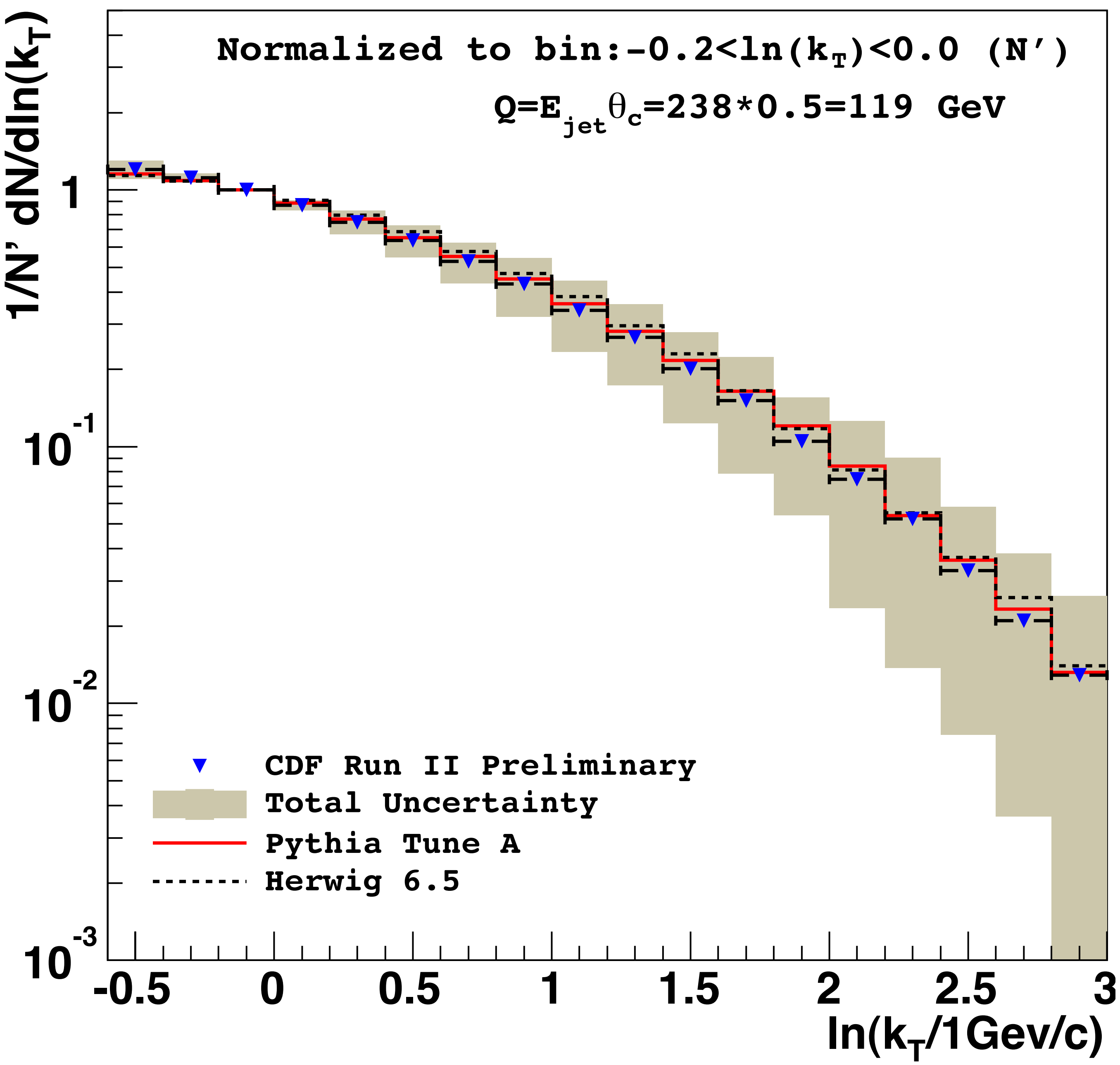


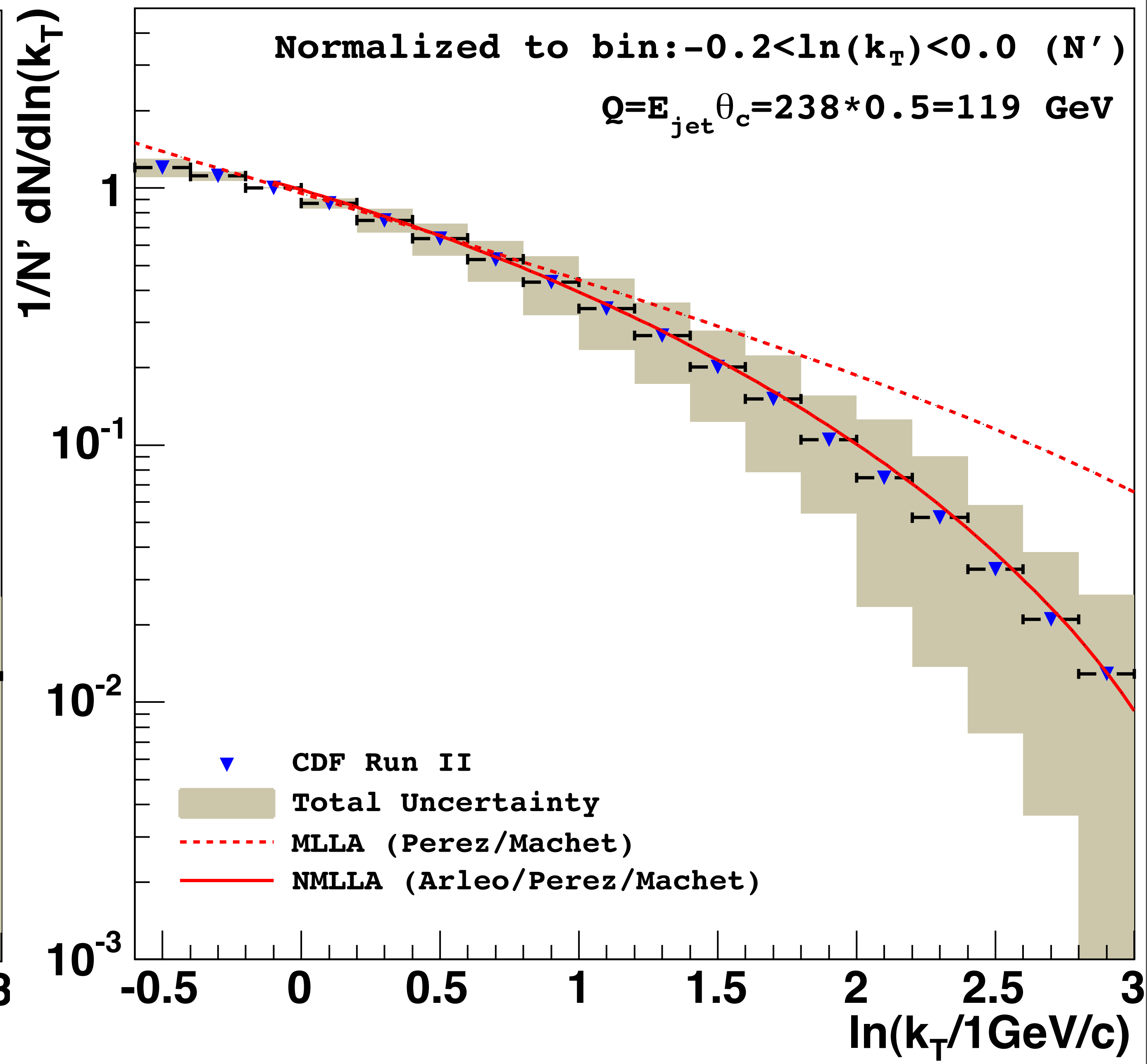


k_t Distribution in Jets



k_t Distribution in Jets





k_t Distribution in Jets

- NMLLA + LPHD models k_T distribution very well

  ⇒ Dominated by perturbative processes

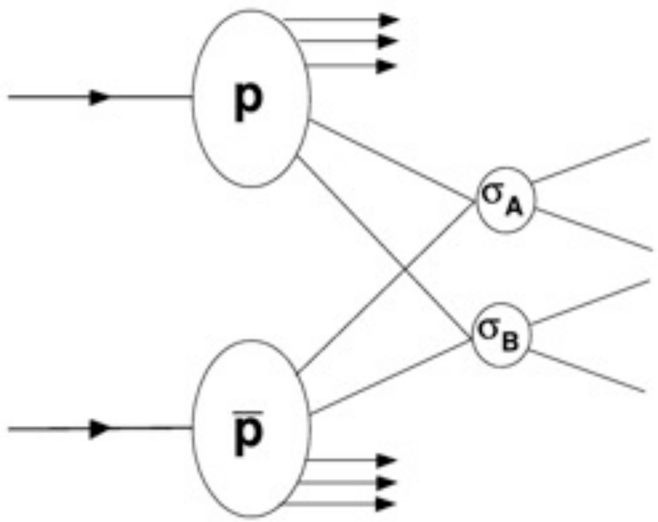
  ⇒ Extra order of precision in NMLLA is needed

- Herwig and Tune A do a similarly good job

  - Due to good existing tuning of hadronisation
  - Measured distributions can be used as further tuning input

DP Events in γ + 3 Jets

- In hadron collisions, we can have significant contribution from double parton (DP) collisions. Both can be *"hard"*.



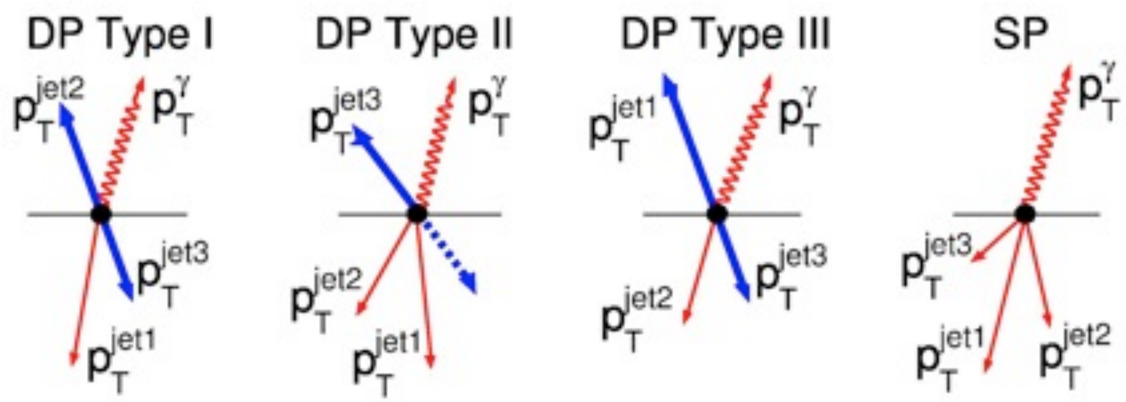
$$\sigma_{\mathrm{DP}} \equiv m \frac{\sigma_{\mathrm{A}}\sigma_{\mathrm{B}}}{2\sigma_{\mathrm{eff}}}$$

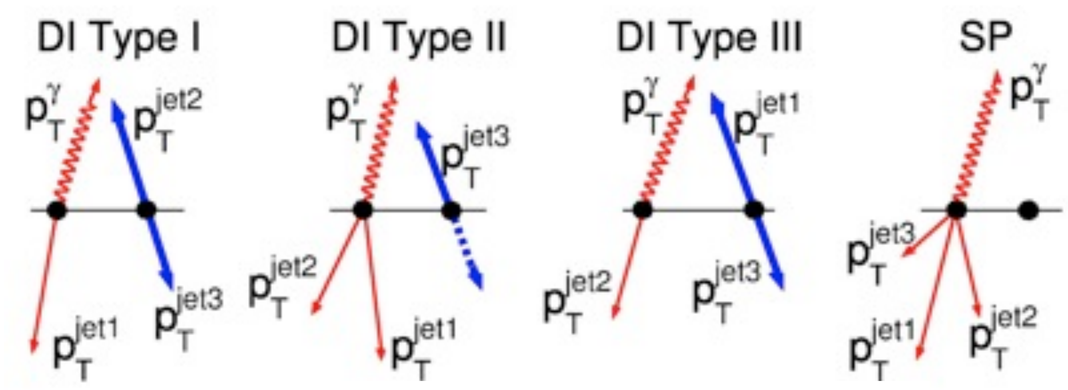
- Scaling factor σ_{eff} :
  - large for evenly distributed partons (fewer DP evts)
  - small for highly concentrated partons (more DP evts)
- Need to measure DP fraction f_{DP} and σ_{eff}

Using 1 fb^{-1}
Mar 2010

Phys. Rev. D **81**, 052012 (2010)

