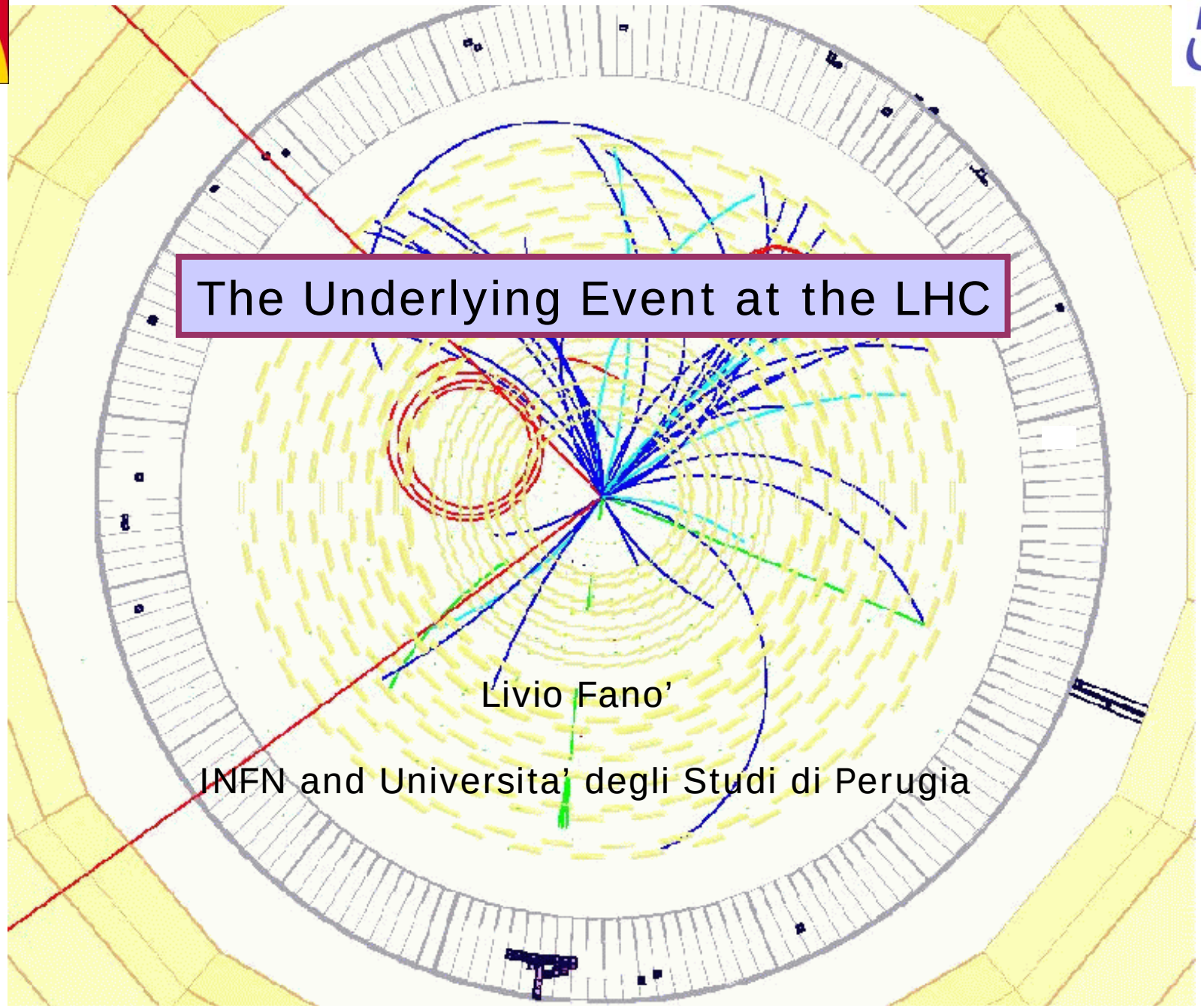
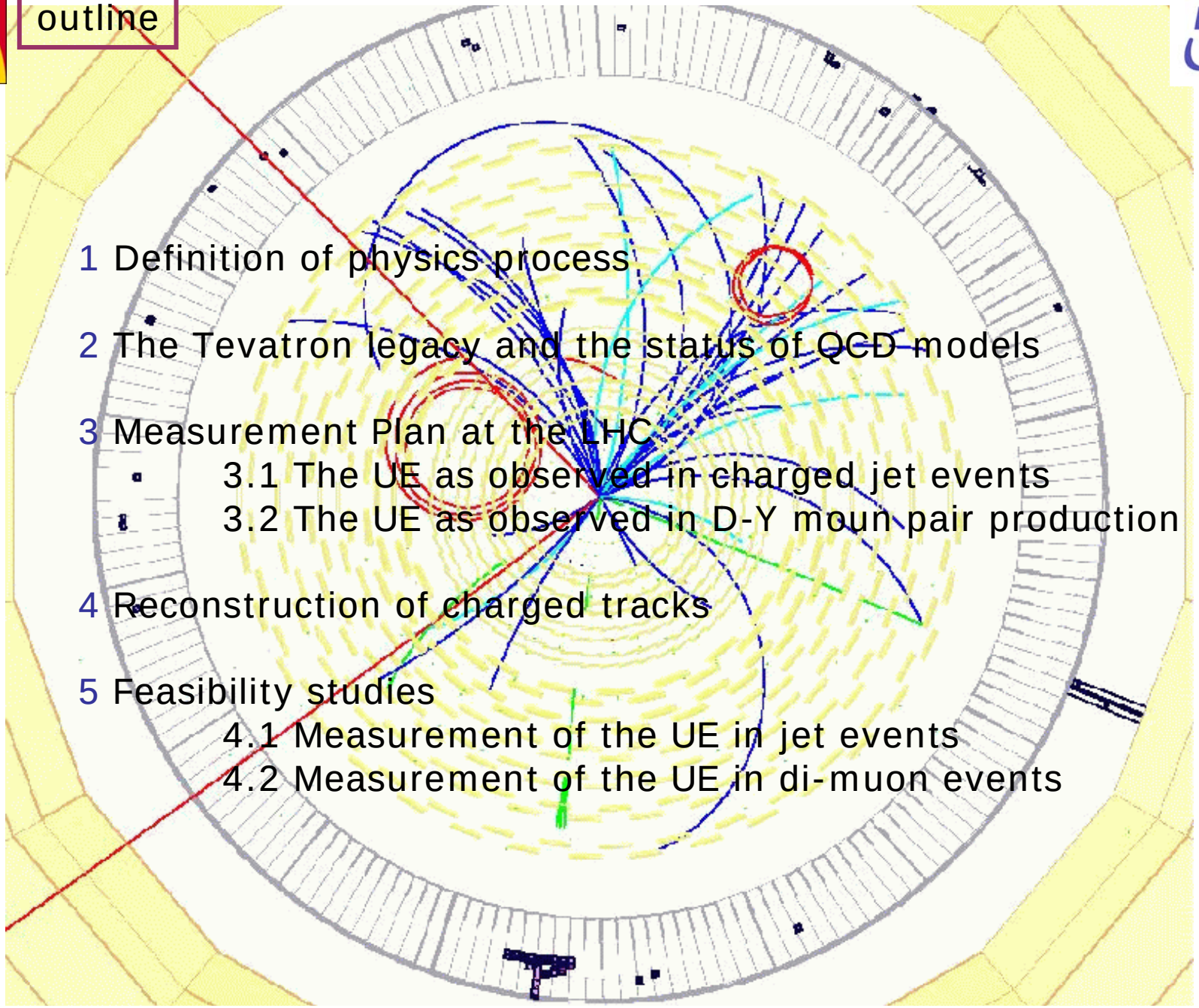


The Underlying Event at the LHC

Livio Fano'

INFN and Universita' degli Studi di Perugia

outline



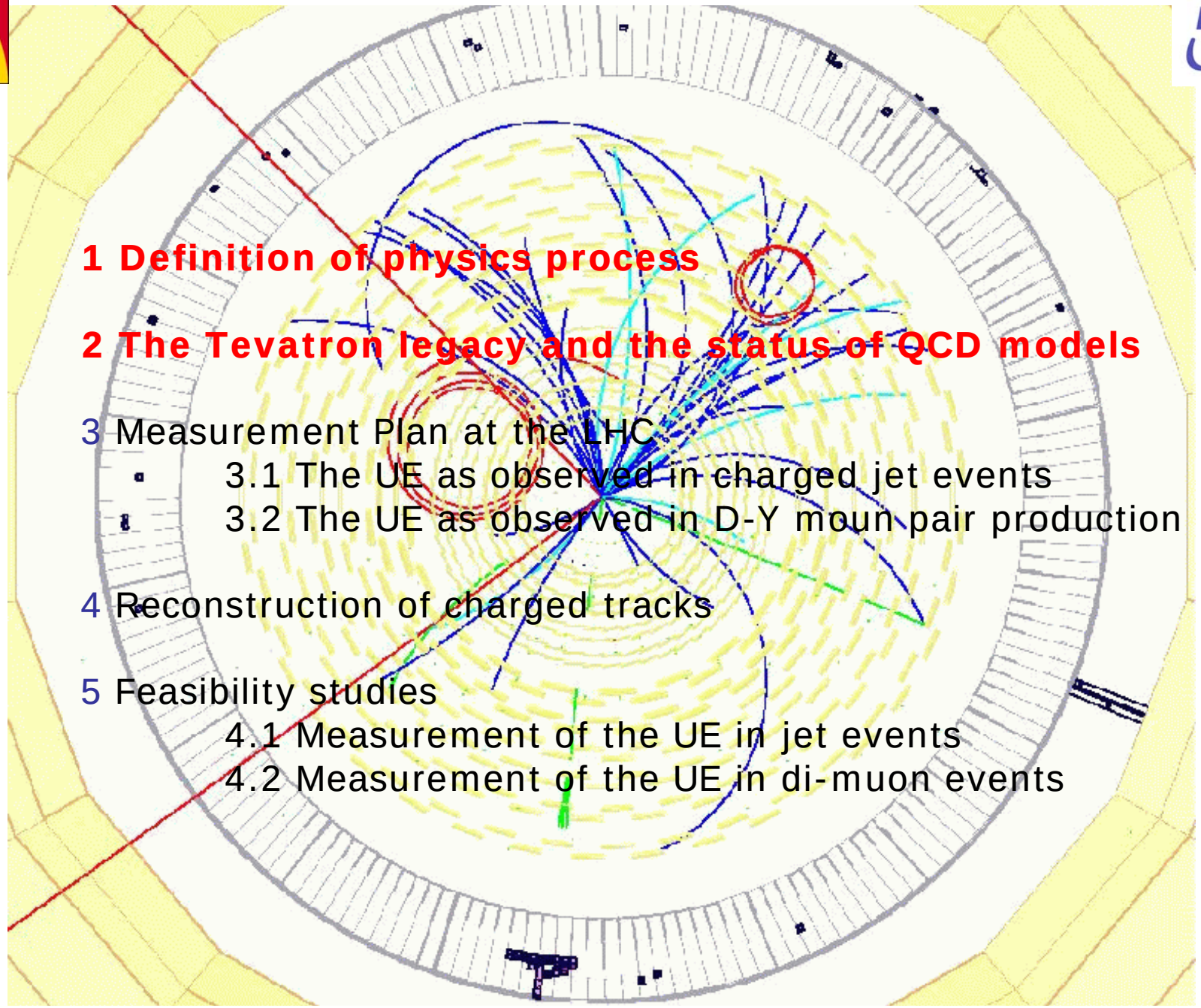
1 Definition of physics process

2 The Tevatron legacy and the status of QCD models

3 Measurement Plan at the LHC
- 3.1 The UE as observed in charged jet events
- 3.2 The UE as observed in D-Y moun pair production

4 Reconstruction of charged tracks

5 Feasibility studies
- 4.1 Measurement of the UE in jet events
- 4.2 Measurement of the UE in di-muon events



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Definition & Models

Minimum Bias (MB)

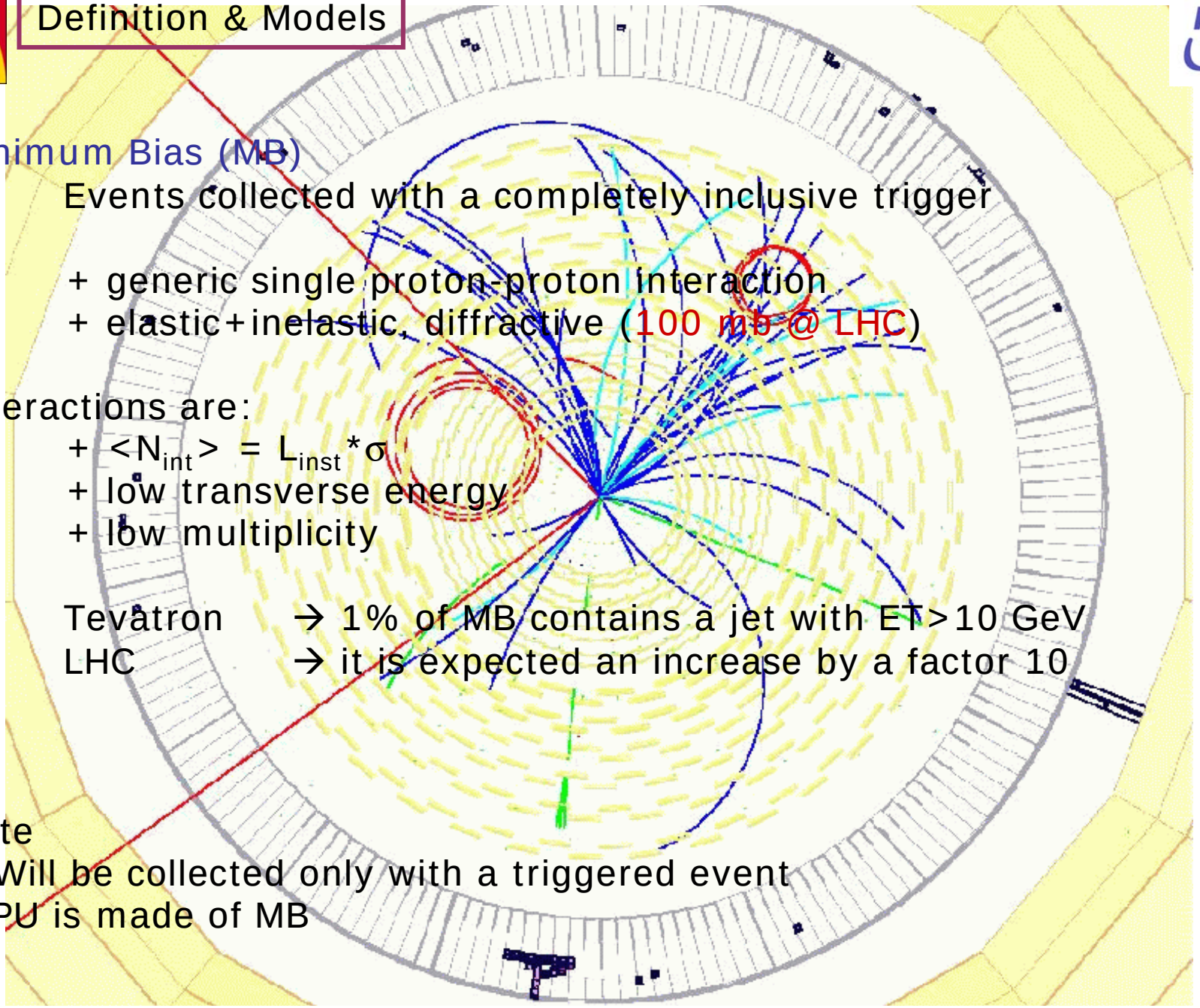
Events collected with a completely inclusive trigger

+ generic single proton-proton interaction
+ elastic+inelastic, diffractive (100 mb @ LHC)

Interactions are:

+ $\langle N_{int} \rangle = L_{inst} * \sigma$
+ low transverse energy
+ low multiplicity

Tevatron → 1% of MB contains a jet with ET>10 GeV
LHC → it is expected an increase by a factor 10



Note

+ Will be collected only with a triggered event
+ PU is made of MB

Definition & Models

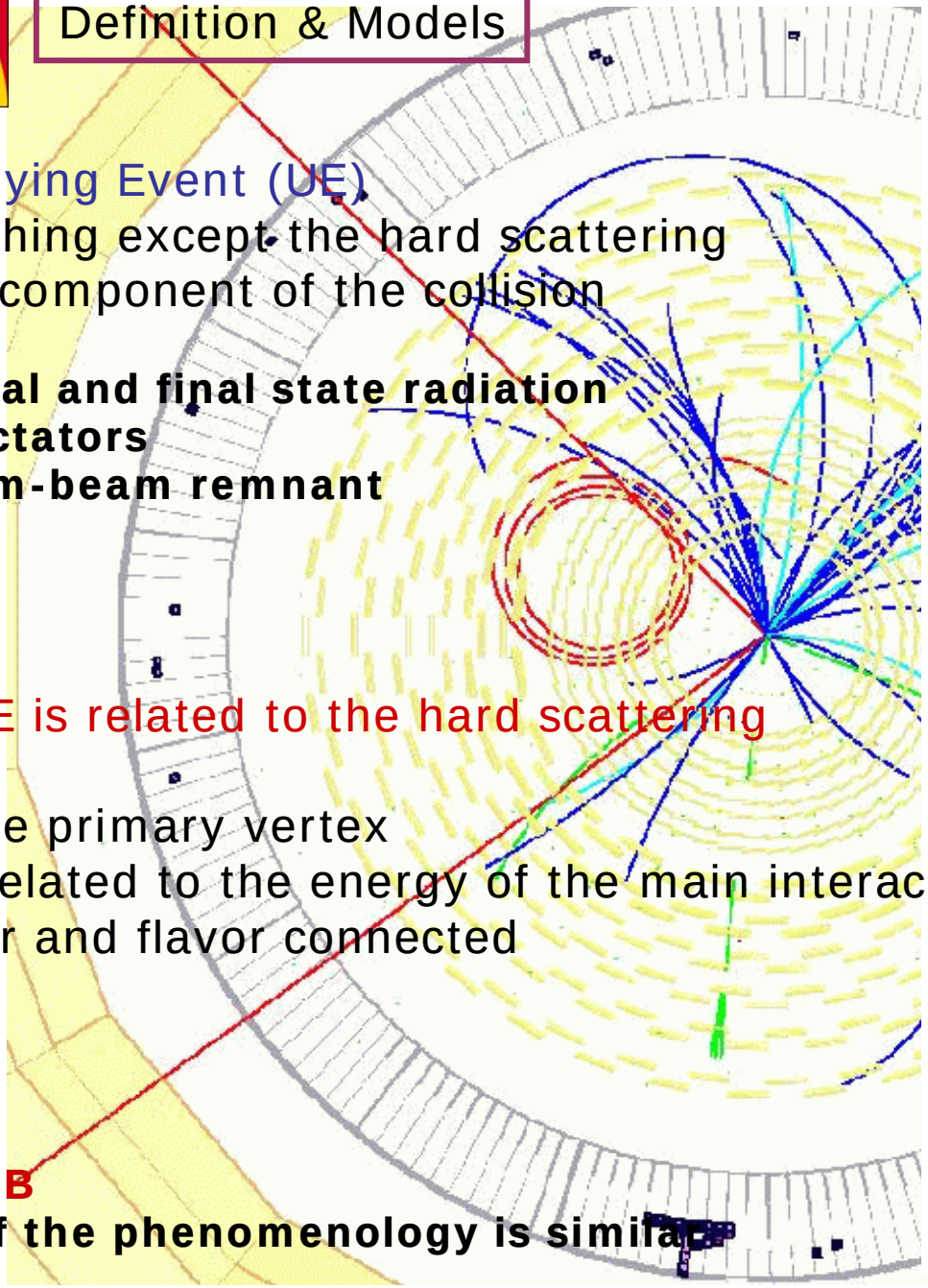
Underlying Event (UE)

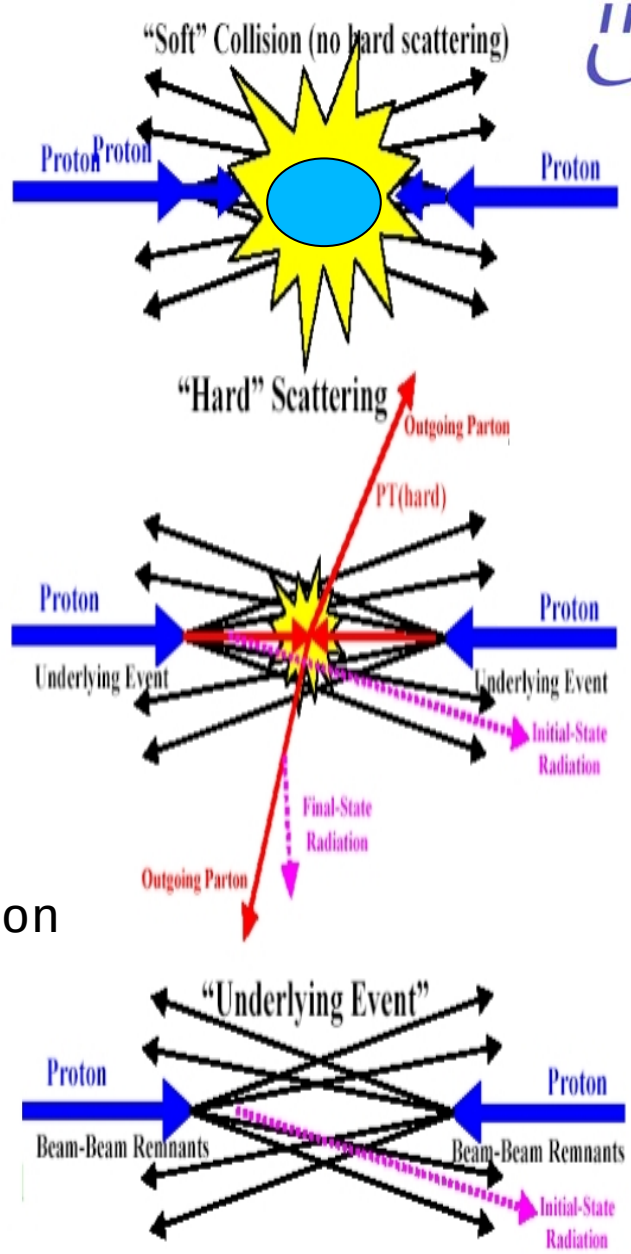
Everything except the hard scattering component of the collision

+ Initial and final state radiation
+ Spectators
+ beam-beam remnant
+ …?

The UE is related to the hard scattering

+ same primary vertex
+ correlated to the energy of the main interaction
+ color and flavor connected



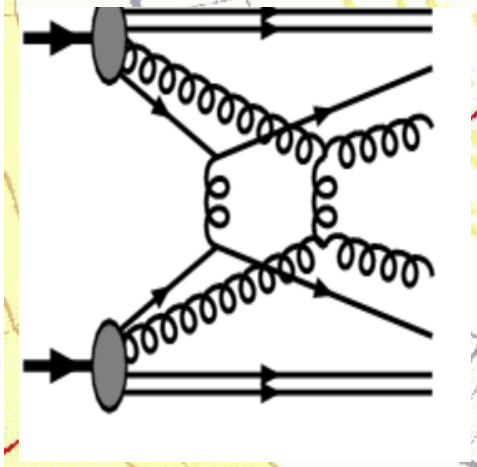


UE! = MB
Even if the phenomenology is similar

Definition & Models

Motivations:
+ New physics discovery needs a deep QCD understanding:
hard scattering component
***plus* the Underlying Event, the softer component of the collision**
+ Understanding of the detector

Different models and several implementations
Pythia use the **Multiple Parton Interactions Model (MPI)**
more than 1 parton-parton interaction in a single proton-proton collision