Eliminating σ_A and σ_B





$$P_{\mathrm{DP}} = \frac{\sigma_{\mathrm{DP}}}{\sigma_{\mathrm{hard}}} = \frac{\sigma^{\gamma j}}{\sigma_{\mathrm{eff}}} \frac{\sigma^{jj}}{\sigma_{\mathrm{hard}}}$$

$$P_{\mathrm{DI}} = 2 \frac{\sigma^{\gamma j}}{\sigma_{\mathrm{hard}}} \frac{\sigma^{jj}}{\sigma_{\mathrm{hard}}}$$

$$N_{\mathrm{DP}} = \frac{\sigma^{\gamma j}}{\sigma_{\mathrm{eff}}} \frac{\sigma^{jj}}{\sigma_{\mathrm{hard}}} N_{1\mathrm{coll}} \, \epsilon_{\mathrm{DP}} \, \epsilon_{1\mathrm{vtx}}$$

$$N_{\mathrm{DI}} = 2 \frac{\sigma^{\gamma j}}{\sigma_{\mathrm{hard}}} \frac{\sigma^{jj}}{\sigma_{\mathrm{hard}}} N_{2\mathrm{coll}} \, \epsilon_{\mathrm{DI}} \, \epsilon_{2\mathrm{vtx}}$$

$$\sigma_{\mathrm{eff}} = \frac{N_{\mathrm{DI}}}{N_{\mathrm{DP}}} \frac{\varepsilon_{\mathrm{DP}}}{\varepsilon_{\mathrm{DI}}} R_c \sigma_{\mathrm{hard}} \quad R_c \equiv (1/2)(N_{1\mathrm{coll}}/N_{2\mathrm{coll}})(\varepsilon_{1\mathrm{vtx}}/\varepsilon_{2\mathrm{vtx}})$$

- SP events are a background and estimated through variables sensitive to the kinematics of the DP type

γ + 3 Jets Selection

- Using 1 fb^{-1} photon triggered data events require:
  - at least 1 photon with $|y|<1$ or $1.5<|y|<2.5$ with $60 < p_T^{\gamma} < 80$ GeV
  - at least 3 Jets with $|y| < 3.0$ with $p_T^{lead} > 25$ GeV and $p_T^{other} > 15$ GeV

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Helps separate Interactions in momentum space

Corrected to particle level

γ + 3 Jets Selection

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  - at least 3 Jets with $|y| < 3.0$ with $p_T^{lead} > 25$ GeV and $p_T^{other} > 15$ GeV
  - Number of events in bins of p_T^{jet2}:

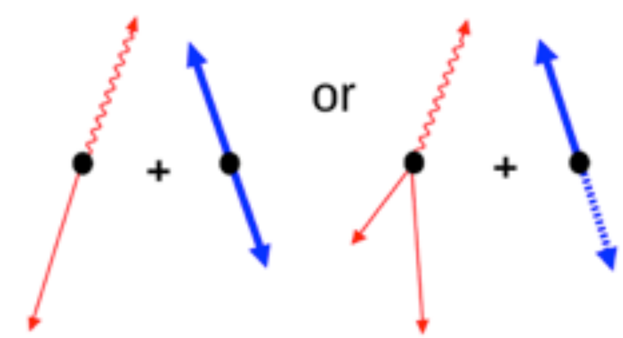
Data Sample	p_T^{jet2} (GeV) 15 – 20	20 – 25	25 – 30
1Vtx	2182	3475	3220
2Vtx	2026	2792	2309

DP/DI Model from Data

- Model for DP interactions is built from mixing data events with exactly one Vertex from exclusive samples A) and B):

    A) photon+≥1 Jet (p_T^{γ}=60-80 GeV, p_T^{jet1}>25 GeV)

    B) ≥1 Jet (pT>15 GeV, recalculated)



- Events need to satisfy γ+3 jets selection

    $\Delta R(\gamma, j1, j2, j3) > 0.7$

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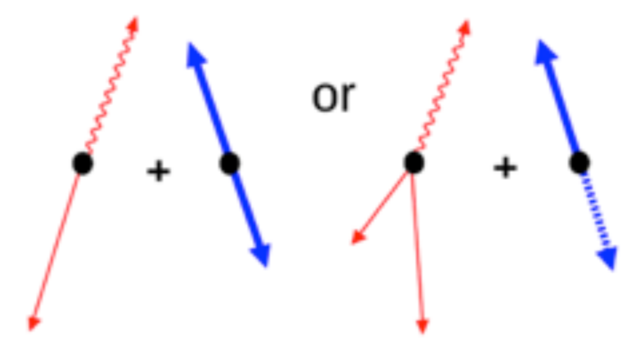
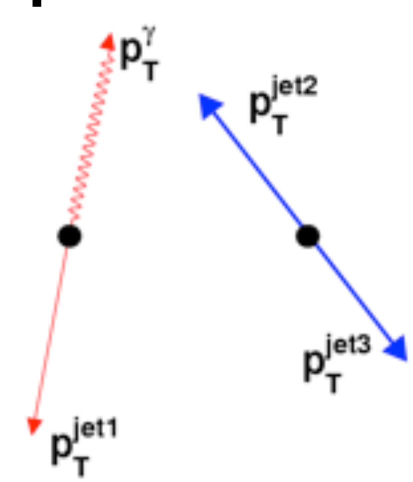


- Events need to satisfy γ+3 jets selection

  $\Delta R(\gamma, j1, j2, j3) > 0.7$

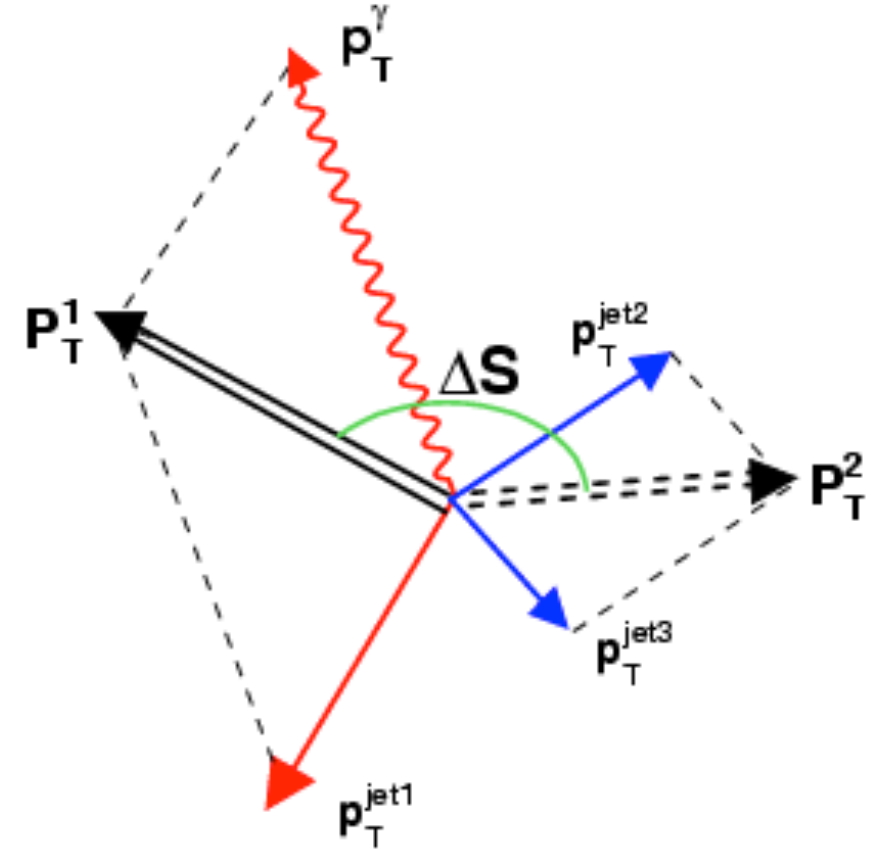
- Model for DI interactions is built similarly from independent samples, but requiring 2 vertices in each event.
  - Main difference: more UE due to 2nd vertex
  - Can also model SP in DI (all jets from same PV)



SP Discrimination: ΔS

Δφ angle between two best pT balanced pairs

$$\Delta S \equiv \Delta\phi\left(\vec{p}_T(\gamma, i),\ \vec{p}_T(j, k)\right)$$



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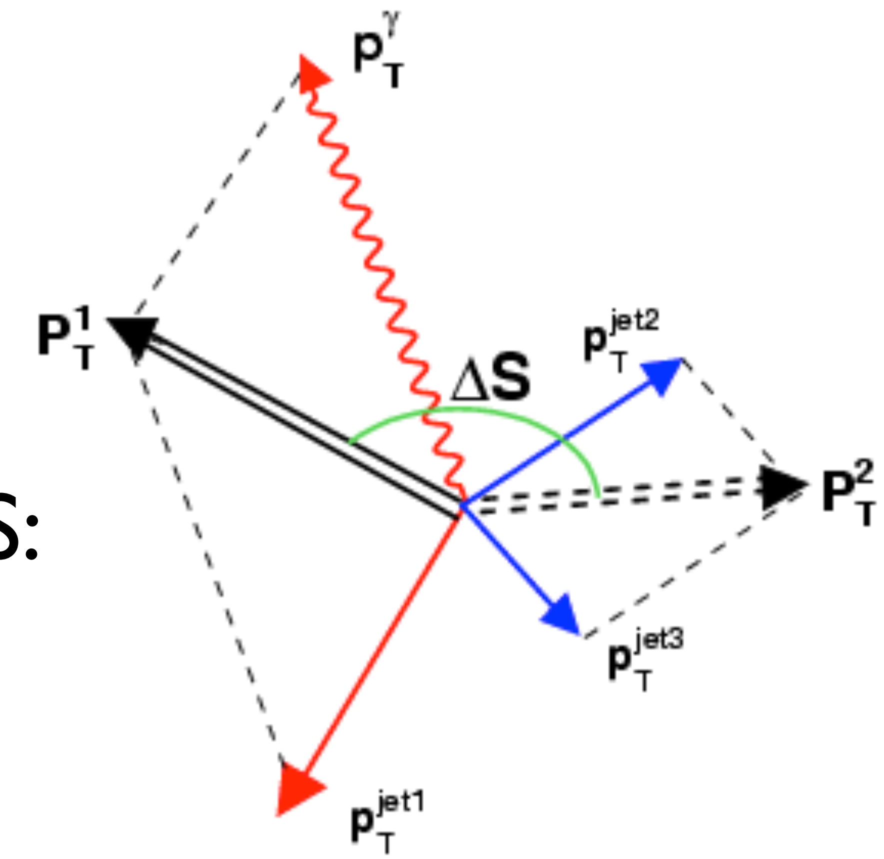


Best balanced pairs found through minimizing S:

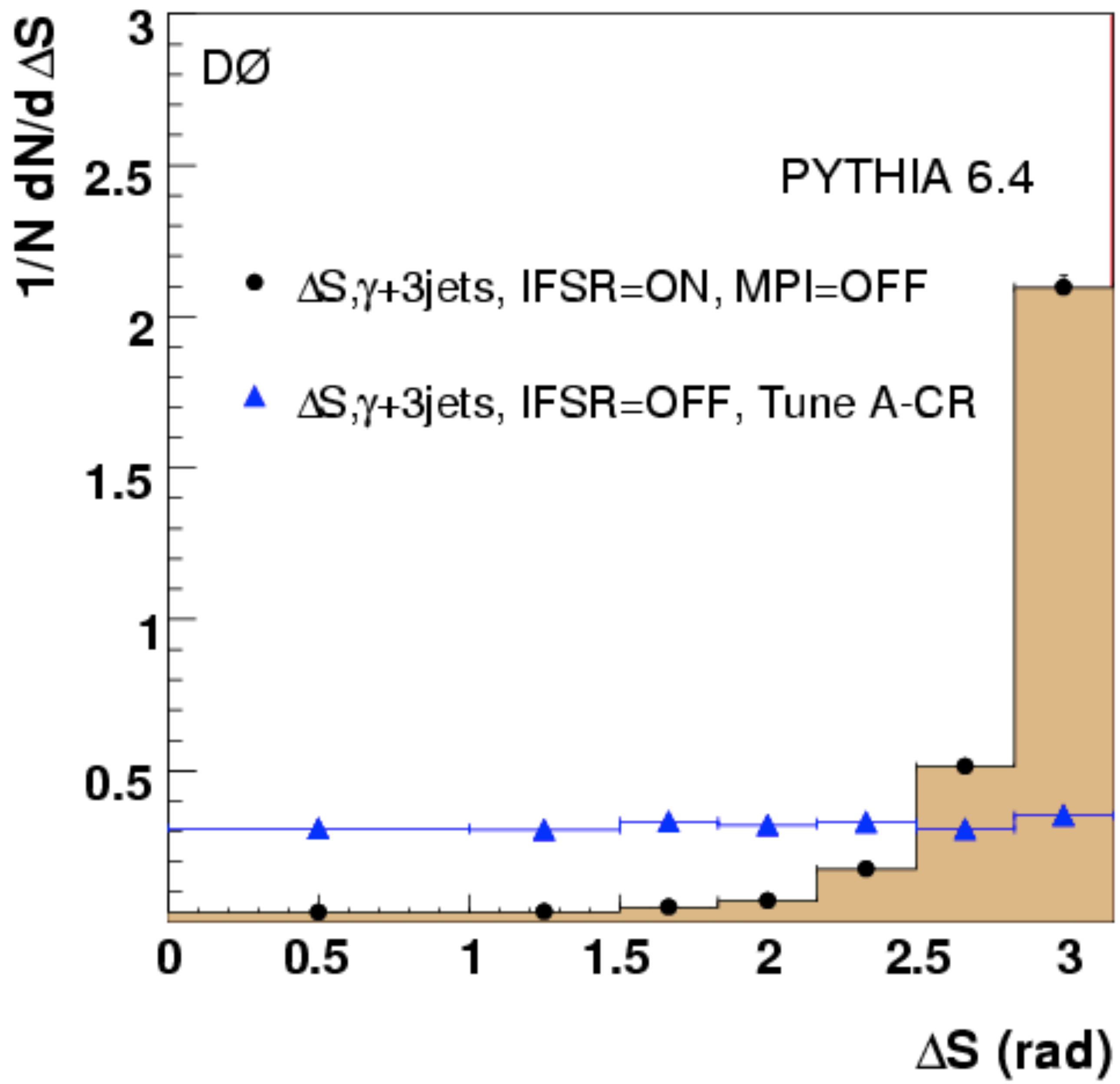
$$S_{p_T} = \frac{1}{\sqrt{2}}\sqrt{\left(\frac{|\vec{p}_T(\gamma, i)|}{\delta p_T(\gamma, i)}\right)^2 + \left(\frac{|\vec{p}_T(j, k)|}{\delta p_T(j, k)}\right)^2},$$

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

$$S_{\phi} = \frac{1}{\sqrt{2}}\sqrt{\left[\frac{\Delta\phi(\gamma, i)}{\delta\phi(\gamma, i)}\right]^2 + \left[\frac{\Delta\phi(j, k)}{\delta\phi(j, k)}\right]^2}.$$

In signal >94% are minimised by pairing photon with leading jet

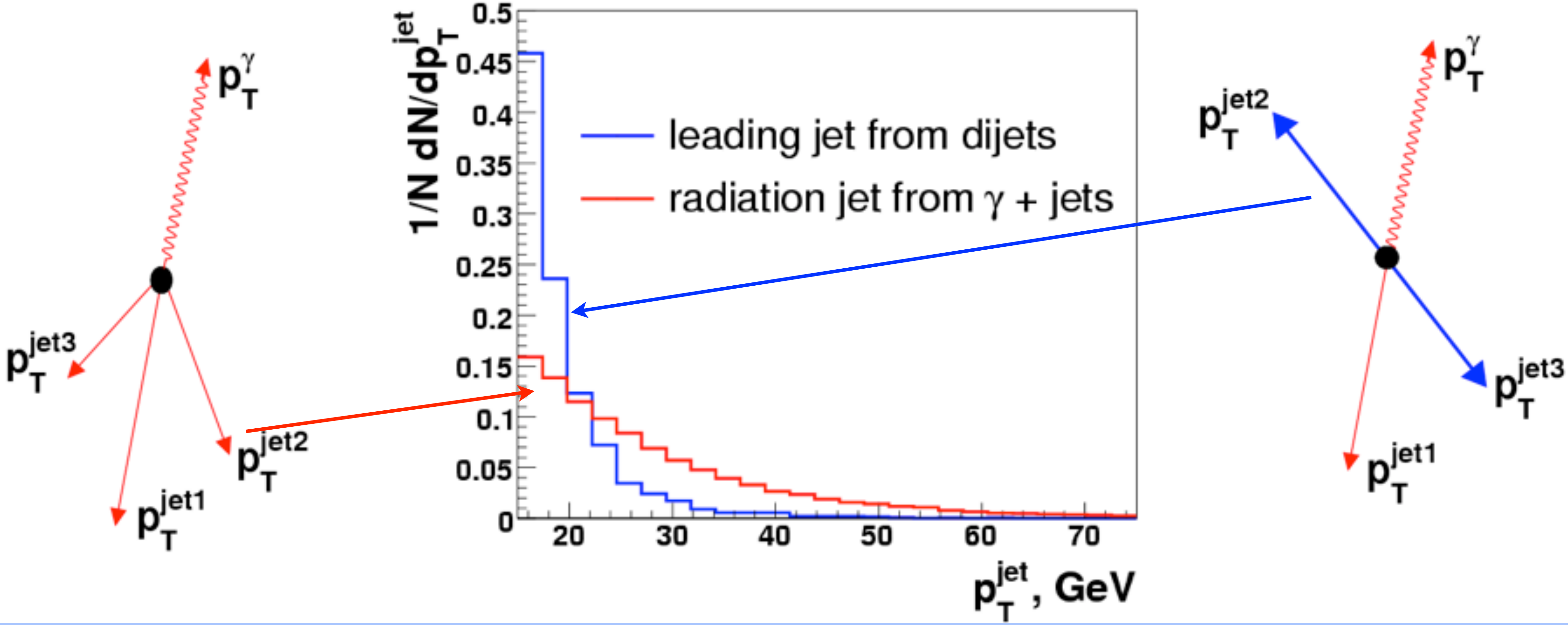
ΔS Distribution in MC



- Single parton: expected to peak at π
- "Ideal" double parton: flat (2nd and 3rd jet from dijet)

Jet p_T Binning

- Jet p_T from di-jet drops faster then for radiation jets.
  ⇒DP Fraction drops with increasing jet p_T
- Define three bins of 2nd jet p_T: 15-20, 20-25, 25-30 GeV
  ⇒This creates DP enriched and depleted subsets

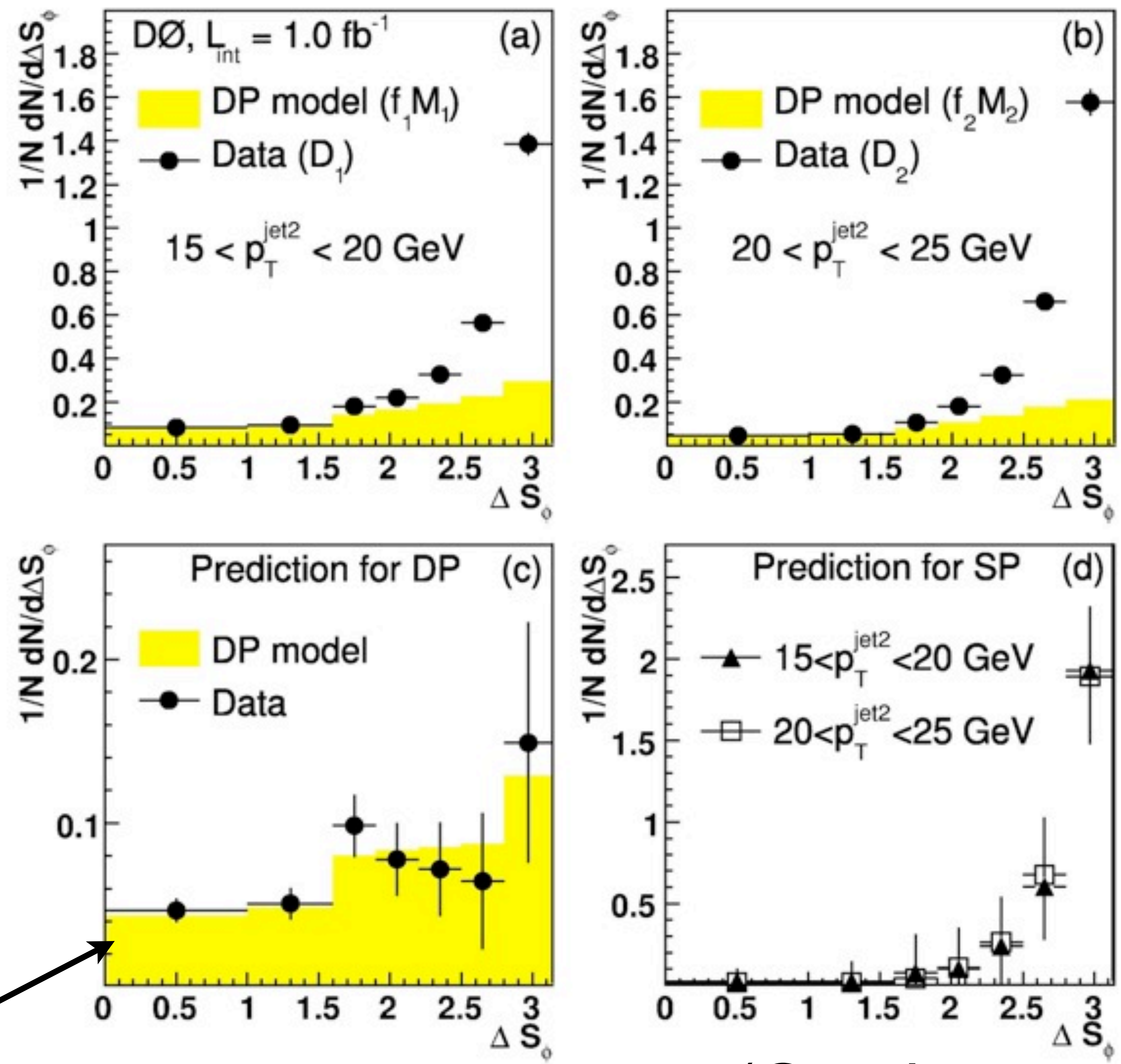


Combined fit of shape from mixed events DP model to two bins has only one free parameter f_I (the DP fraction)

Two Dataset Fit

Set 1:
2nd jet pT:
15-20 GeV

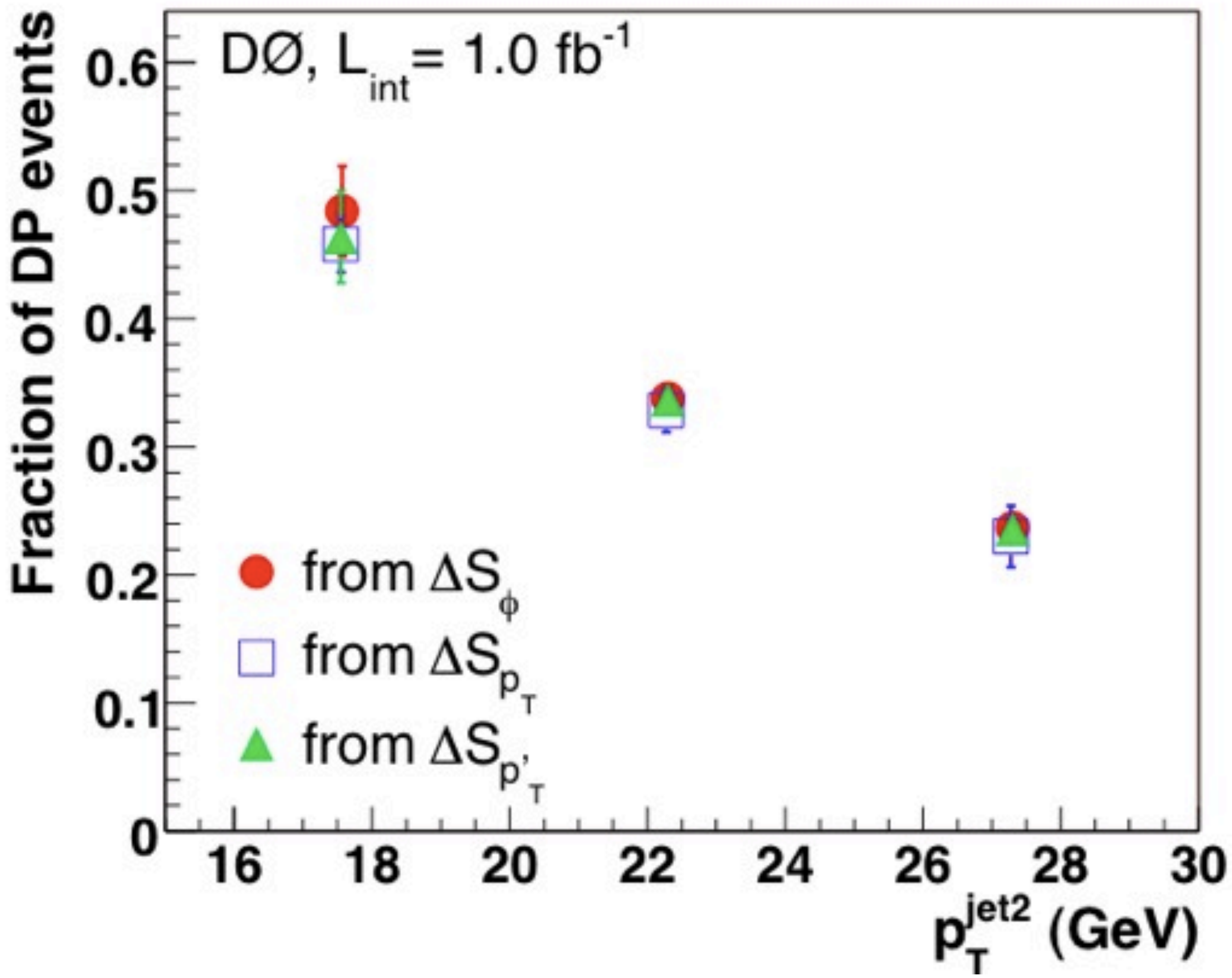
Set 2:
2nd jet pT:
20-25 GeV



Data correted
for DP fractions

(Good agreement between
SP fraction from Data
and MC simulation)