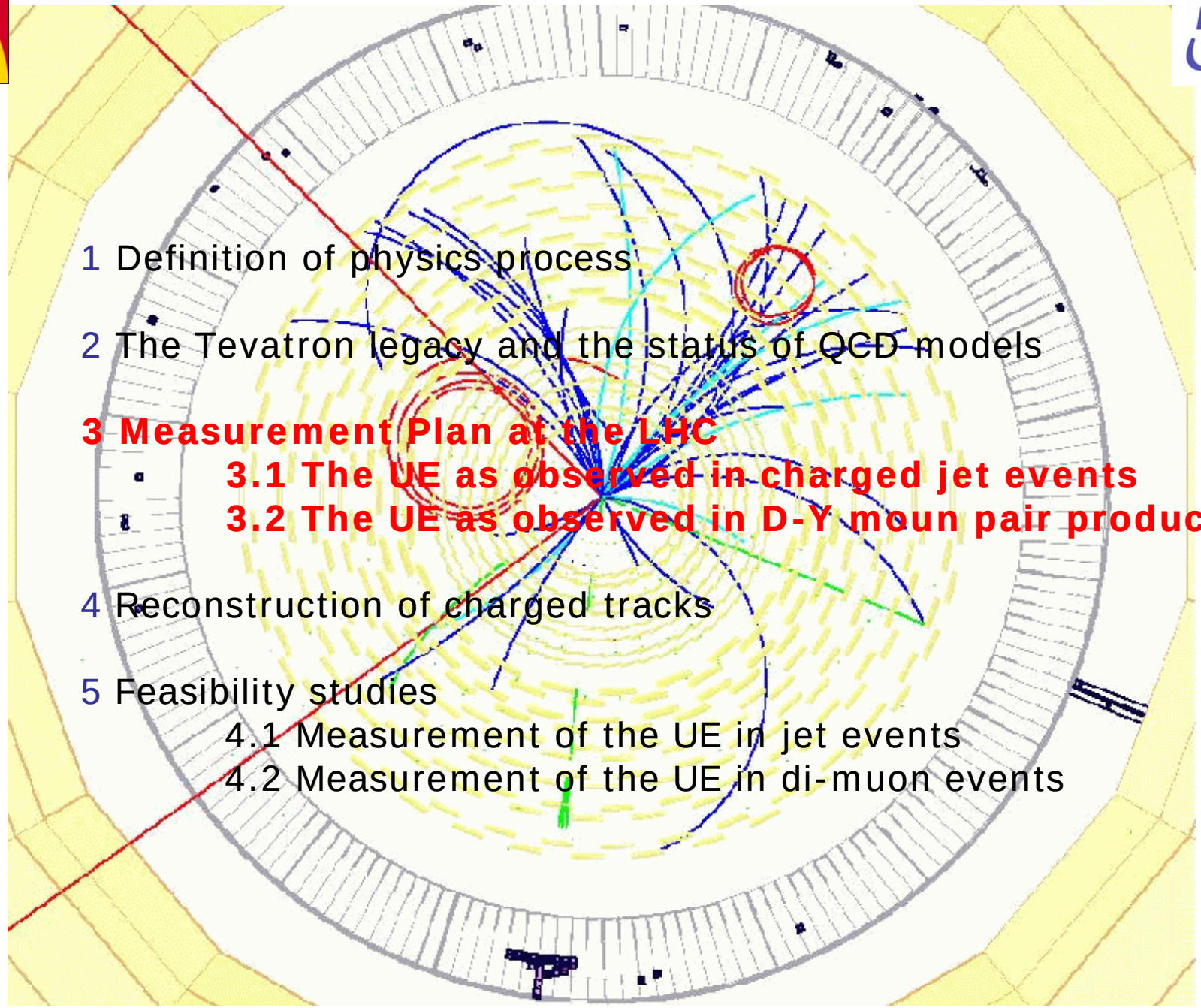


PT cut-off
+ x-sec regularization for PT->0
+ inverse of the color-screening distance

Poisson statistics
+ multiplicity ($<\#int> = \sigma_{par\_par} / \sigma_{p\text{-}p}$)

IP
+ variable impact parameter
+ gaussian matter density distribution

Correlations
+color, flavor, momentum



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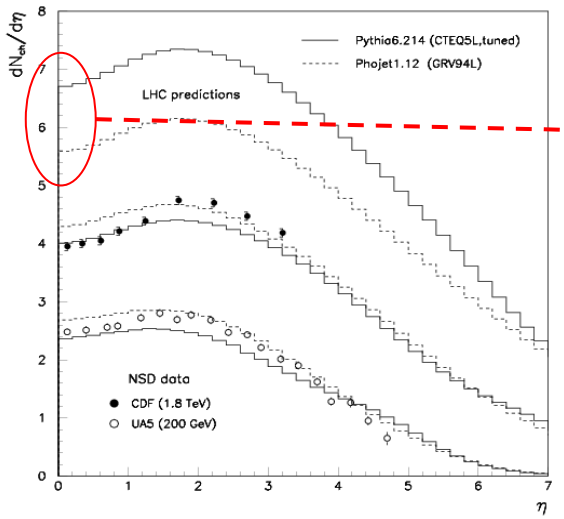
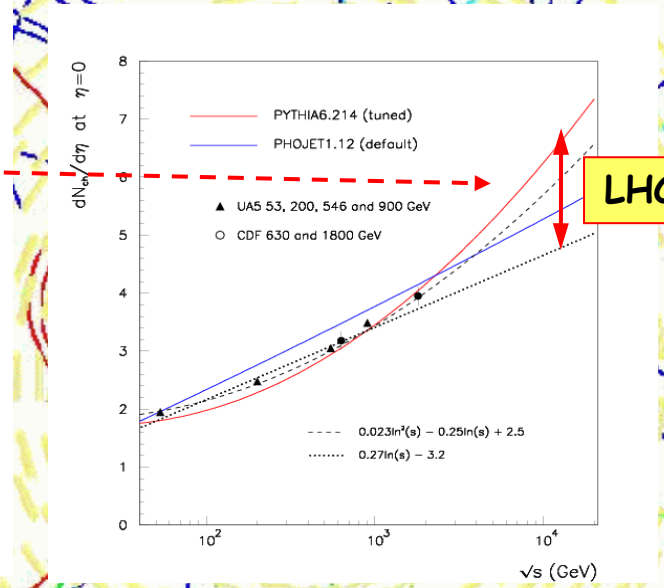
The measurement plan - MB

ATLAS ***Moraes, Buttar, Dawson***
hep-ph/0403100
ATL-PHYS-PUB-2005-007

Main observables, obvious first measurements with min-bias data:

$dN_{ch}/d\eta$; dN_{ch}/dp_T





LHC?

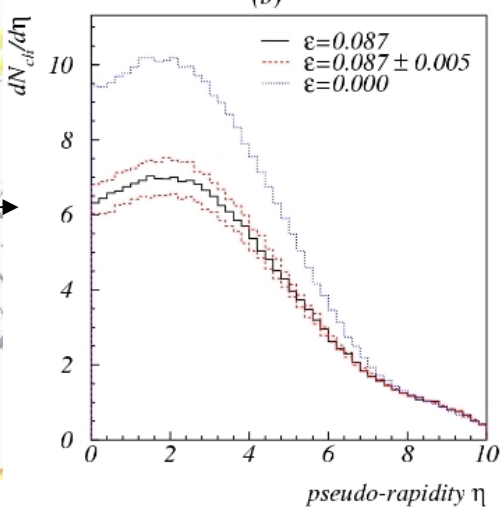
PHOJET (DPM) -> ln(s)
PYTHIA (MPI) -> $\ln^2(s)$

Pythia Tuning from LHCb

CERN 2000-004

(cut-off tuning for different PDF with UA5 and CDF data)

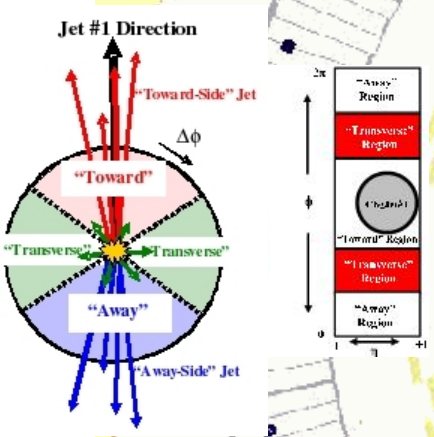
$$P_{T\min} = P_{T\min}^{LHC}\left(\frac{\sqrt{s}}{14\ TeV}\right)^{2\varepsilon}$$



The measurement plan - UE

From charged jet

Topological structure of p-p collision from charged tracks
Charged jet definition -> ICA algorithm with massless charged tracks as input



The leading Ch_jet1 defines a direction in the ϕ plane

The transverse region is sensitive to the UE

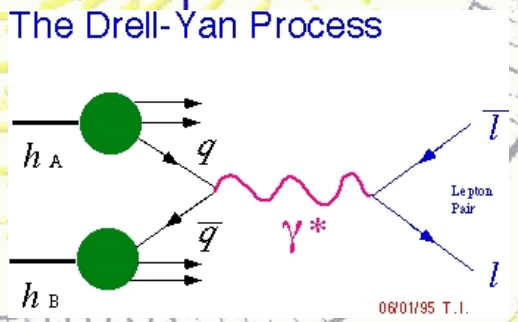
Main observables:

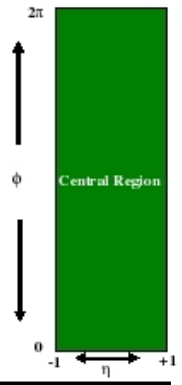
+ $dN/d\eta d\phi$, charged density

+ $d(PT_{sum})/d\eta d\phi$, energy density

From D-Y muon pairs production

observables are the same but
defined in all the ϕ plane





(after removing the μ pairs everything else is UE)

Idea from R. Field

Organization of the work

New collaboration is born in CMS for UE and MB studies

Florida (D. Acosta, P. Bartalini, R. Field, K. Kotov)
- generator-level studies
- reconstruction studies -> DY

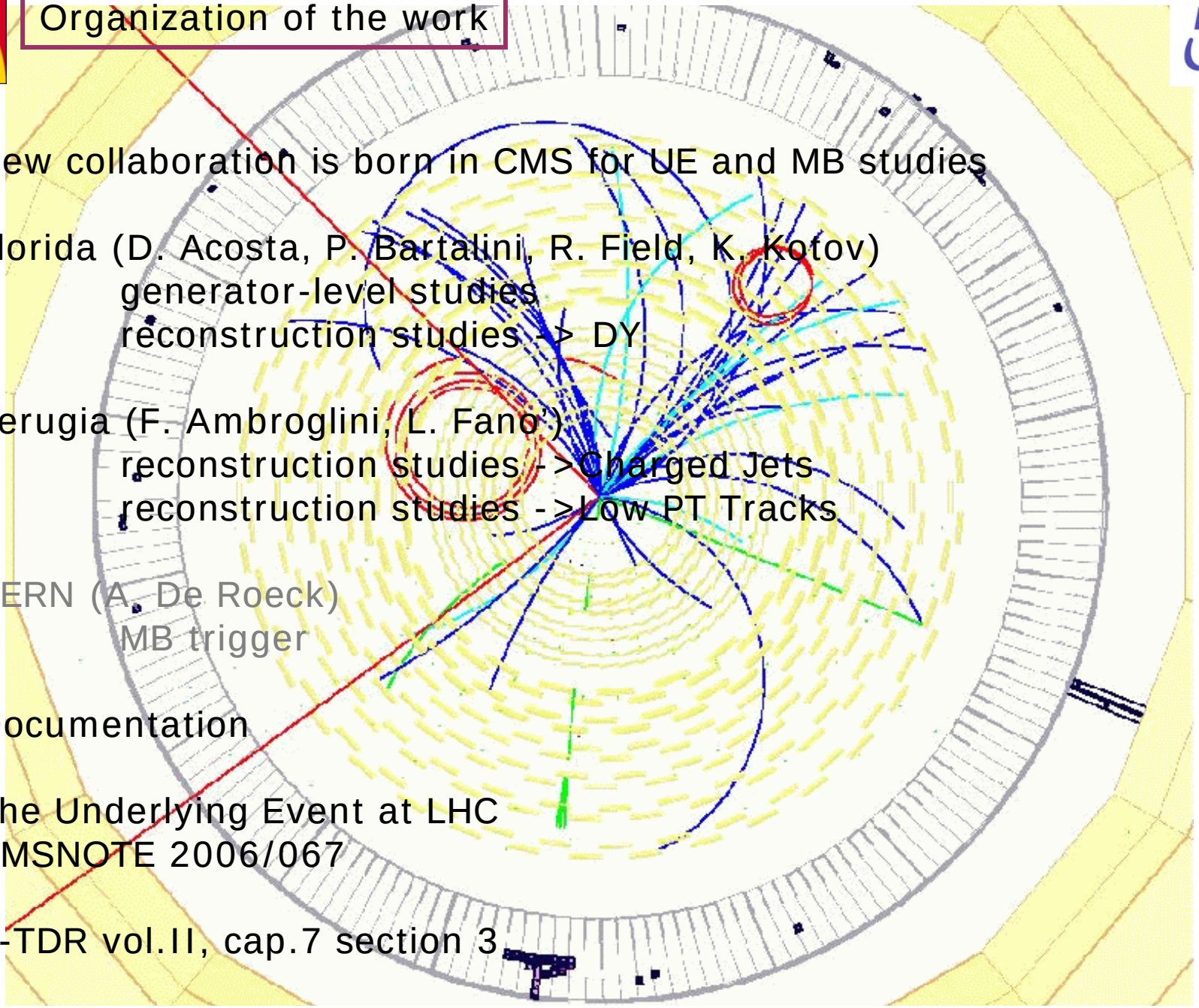
Perugia (F. Ambroglini, L. Fano')
- reconstruction studies -> Charged Jets
- reconstruction studies -> Low PT Tracks