Double Parton Fraction



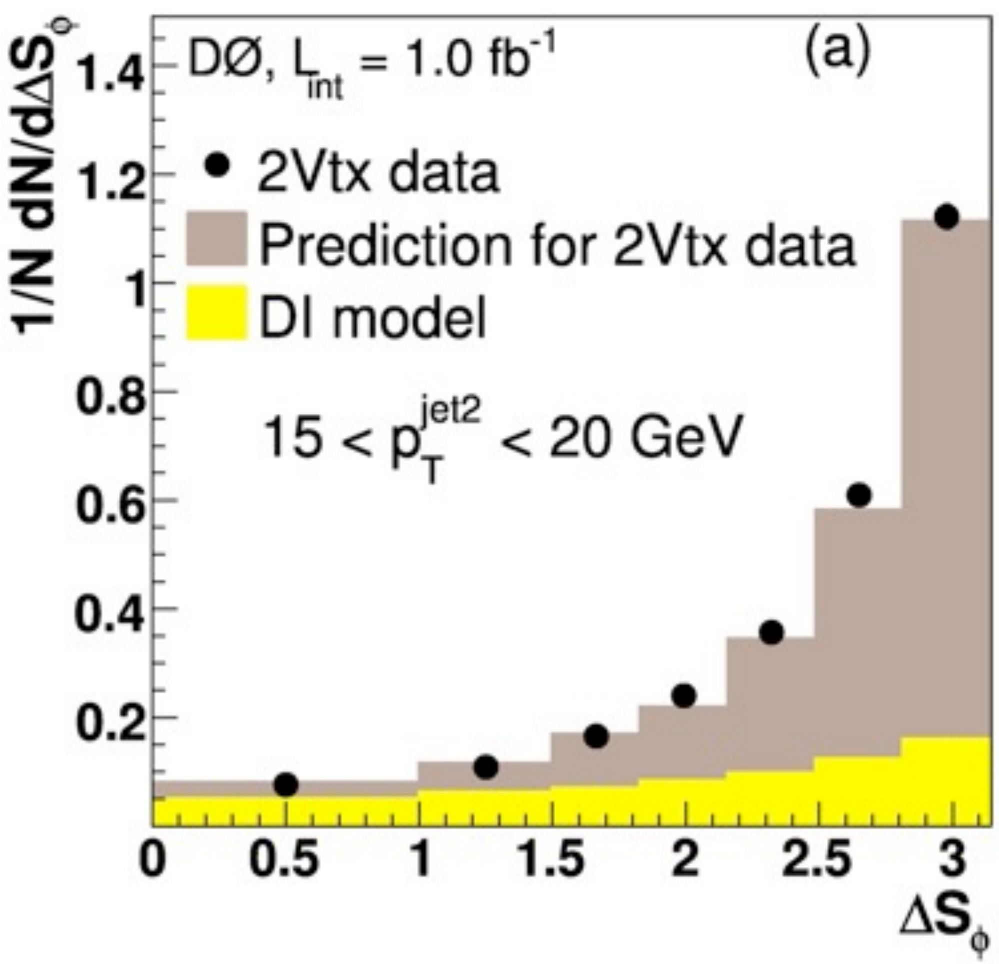
Relative uncertainties:
7-12%

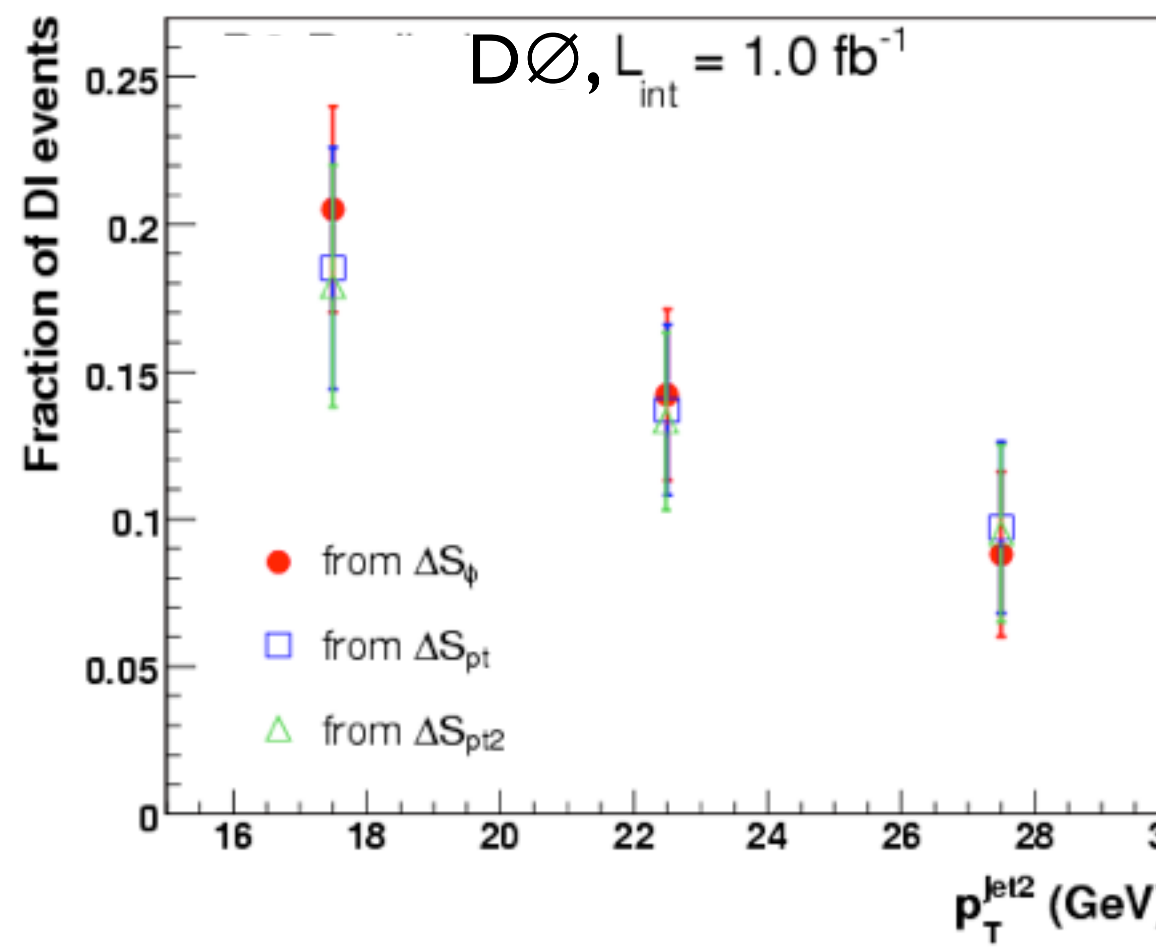
2nd jet p_T range	15-20 GeV	20-25 GeV	25-30 GeV
DP fraction	~47%	~33%	~23%

DI Events Fractions

For σ_{eff} we also need $N_{DI} = f_{DI}\, N_{2vtx}$:

Use ΔS shapes and fit DI signal and SP background distributions to 2-vertex data

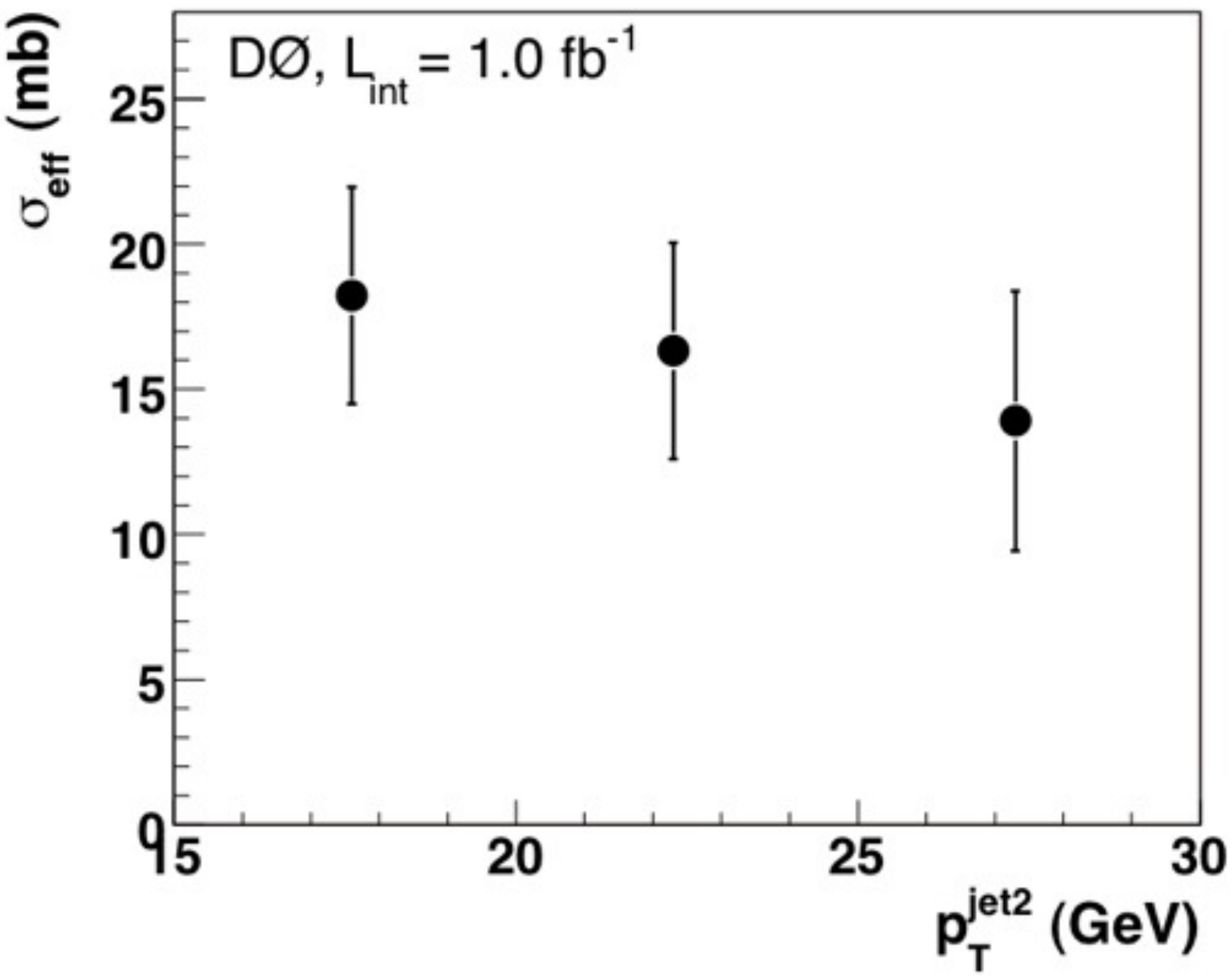




Sum of Signal and BG agrees well with data

Main uncertainties:
Statistics of DI and BG models

DP in γ + 3 jets results



Values of σ_{eff} in bins of 2nd jet p_T are compatible with each other (or slow drop)

Very small correlations of systematic uncertainties between the bins

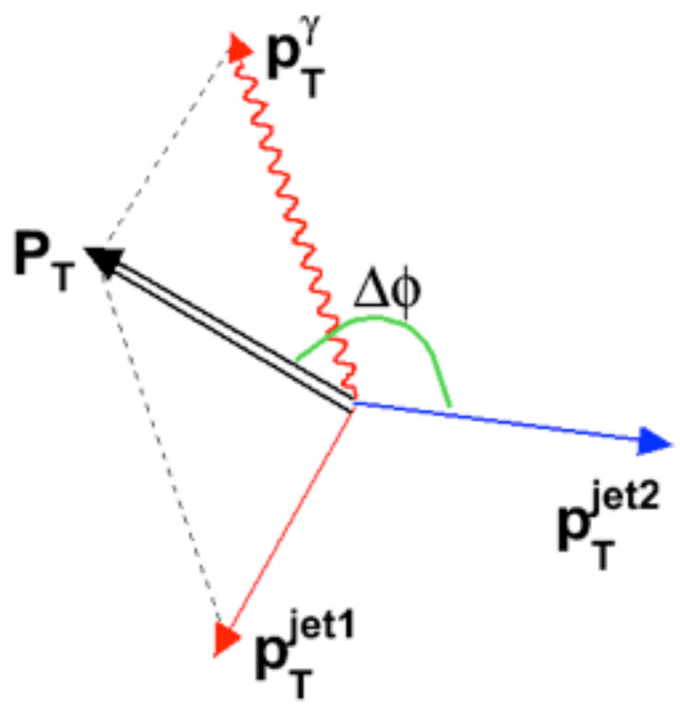
$$\sigma_{eff}^{ave} = 16.4 \pm 0.3(\text{stat}) \pm 2.3(\text{syst}) \quad \text{mb}$$

p_T^{jet2} (GeV)	Systematic uncertainty sources f_{DP}	f_{DI}	$\varepsilon_{DP}/\varepsilon_{DI}$	JES	$R_c\sigma_{hard}$	δ_{syst} (%)	δ_{stat} (%)	δ_{total} (%)
15 – 20	7.9	17.1	5.6	5.5	2.0	20.5	3.1	20.7
20 – 25	6.0	20.9	6.2	2.0	2.0	22.8	2.5	22.9
25 – 30	10.9	29.4	6.5	3.0	2.0	32.2	2.7	32.3

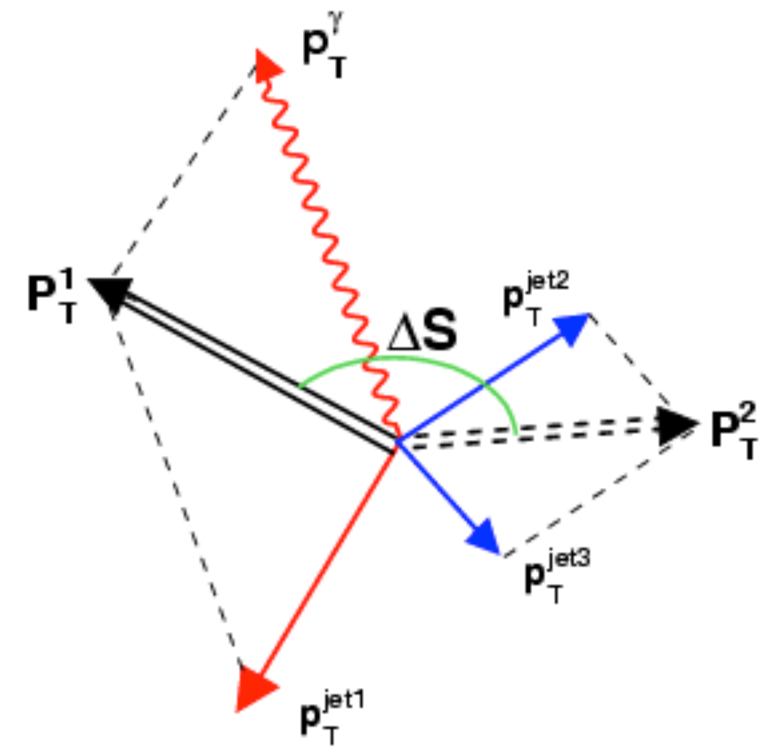
DP in γ + 2(3) Jets

Update of DP study including γ+ 2jets and DP interactions

γ+2 jet events: $\Delta\phi(\gamma$+jet1, jet2)



γ+3 jet events: ΔS variable

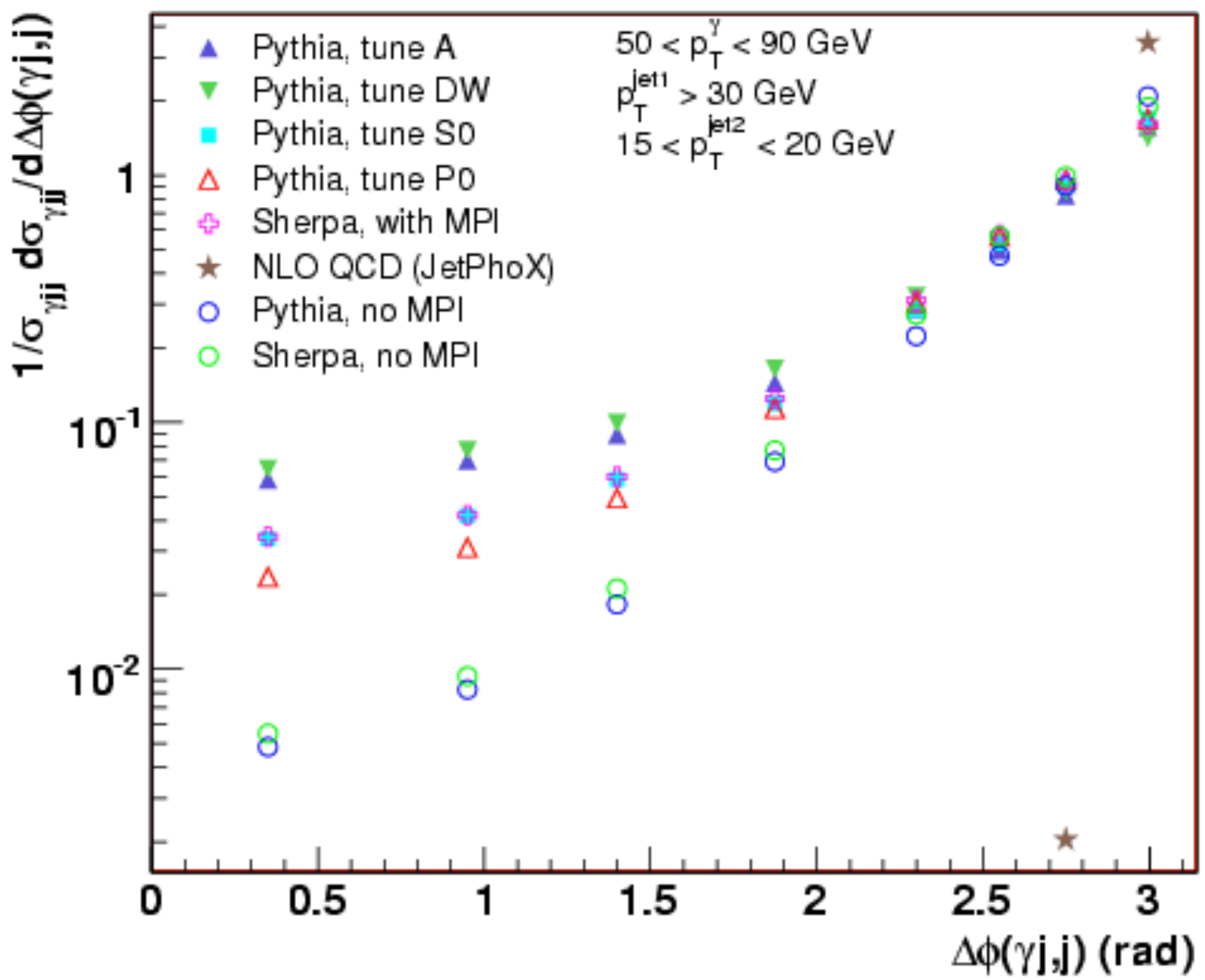


Normalised Δφ cross sections in bins of 2nd jet p_T are measured
Compared to MPI models in Pythia, Sherpa and NLO QCD for γ + 2 jets

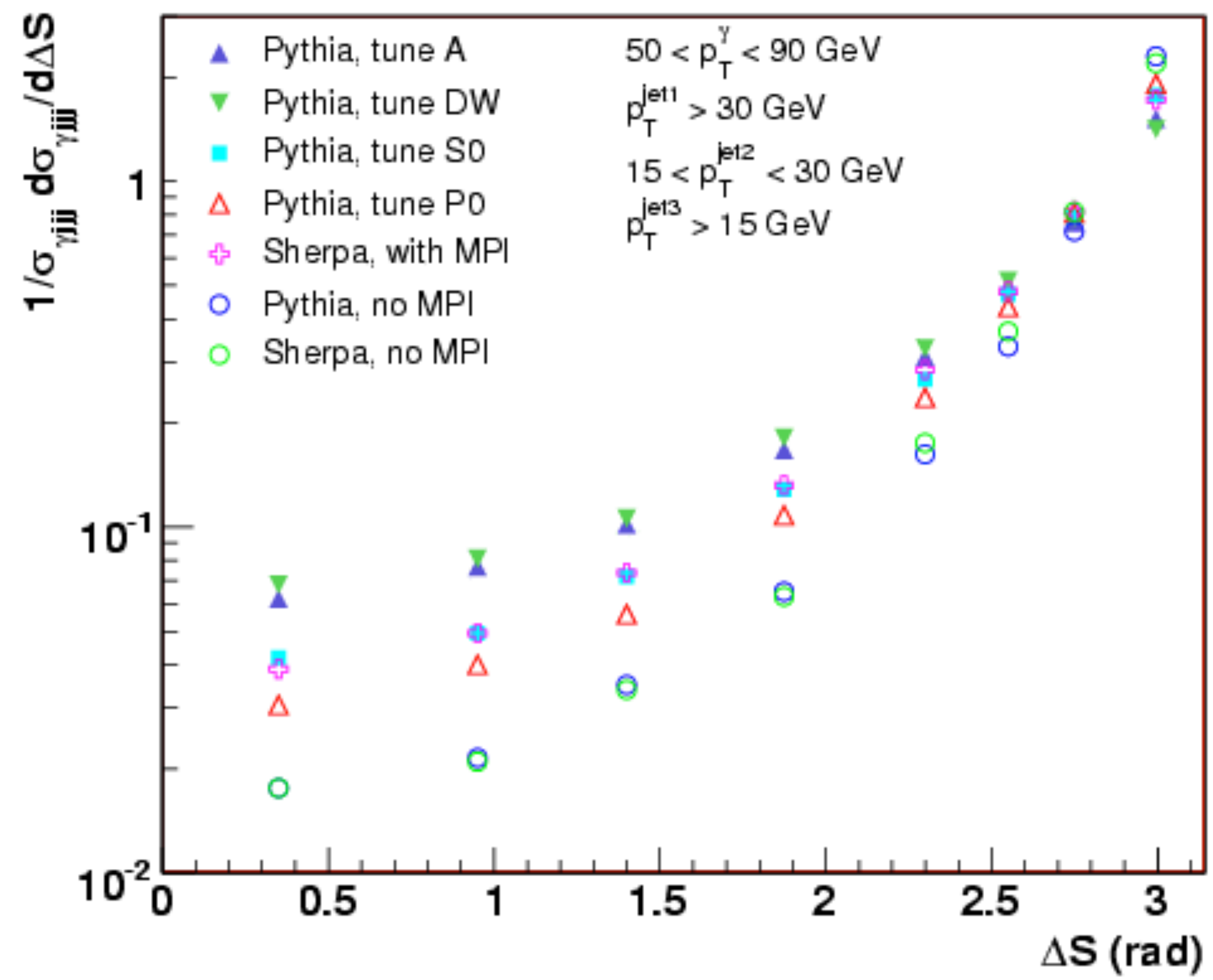
Also: Determination of DP+TP fraction in γ+2Jets

ΔS and Δφ in MC Models

Δφ predictions



ΔS predictions



- Variations of factor 2-2.5 between MPI models
- SP distributions differ substantially
- QCD NLO predicts sharp peak at Δφ=π only

Summary

- Tevatron experiments provide MPI measurements over a wide scale. Most recently:
  - UE studies in Drell-Yan (compared to di-jet)
  - Shape of MinBias Events
  - Showering and hadronisation in hard jets
  - Double parton interactions (at higher scales than before)

- This scale spans the whole range from mostly non-perturbative to purely perturbative description.
- And there's still more to come from the Tevatron ...