CERN (A. De Roeck)
- MB trigger

Documentation

The Underlying Event at LHC
CMSNOTE 2006/067

P-TDR vol.II, cap.7 section 3



Generator level studies – generators and tuning

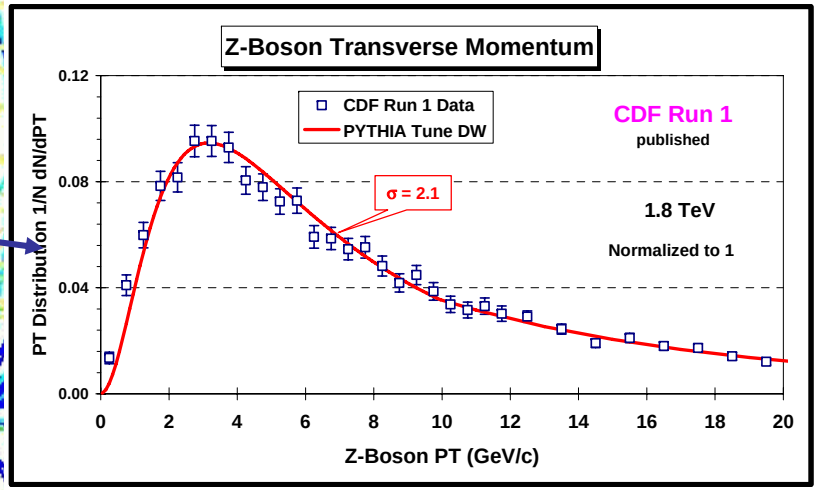
Generators setup used
(further details in backup slides)

+ Pythia Tune DW
  TuneA (UE@CDF) + Z boson PT

+ Pythia Tune Atlas (with MPI)
  adopted by CMS

+ Pythia Tune DWT
  (with PARP(90) of Atlas)

+ HERWIG
  (without MPI)



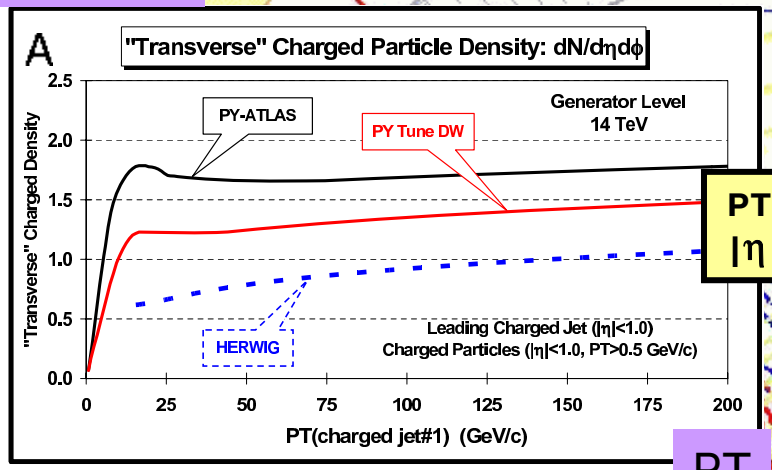
Shows the Run 1 Z-boson p_T distribution ($<p_T(Z)>$ ≈ 11.5 GeV/c) compared with PYTHIA Tune DW ($<p_T(Z)>$ = 11.7 GeV/c).

PY Tune DW and PY Tune A (run 1 tune) predict the same "underlying event" at 1.96 TeV, but Tune DW fits the $P_T(Z)$ distribution.

PY Tune DW and Tune DWT are identical at 1.96 TeV, but Tune DWT uses the ATLAS energy dependence, PARP(90) = 0.16, instead of the Tune A value of 0.25.

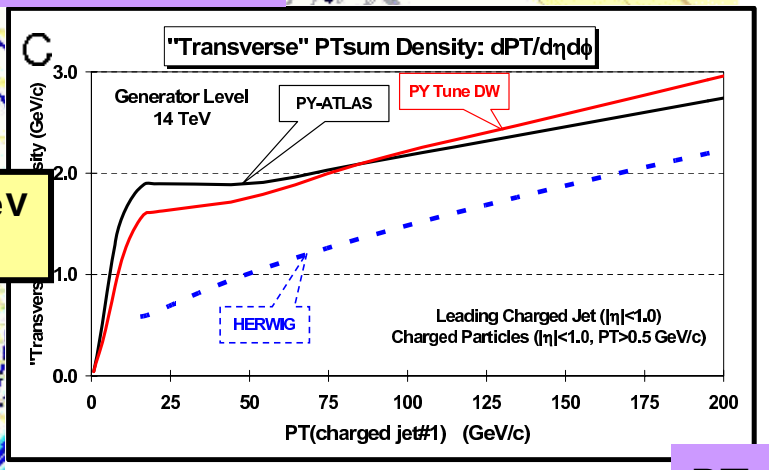
Generator level studies – charged jet - observables

dN / dηdϕ

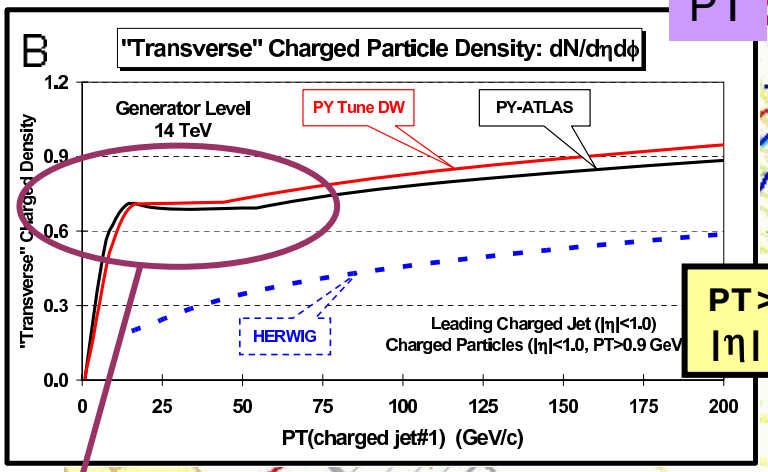


PT > 0.5 GeV
|η| < 1

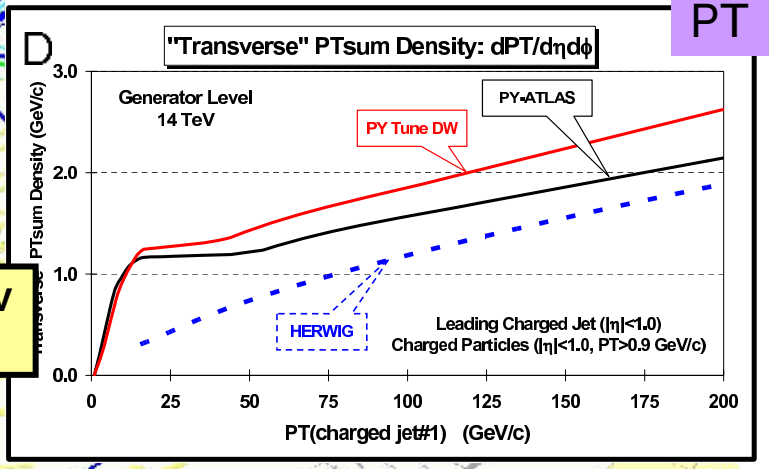
dPT$_{sum}$ / dηdϕ



PT



PT > 0.9 GeV
|η| < 1

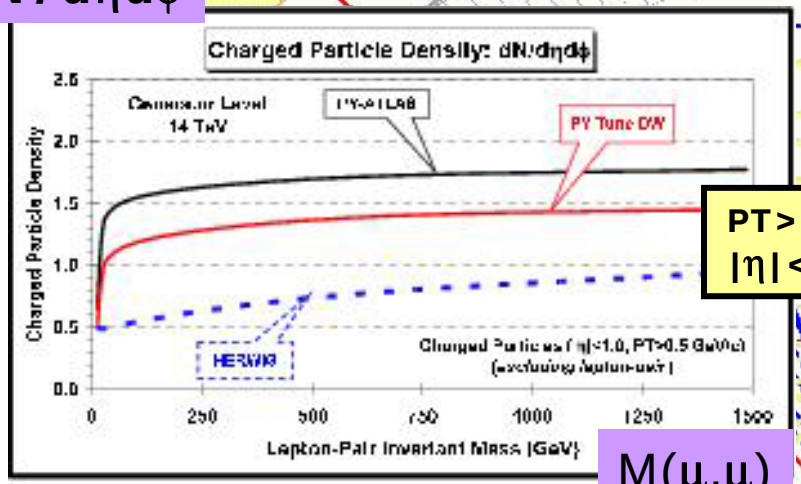


PT

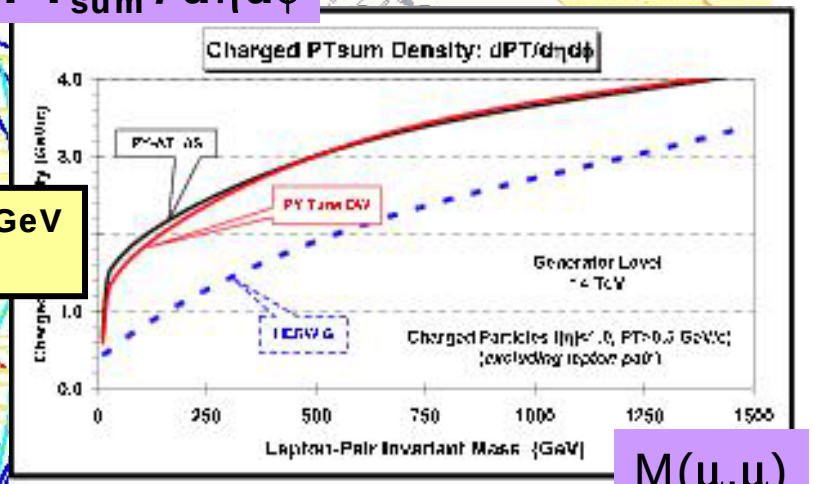
Rise for PT>50 due to radiation (ISR+FSR)

Generator level studies – DY – observables

$dN/d\eta d\phi$

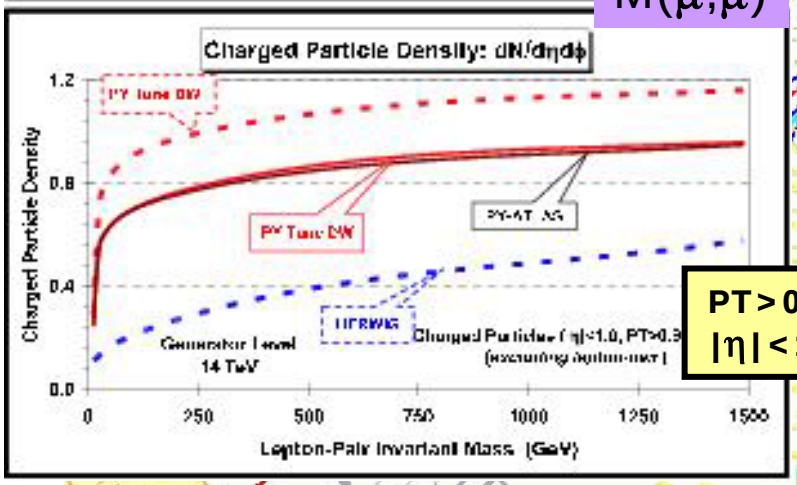


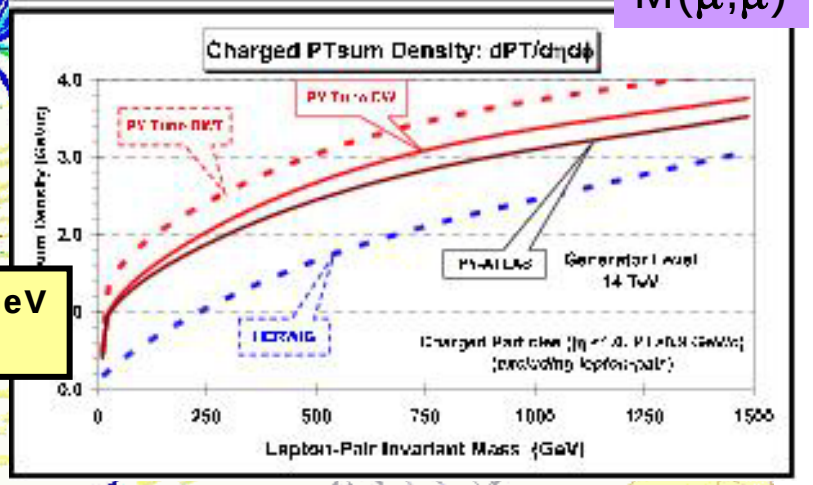
$dPT_{sum}/d\eta d\phi$



PT > 0.5 GeV
|η| < 1

M(μ,μ)



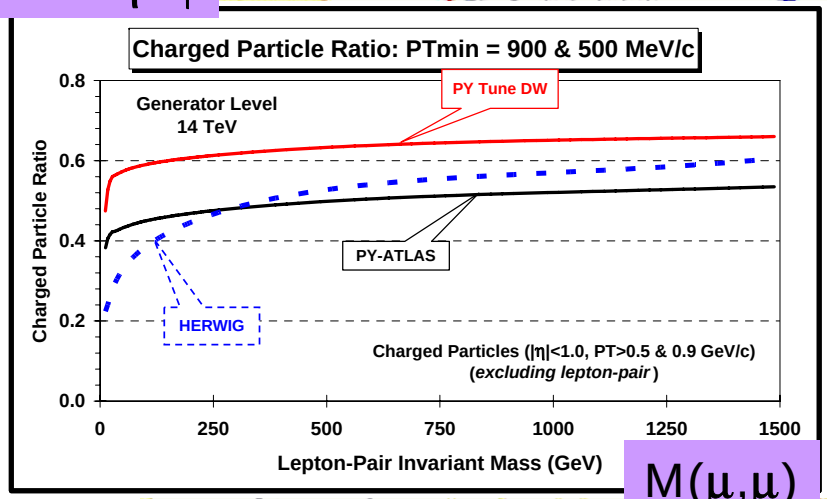


PT > 0.9 GeV
|η| < 1

M(μ,μ)

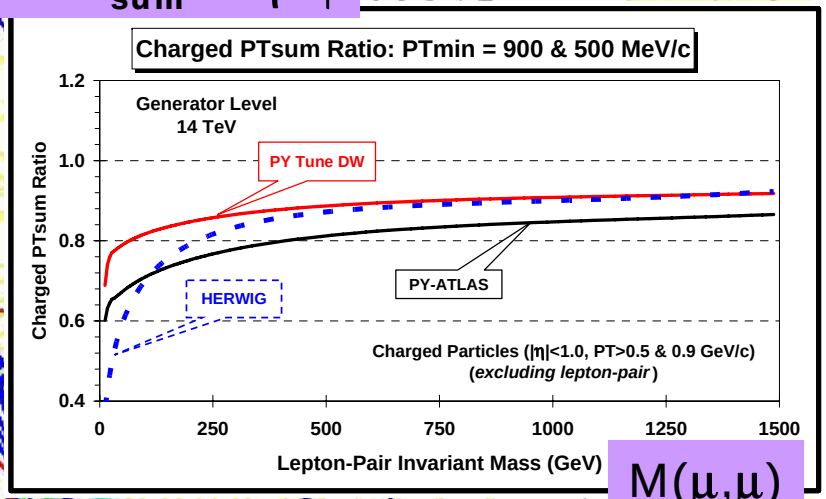
Generator level studies – DY – track PT sensitivity

$dN/d\eta d\phi$



$M(\mu,\mu)$

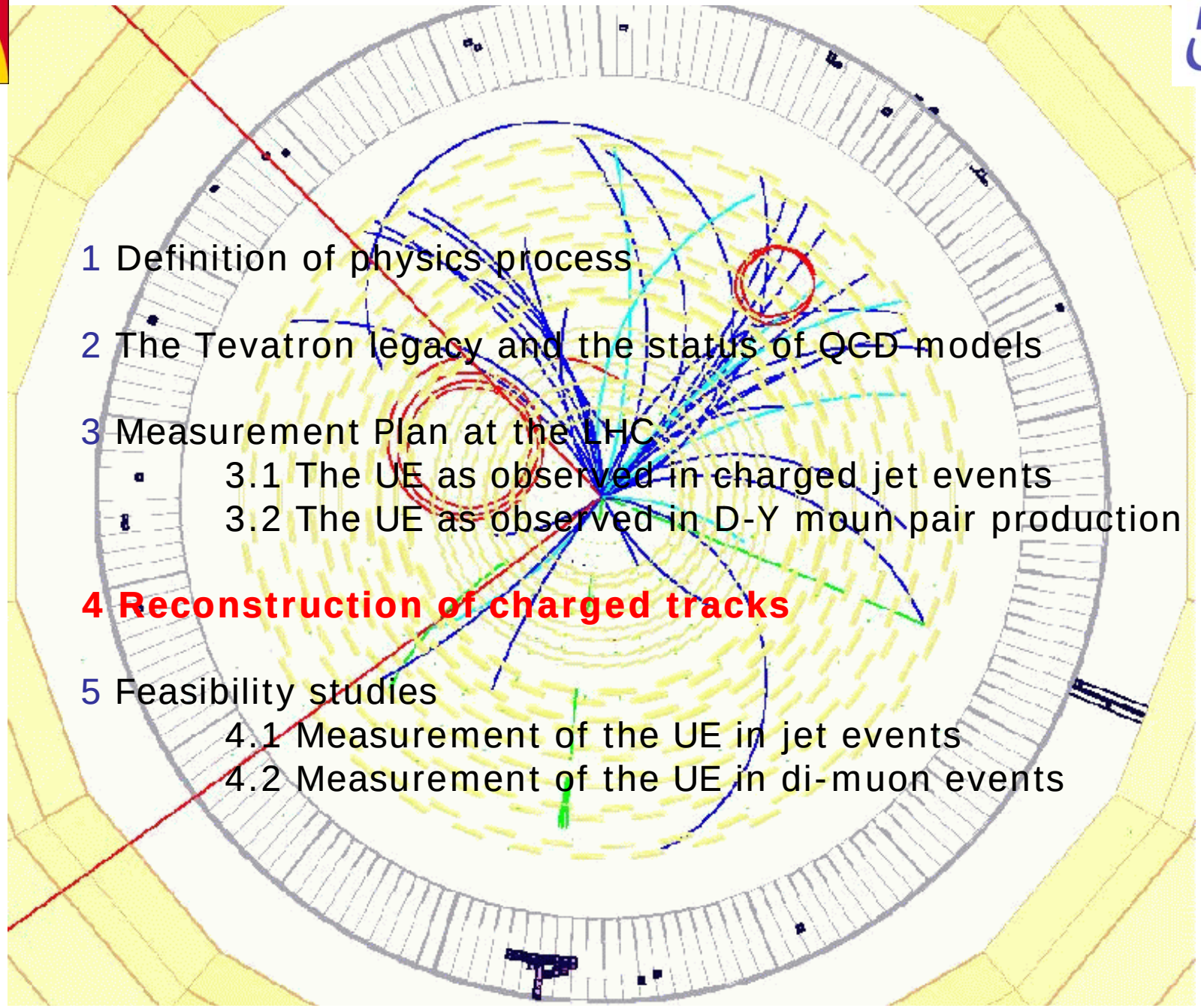
$dPT_{sum}/d\eta d\phi$



$M(\mu,\mu)$

ratio 0.9/0.5 PT tracks threshold

PY-Atlas Tune (-> optimized also for MB)
has a softer PT distribution than PY-DW **(done at CDF)** (-> optimized for UE)



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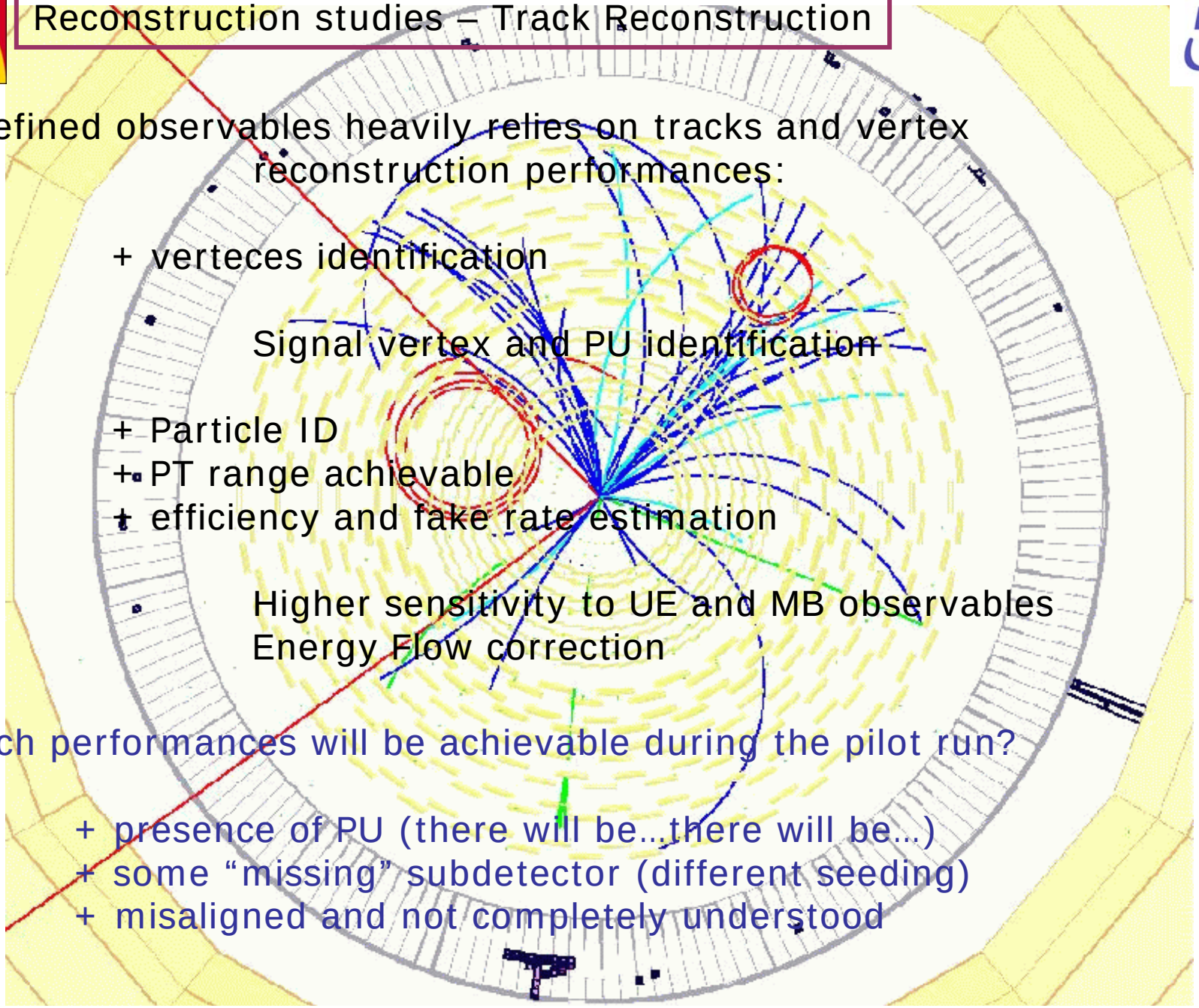
Reconstruction studies – Track Reconstruction



Defined observables heavily relies on tracks and vertex reconstruction performances:

+ verteces identification

Signal vertex and PU identification

+ Particle ID
+ PT range achievable
+ efficiency and fake rate estimation

Higher sensitivity to UE and MB observables
Energy Flow correction

Which performances will be achievable during the pilot run?