Backup

Other Input to σ_{eff}

$$\sigma_{\text{eff}} = \frac{N_{\text{DI}}}{N_{\text{DP}}}\frac{\varepsilon_{\text{DP}}}{\varepsilon_{\text{DI}}} R_{\text{c}}\sigma_{\text{hard}} \quad R_c \equiv (1/2)(N_{\text{1coll}}/N_{\text{2coll}})(\varepsilon_{\text{1vtx}}/\varepsilon_{\text{2vtx}})$$

- Number of Events with 1 or 2 hard collisions: calculated from $<n> = (L_{inst}/f_0)\sigma_{hard}$ (Poisson statistics)
  - $\sigma_{\text{hard}} = 44.7 \pm 2.9\text{mb}$
- Selection efficiency for 1 or 2 vertices
  - Measured in data: 1.08 ± 0.01
- Jet and photon efficiencies for DP and DI events
  - Uses MC and Mixed DI and Mixed DP events
  - photon efficiency ratio: 0.96±0.03
  - jet efficincy ratio: 0.93 ± 0.04

(N)MLLA and LPHD

- MLLA
  - Calculates observables by complete resummation of perturbative terms
    - Aproximation: term of order n is calculated to leading and next-to-leading log.
  - NMLLA adds one order of precision

=> (N)MLLA makes predictions on parton level in a small cone around the original parton direction

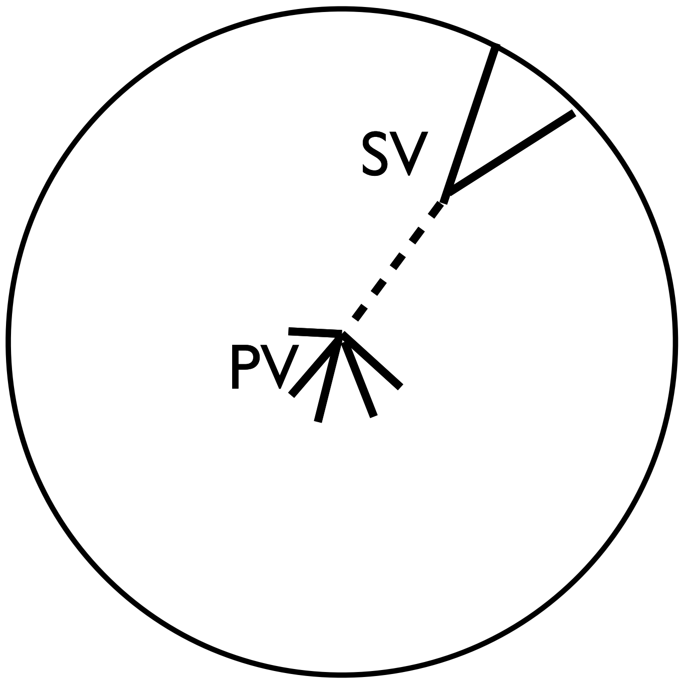
calculations are different for gluon or quark jets

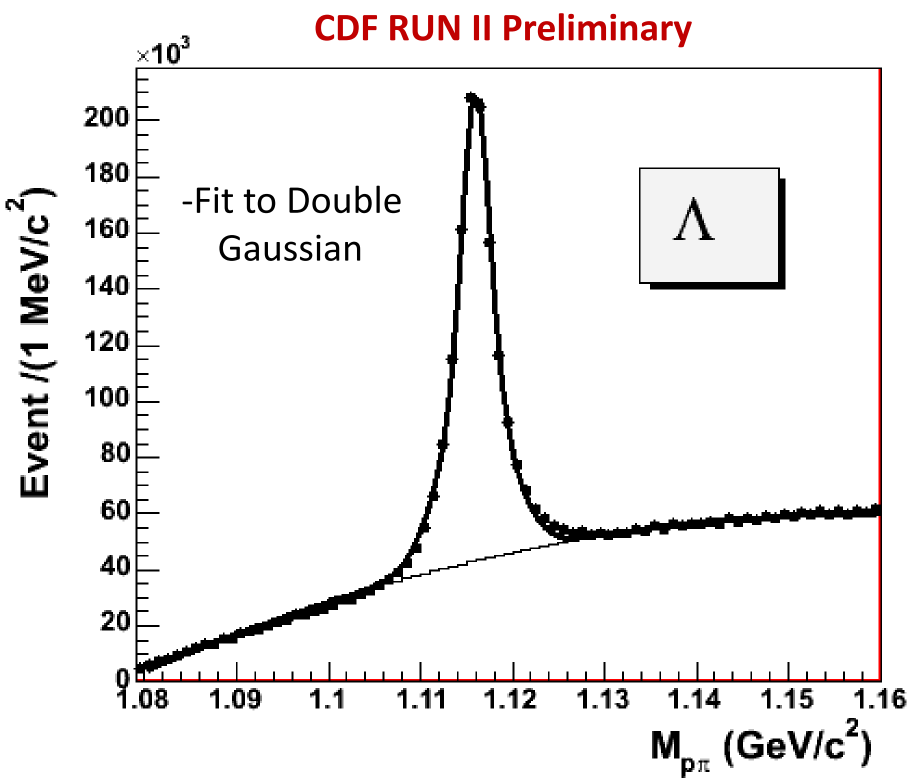
=> Need to know fraction of gluon jets in data (from MC)

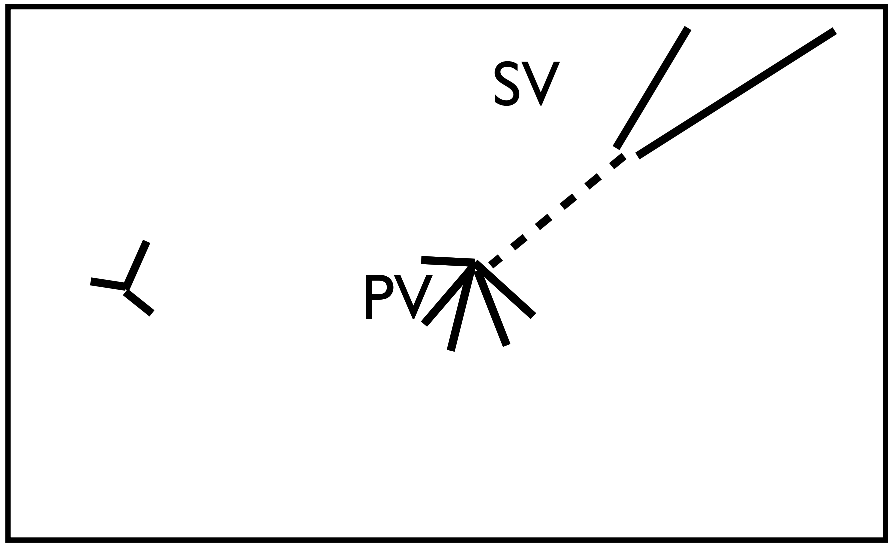
- LPHD is used to translate to particle/hadron level
  - parton and hadron k_T are related by constant $K_{LPHD} \sim 1$

Lambda selection

- Select best, isolated PV and good tracks
- Track p_T > 0.325 GeV, $|\eta| < 1.0$
- Vertexing conditions:
  - ΔZ(tracks) < 1.5cm
  - $d0(\Lambda,PV) < .25$ cm, $\Delta Z(\Lambda,PV) < 2$cm
  - $L_\Lambda > 2.5$ cm
  - higher p_T track assumed to be proton