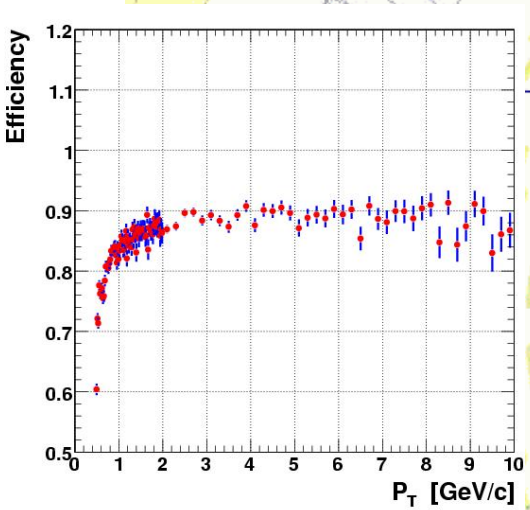
+ presence of PU (there will be…there will be…)
+ some “missing” subdetector (different seeding)
+ misaligned and not completely understood

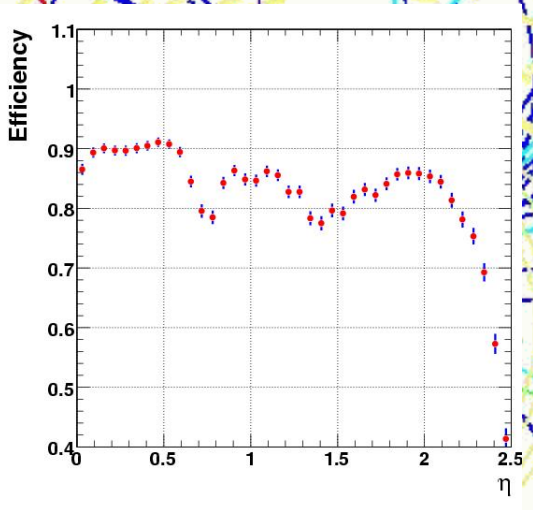
Reconstruction studies – Track Reconstruction

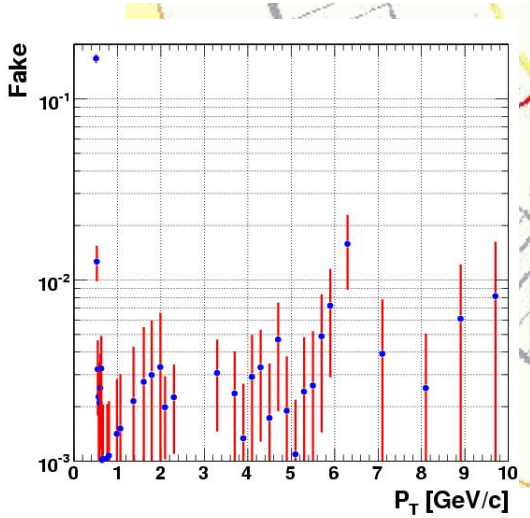
Studies are ongoing for **ATLAS** (see Marina Cobal yesterday talk)

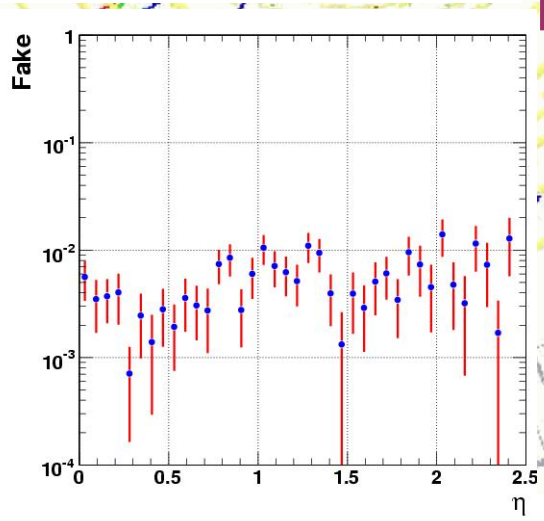
and **CMS:**

QCD sample
(70-90 GeV)









Signal Vertex identification efficiency > 90% in 500 um

Efficiency > 70% for PT>500 MeV
Efficiency ~ 90% for PT>2 GeV

Fakes are below 1%

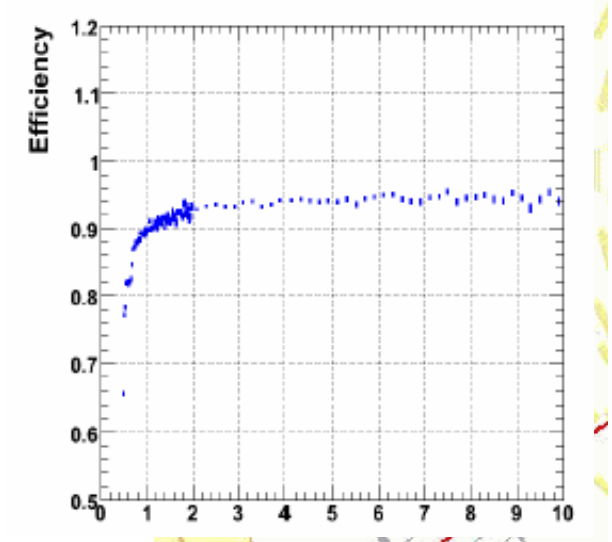
Reconstruction studies – Track Reconstruction

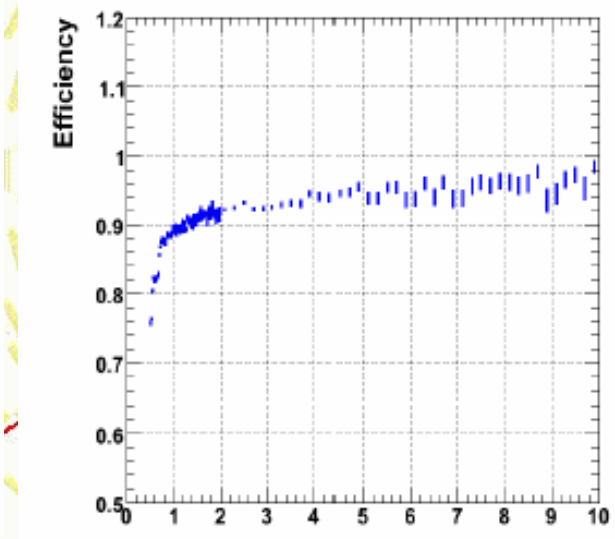
Other ongoing (PRELIMINARY) studies:

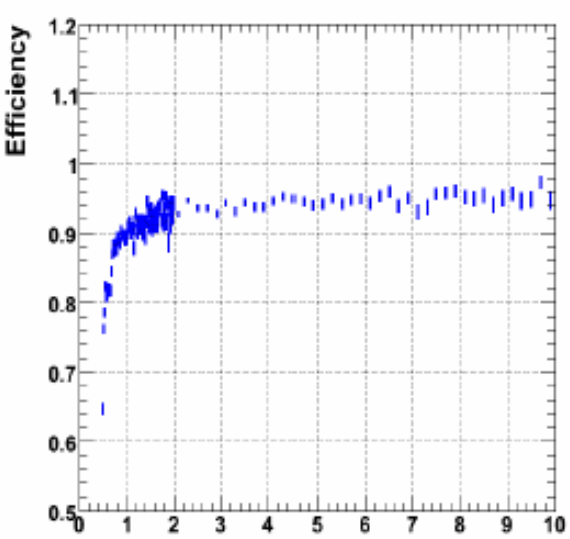
+ performances optimization

+ different event

+ tracks from pile up







QCD (230_300) with Low Luminosity PU

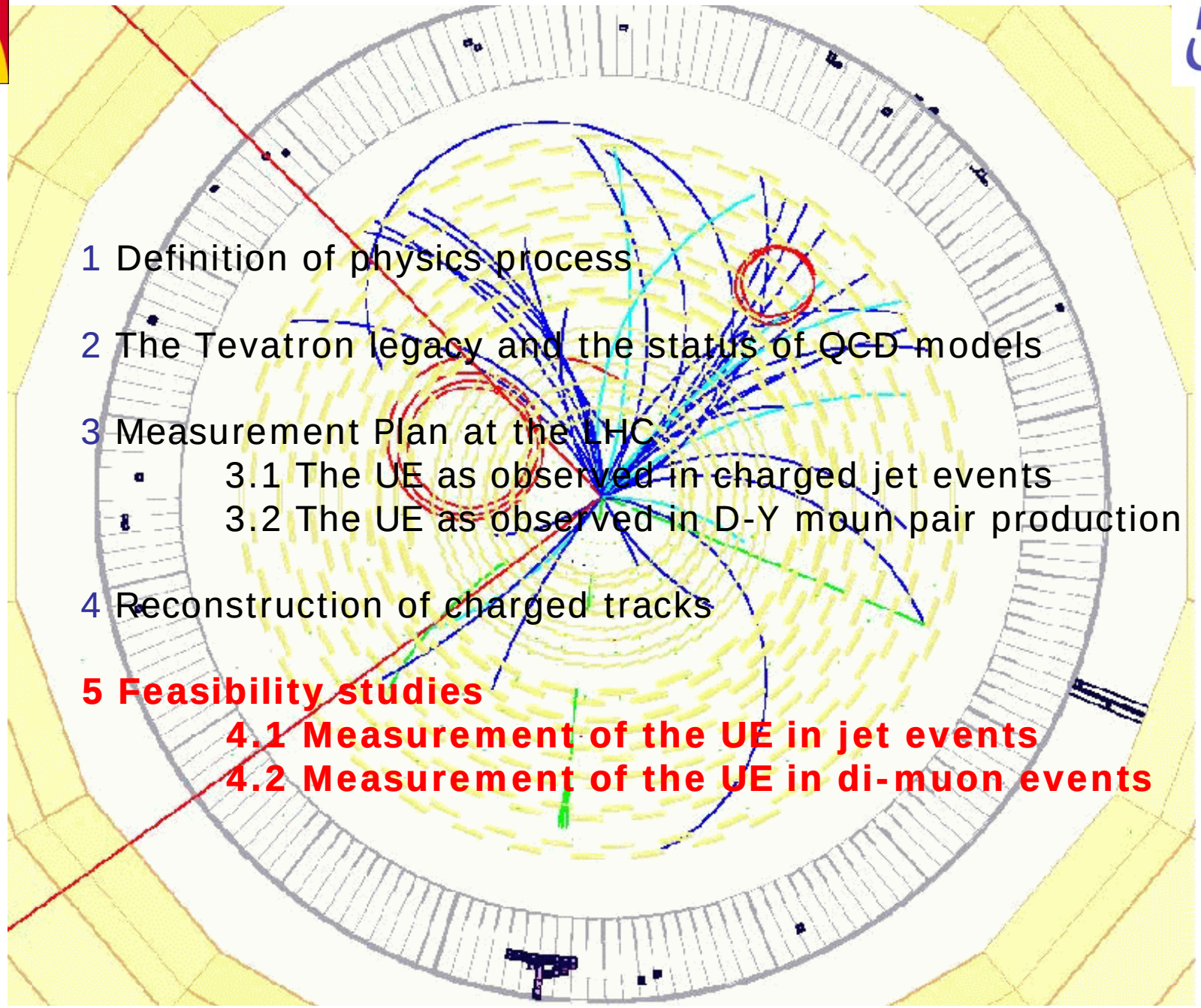
Global eff=88%
Fake = 0.8 %

DY with Low Luminosity PU

Global eff=85%
Fake = 0.5%

Tracks from first PU vertex

Global eff=89%
Fake = 0.8 %



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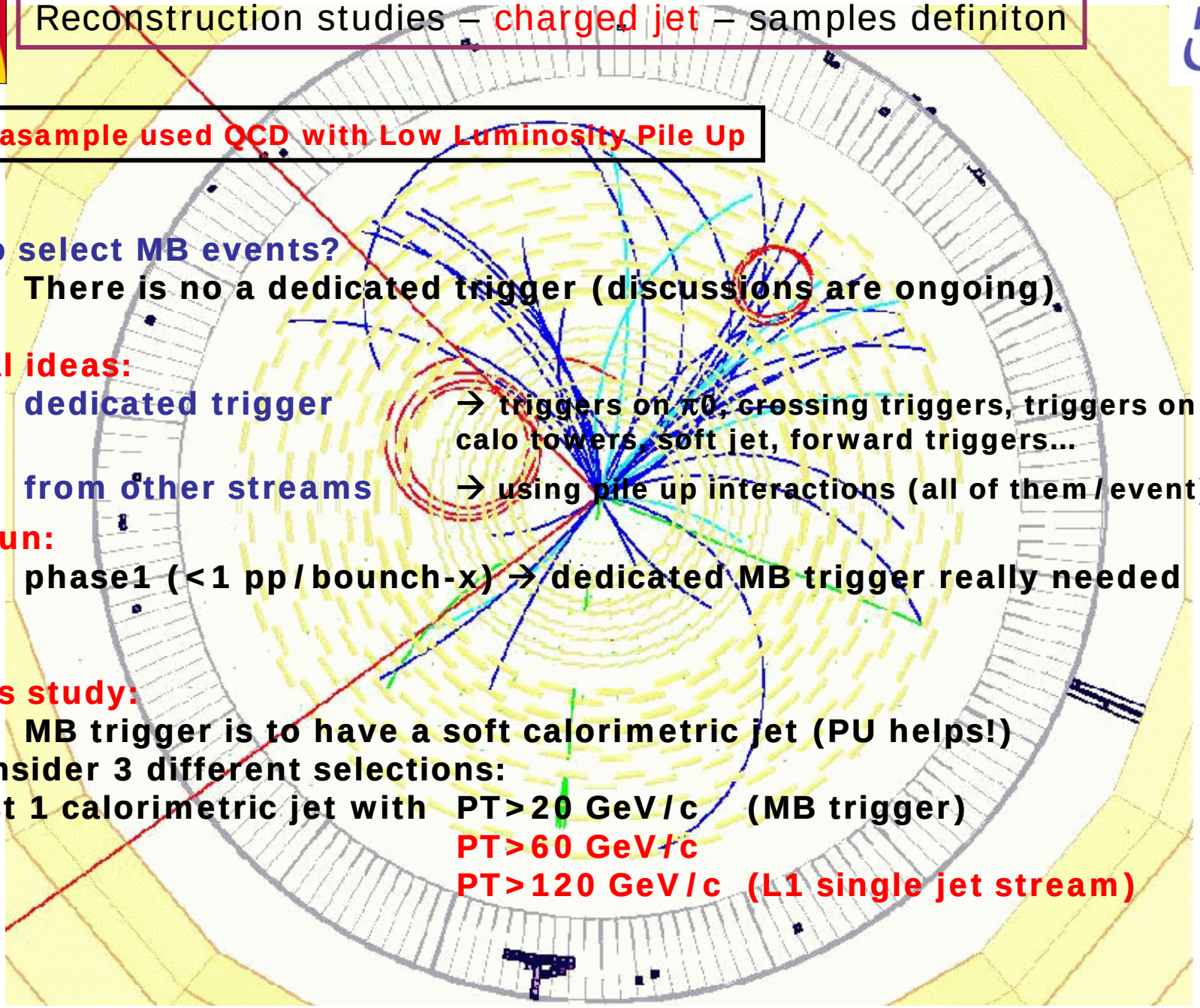
Reconstruction studies – charged jet – samples definiton

Datasample used QCD with Low Luminosity Pile Up



How to select MB events?

There is no a dedicated trigger (discussions are ongoing)

Several ideas:

dedicated trigger → triggers on π^0, crossing triggers, triggers on calo towers, soft jet, forward triggers...

from other streams → using pile up interactions (all of them / event)

Pilot Run:

phase1 (<1 pp / bounch-x) → dedicated MB trigger really needed

For this study:

MB trigger is to have a soft calorimetric jet (PU helps!)

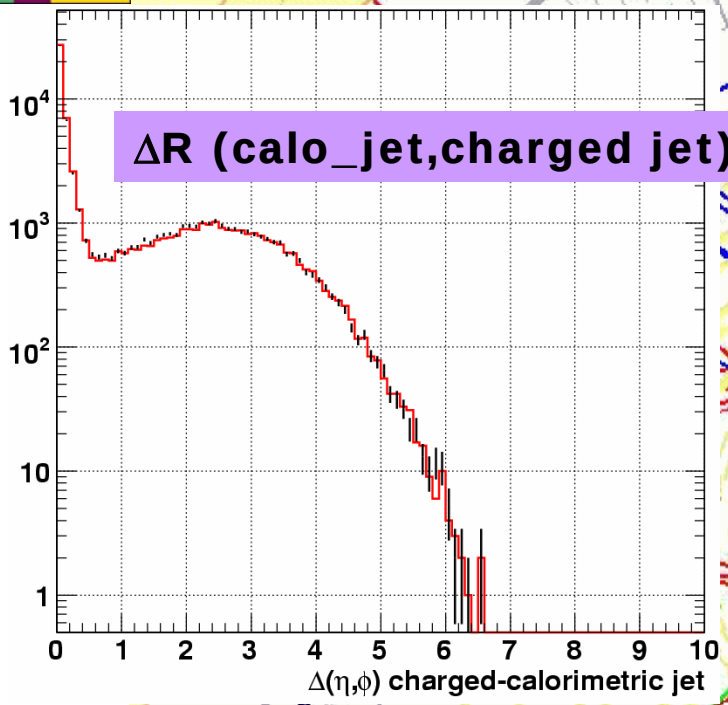
We consider 3 different selections:

At least 1 calorimetric jet with PT>20 GeV/c (MB trigger)

PT>60 GeV/c

PT>120 GeV/c (L1 single jet stream)

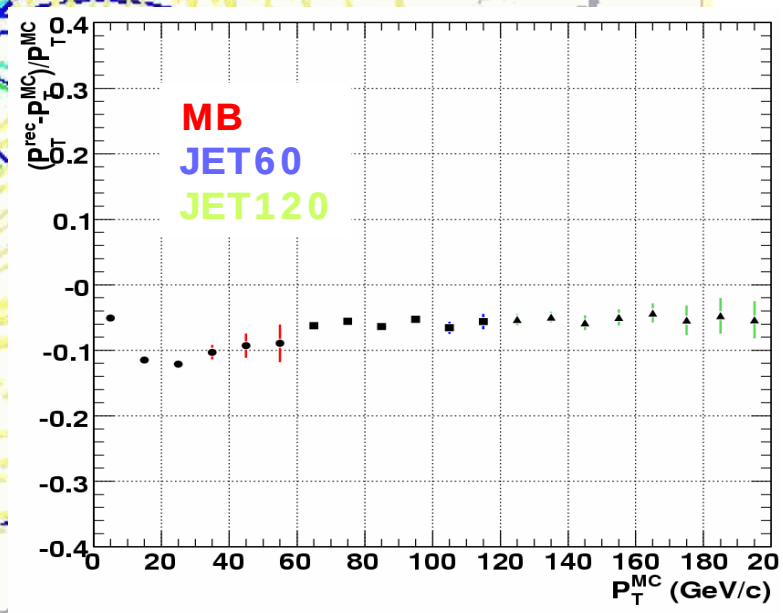
Reconstruction studies – charged jet - definitions



X-check with calo jet:

+ HLT jet reconstruction (0.5)
+ Charged jet is reconstructed with ICA (0.7) on massless particle
+ ΔR is between the leading charged jet and the nearest calo jet