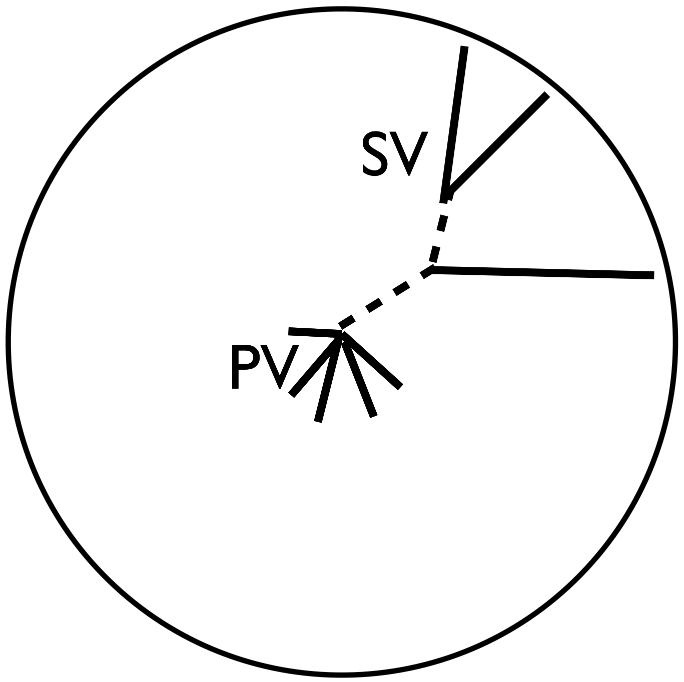


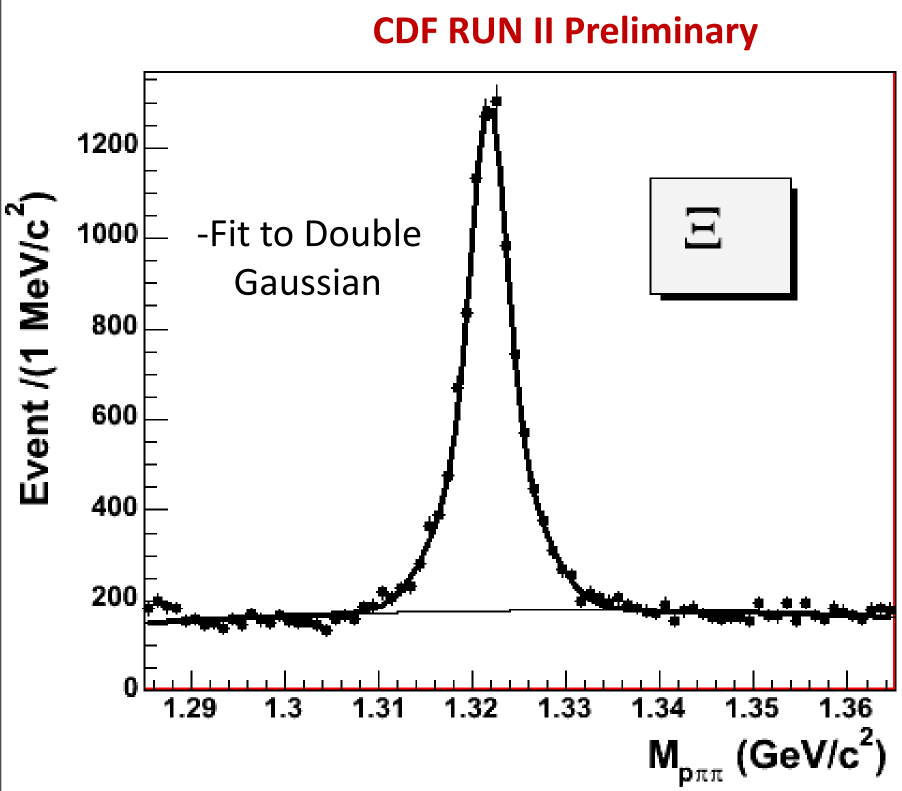


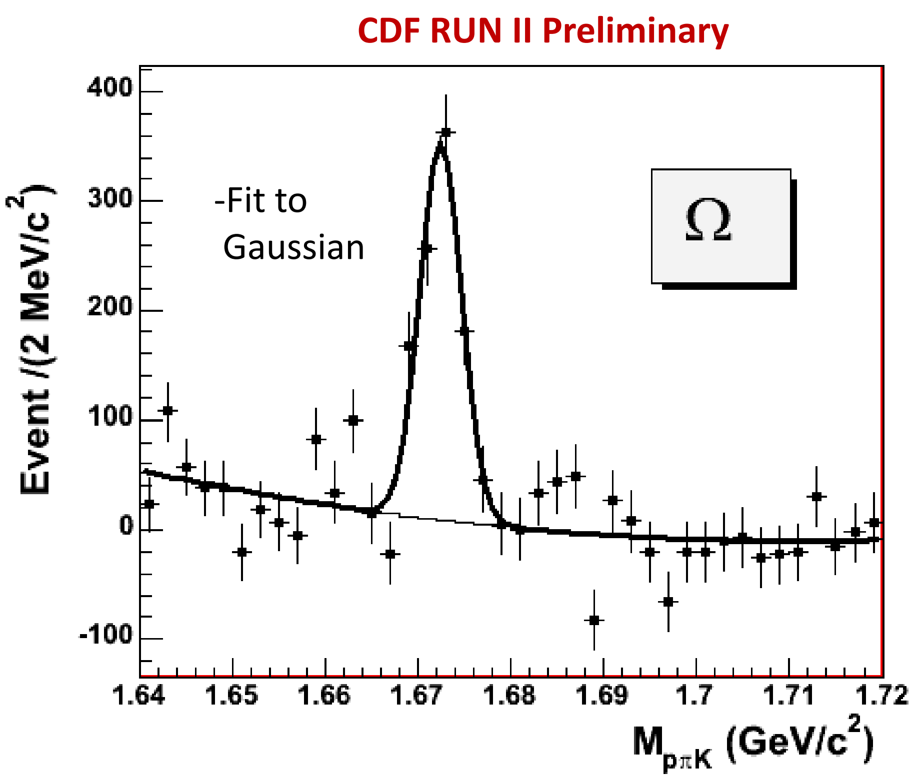


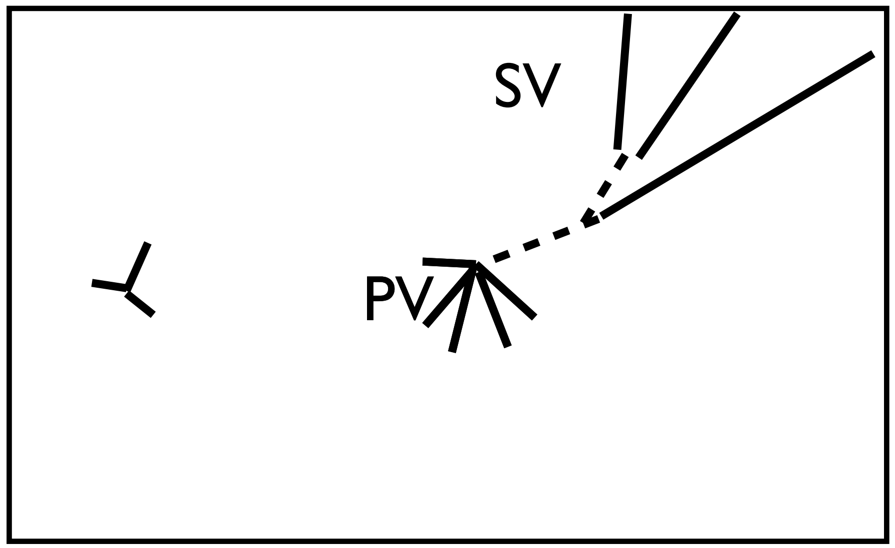
Ξ/Ω selection

- Additional track vertexed with Λ candidate (Λ mass constrained)
  - $L_{\Xi/\Omega}>1$ cm, $L_{\Lambda}>2.5$ cm, $\Delta L>0.5$ cm
  - d0(Ξ/Ω, PV)<0.25cm, ΔZ(Ξ/Ω, PV)<2cm
- Use pion mass for Ξ, kaon for Ω

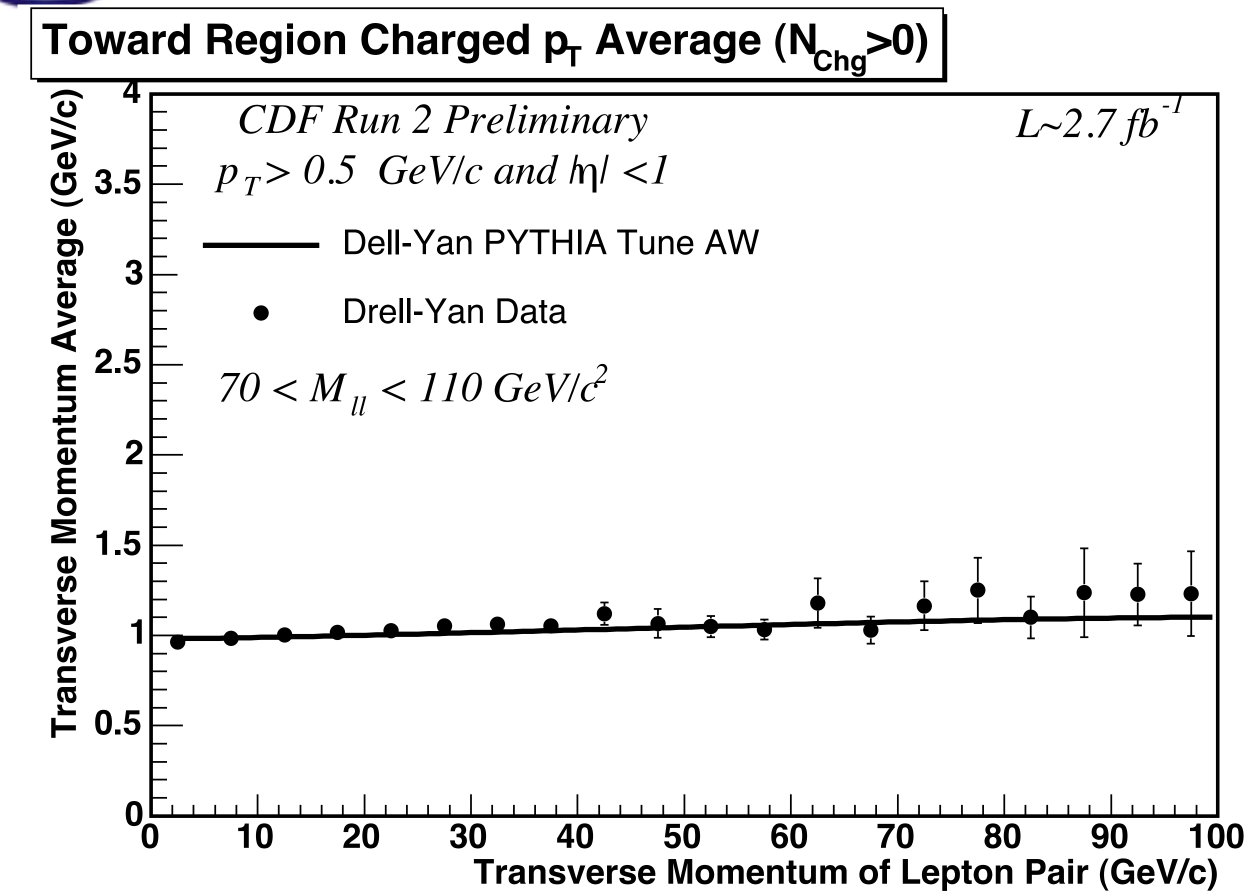


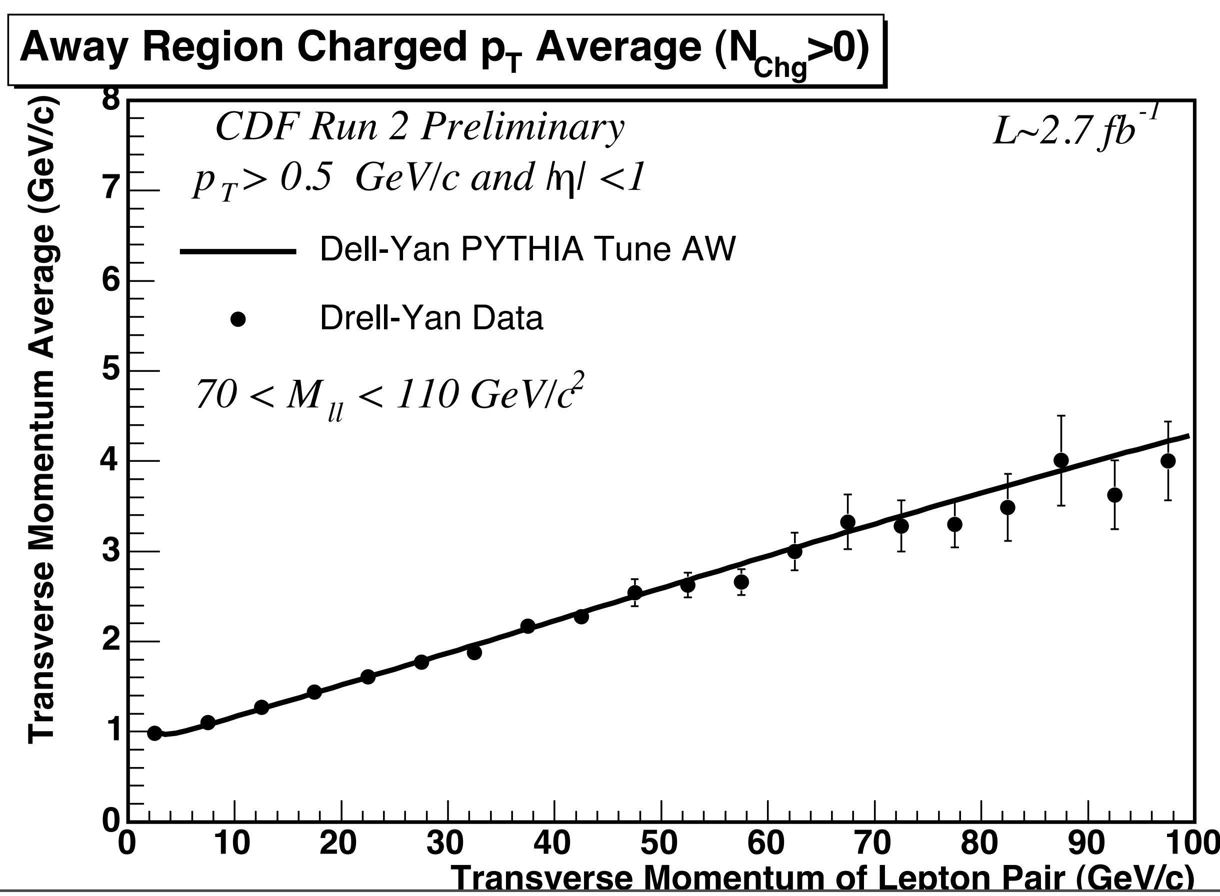




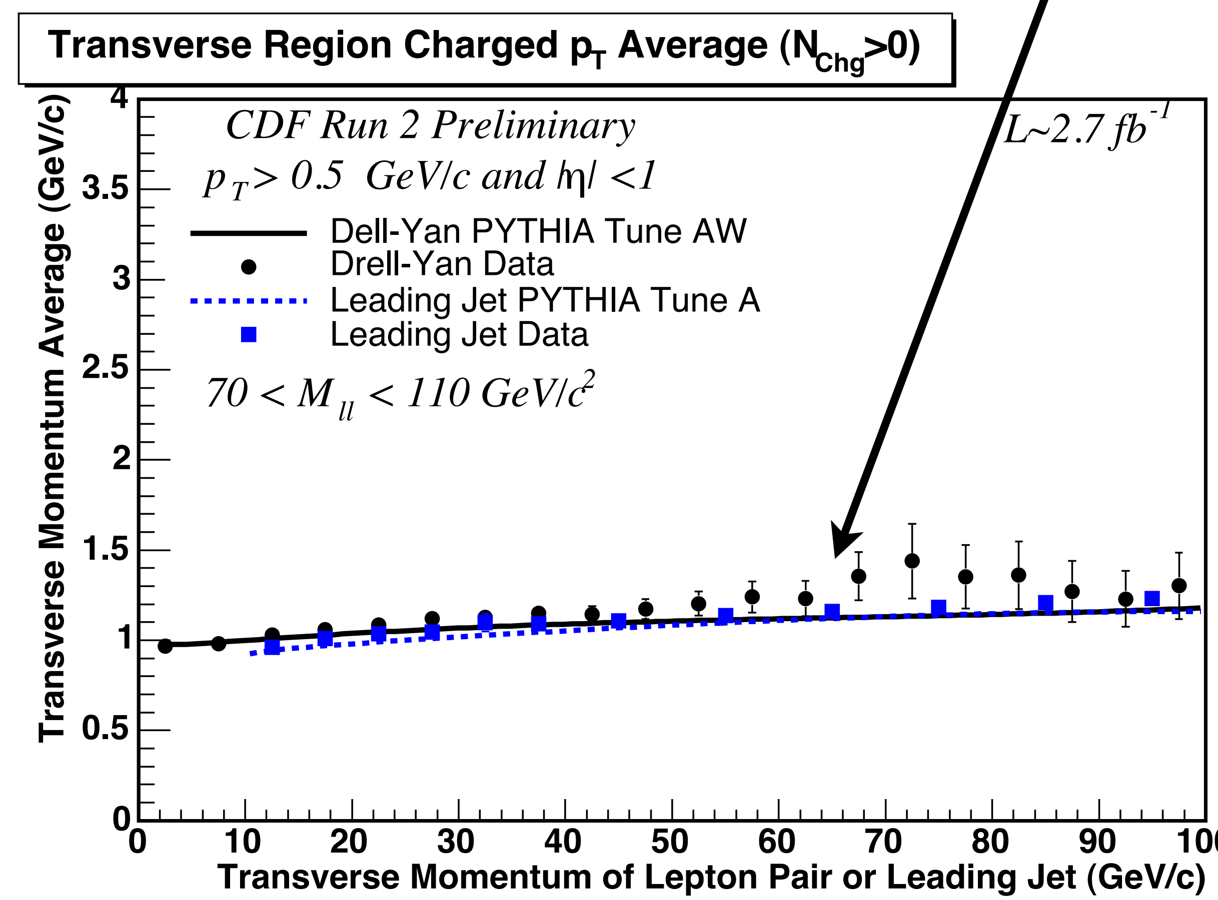


Average p_T



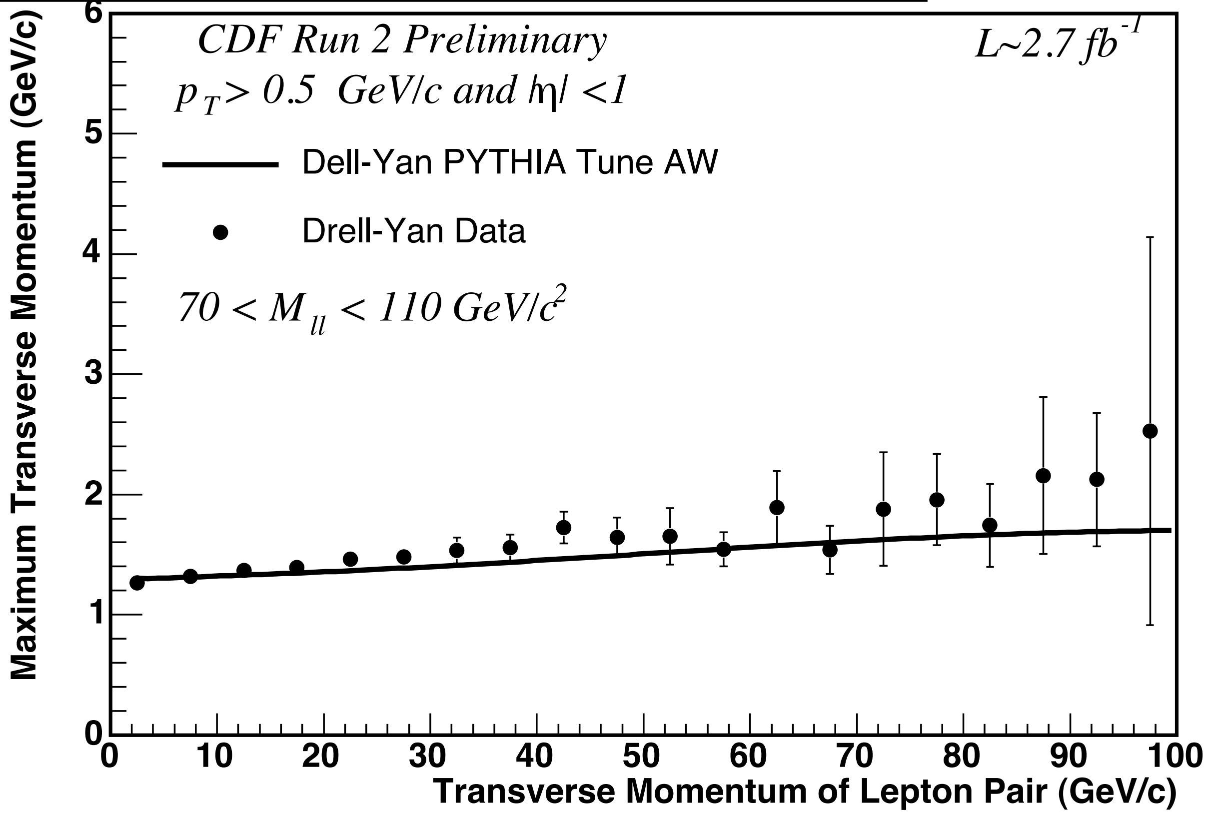


Transverse region very similar and well modelled

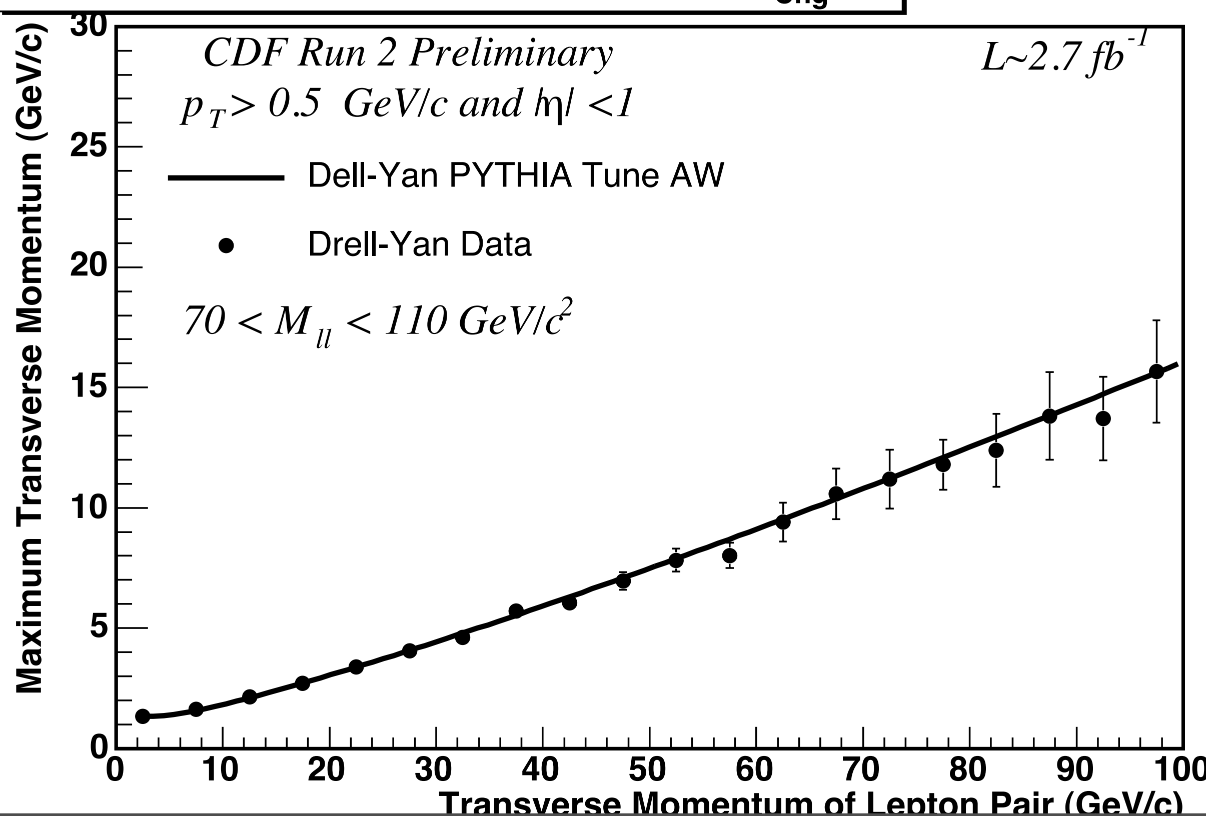


Maximum p_T

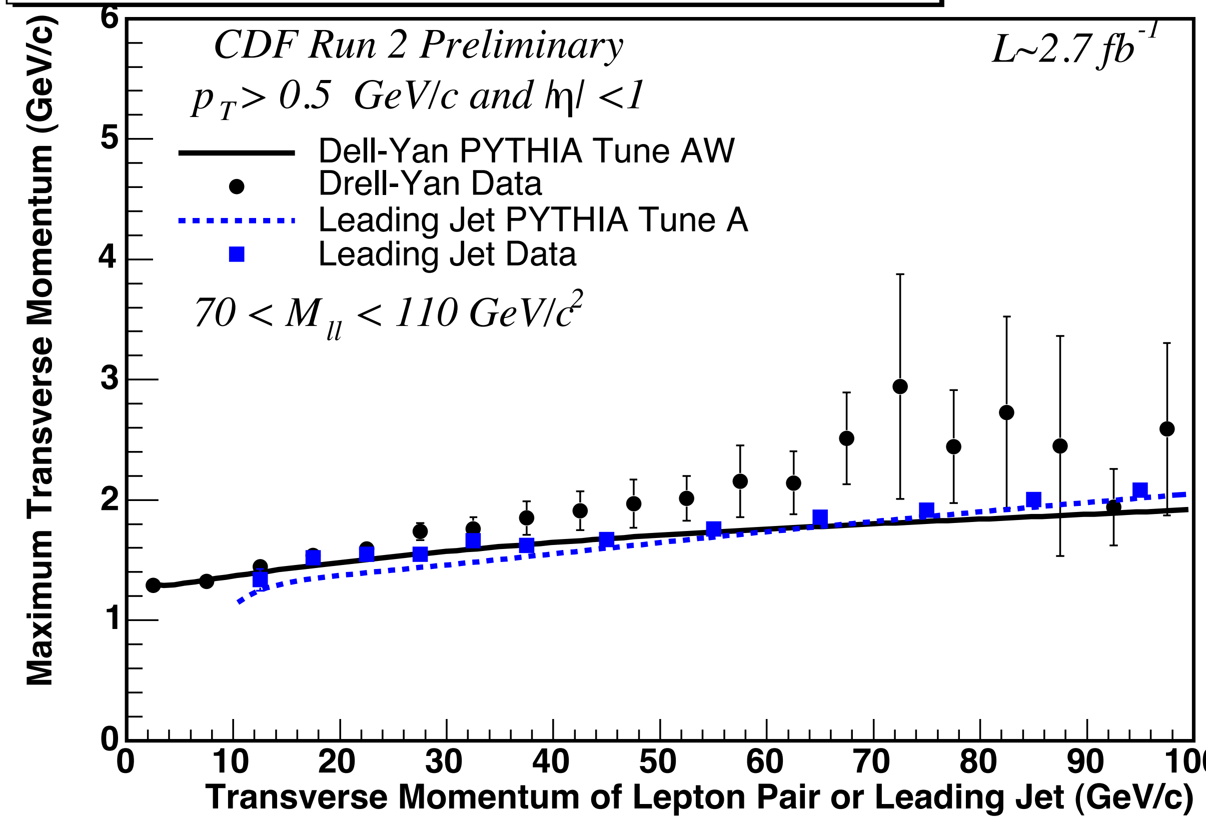
Toward Region Charged p_T Maximum (N_{Chg}>0)



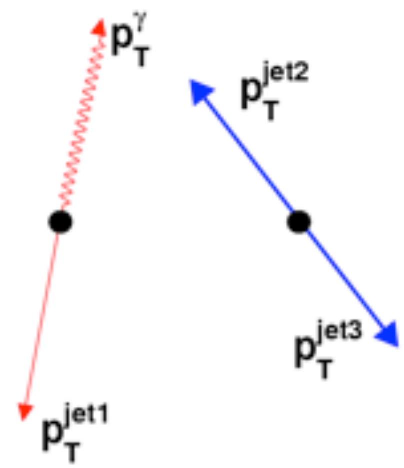
Away Region Charged p_T Maximum (N_{Chg}>0)



Transverse Region Charged p_T Maximum (N_{Chg}>0)



DI Model from Data



- Model for DI interactions is built similarly from independent samples, but requiring 2 vertices in each event.
- For di-jet events, both have to originate from same PV
  - Also construct background to DI by requiring all 3 Jets to come from same vertex (i.e. SP plus 2nd Vertex)
- Main difference: More underlying event from 2 vertices, reduces photon and jet ID efficiencies.

Fitting in Bins of p_T^{jet2}

ΔS Distribution of Data in p_T bin i (D_i) as a function of DP fraction f_i Signal Model M_i and Background B_i

$$D_1 = f_1 M_1 + (1 - f_1) B_1$$
$$D_2 = f_2 M_2 + (1 - f_2) B_2$$

$$\Rightarrow \quad D_1 - \lambda K D_2 = f_1 M_1 - \lambda K C f_1 M_2$$

with: $\lambda = B_1 / B_2 , \quad K = (1 - f_1)/(1 - f_2)$

$$C = f_2 / f_1 = (N_2^{\mathrm{MixDP}} / N_2^{\mathrm{data}}) / (N_1^{\mathrm{MixDP}} / N_1^{\mathrm{data}})$$

Fitting in Bins of p_T^{jet2}

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$$\Rightarrow \quad D_1 - \lambda K D_2 = f_1 M_1 - \lambda K C f_1 M_2$$

From Pythia w/o MPI
0.95 - 1.3 for diff ΔS bins

with: $\lambda = B_1/B_2\,, \quad K = (1 - f_1)/(1 - f_2)$

$$C = f_2/f_1 = (N_2^{\mathrm{MixDP}}/N_2^{\mathrm{data}})/(N_1^{\mathrm{MixDP}}/N_1^{\mathrm{data}})$$

From MixDP samples without knowing DP fraction

Fitting in Bins of p_T^{jet2}

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with: $\lambda = B_1/B_2 , \quad K = (1 - f_1)/(1 - f_2)$

$$C = f_2/f_1 = (N_2^{\mathrm{MixDP}}/N_2^{\mathrm{data}})/(N_1^{\mathrm{MixDP}}/N_1^{\mathrm{data}})$$

One parameter (f_1) left to extract from fit to pairs of ΔS distributions