PT>0.9
|η|<1



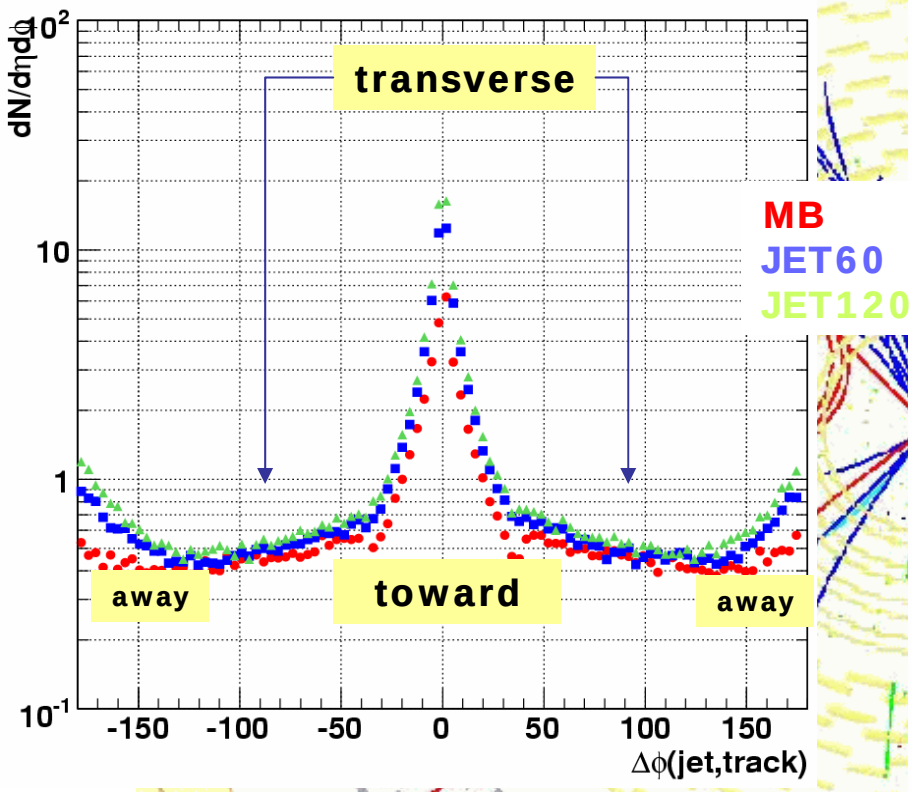
Charged jet calibration and resolution

$(PT_{REC}-PT_{MC})/PT_{MC}$ VS PT_{MC}

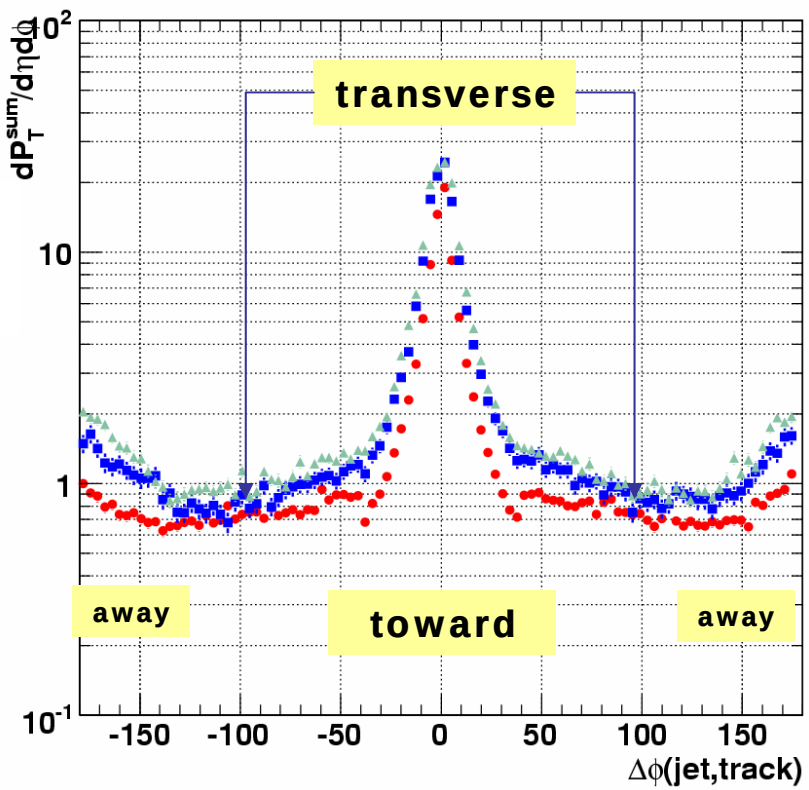
Abs(Ipz$_{trk}$ – PVZ) < 1mm

Reconstruction studies – charged jet - track and energy density

$dN_{ch}/d\eta d\phi$ VS $\Delta\phi$



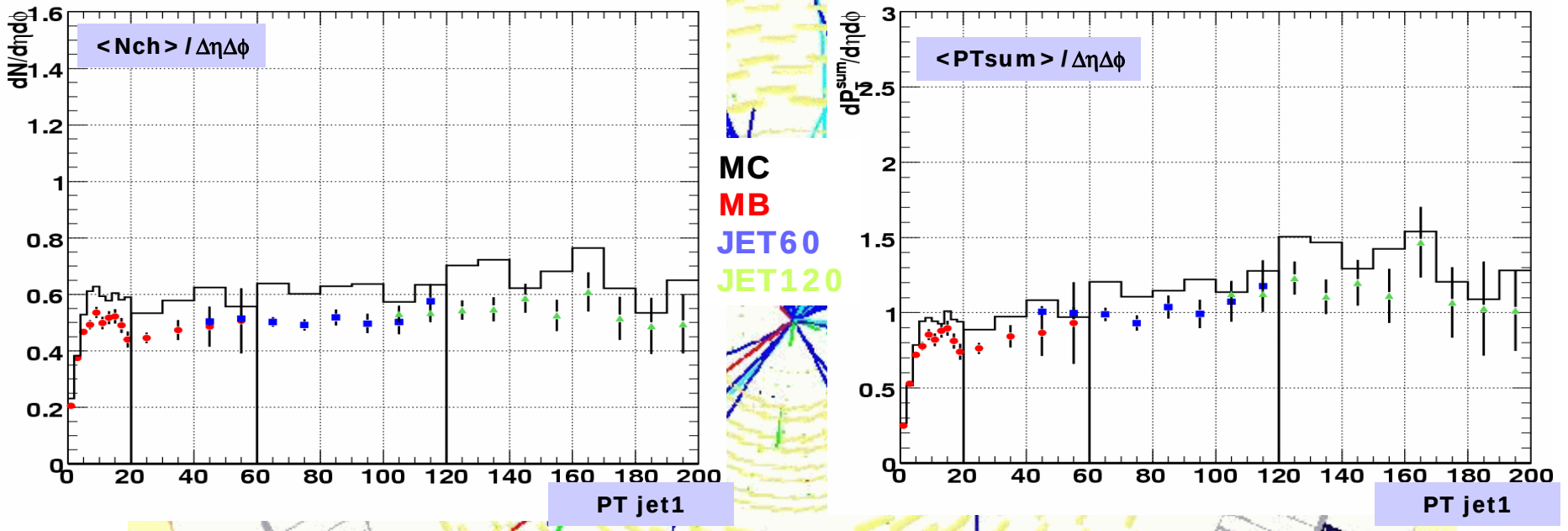
$dPT_{sum}/d\eta d\phi$ VS $\Delta\phi$



PT>0.9
|η|<1

Reconstruction studies – charged jet - transverse region

PT>0.9, |η|<1



Events re-weighted with corresponding x-sec

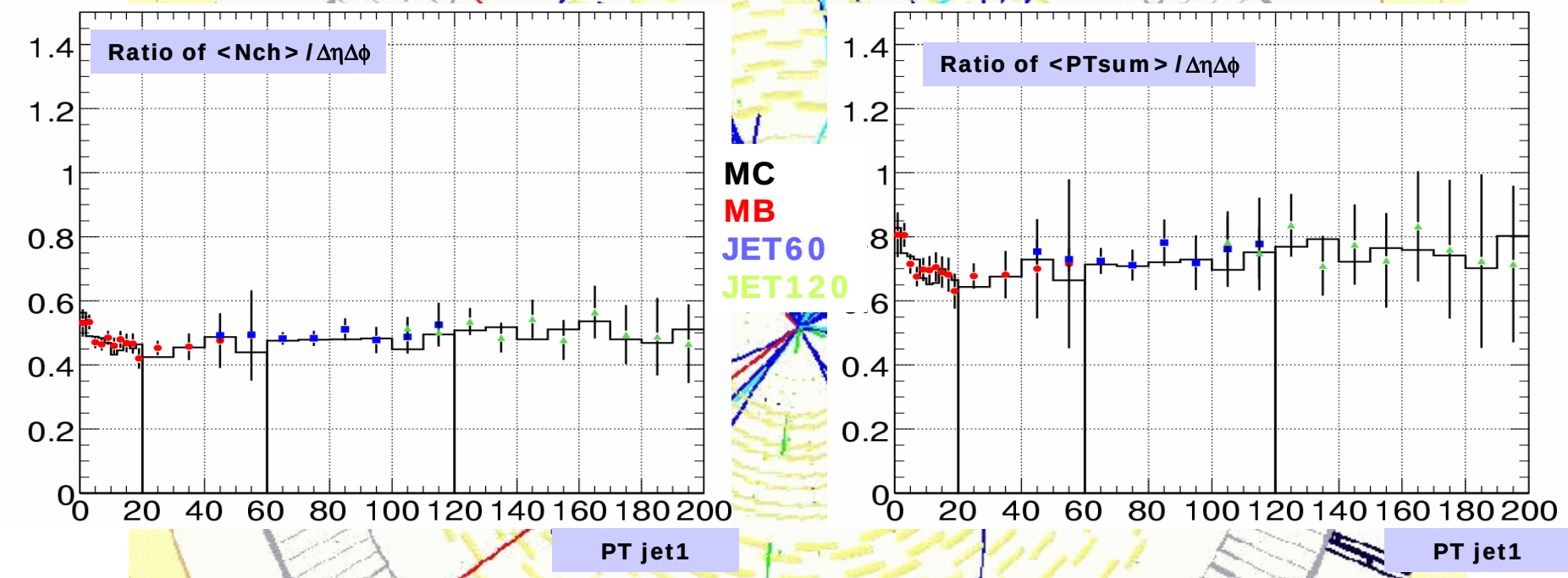
(error bars dominated by MC statistics, arbitrary luminosity but scaling correctly)

Good RECO/MC agreement in shape

Differences compatible with the expected corrections
from charged jet PT calibration, charged tracks innefficiencies and fake rate

Reconstruction studies – charged jet - transverse region

Ratio PT>0.9 / PT>0.5



Events re-weighted with corresponding x-sec.

(error bars dominated by MC statistics, arbitrary luminosity but scaling correctly)

Really Good RECO/MC agreement.

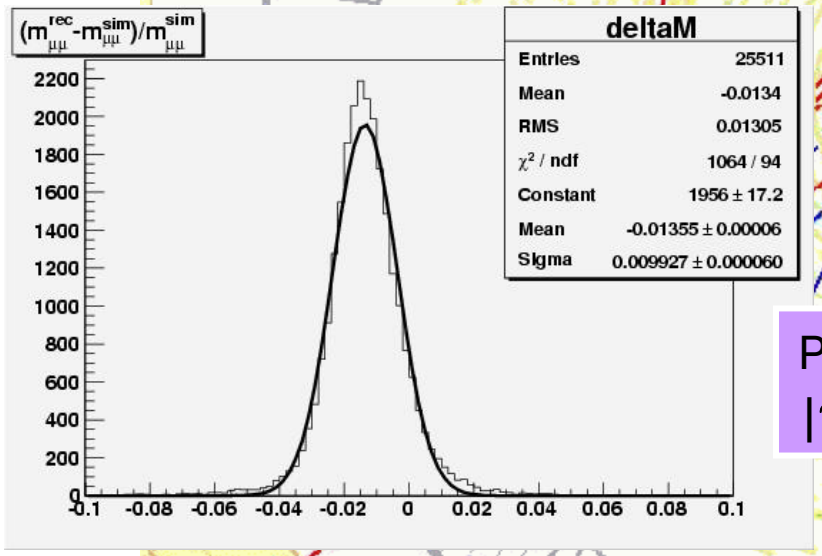
RECO/MC Differences absorb in the ratio, no need to apply corrections.

Reconstruction studies – DY muon pairs

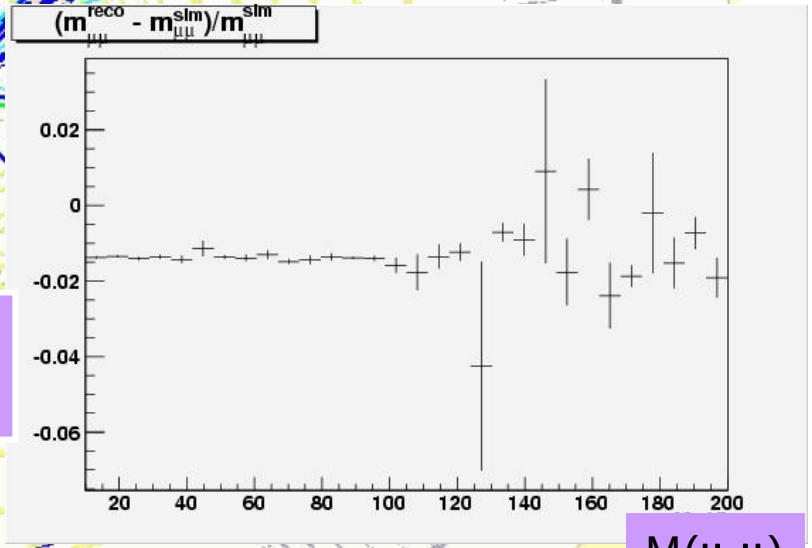
sm05_dy2mu ~50K events, M(μ,μ) > 15 GeV

Cut on Tracks: Abs(Ipz$_{trk}$ – PVZ) < 1mm

$(M_{\mu\mu}^{rec} - M_{\mu\mu}^{MC})/M_{\mu\mu}^{MC}$

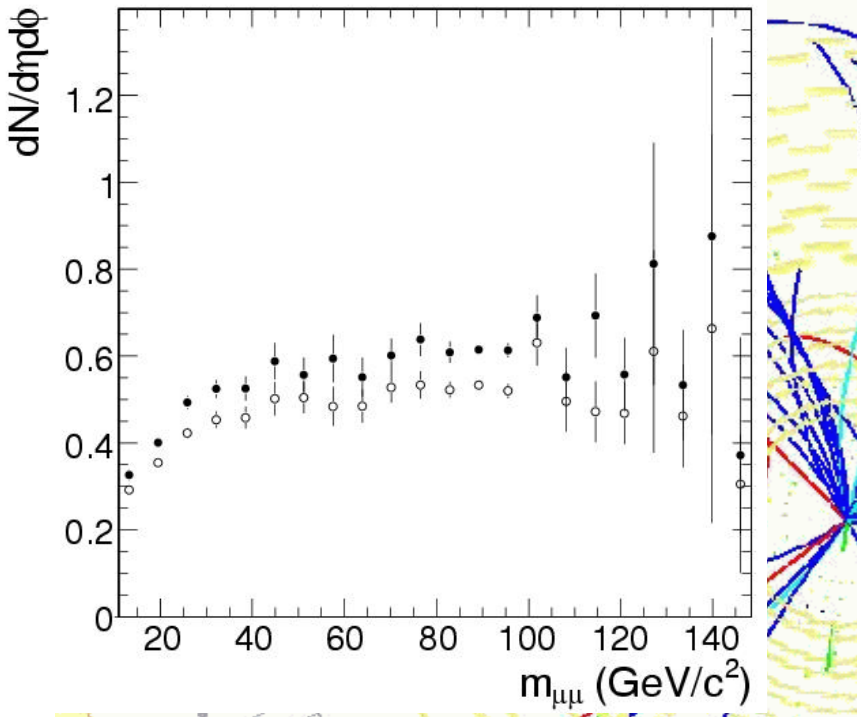


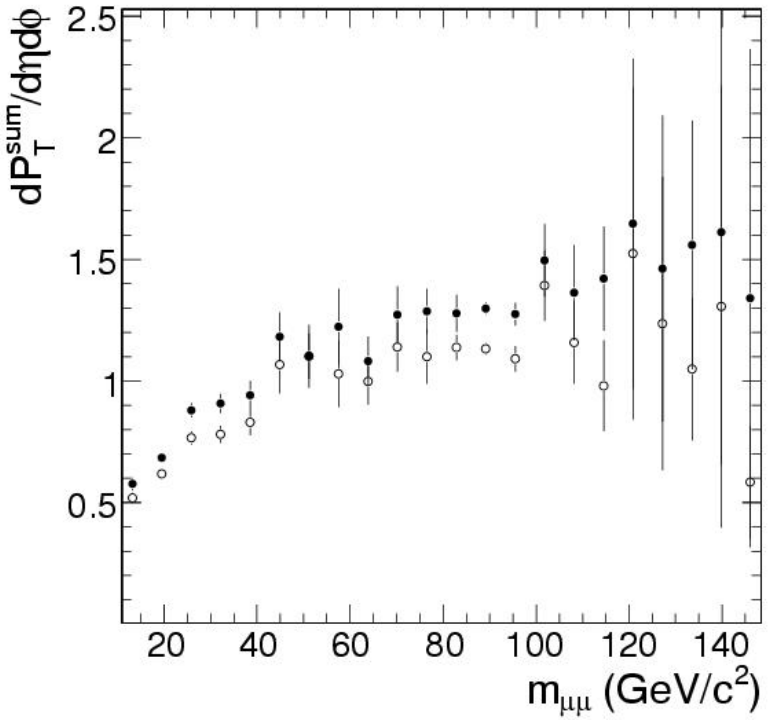
PT>0.9
|η|<1



Essentially due to a different map of the magnetic field used for event simulation and reconstruction

Reconstruction studies – DY - isolated muon pairs





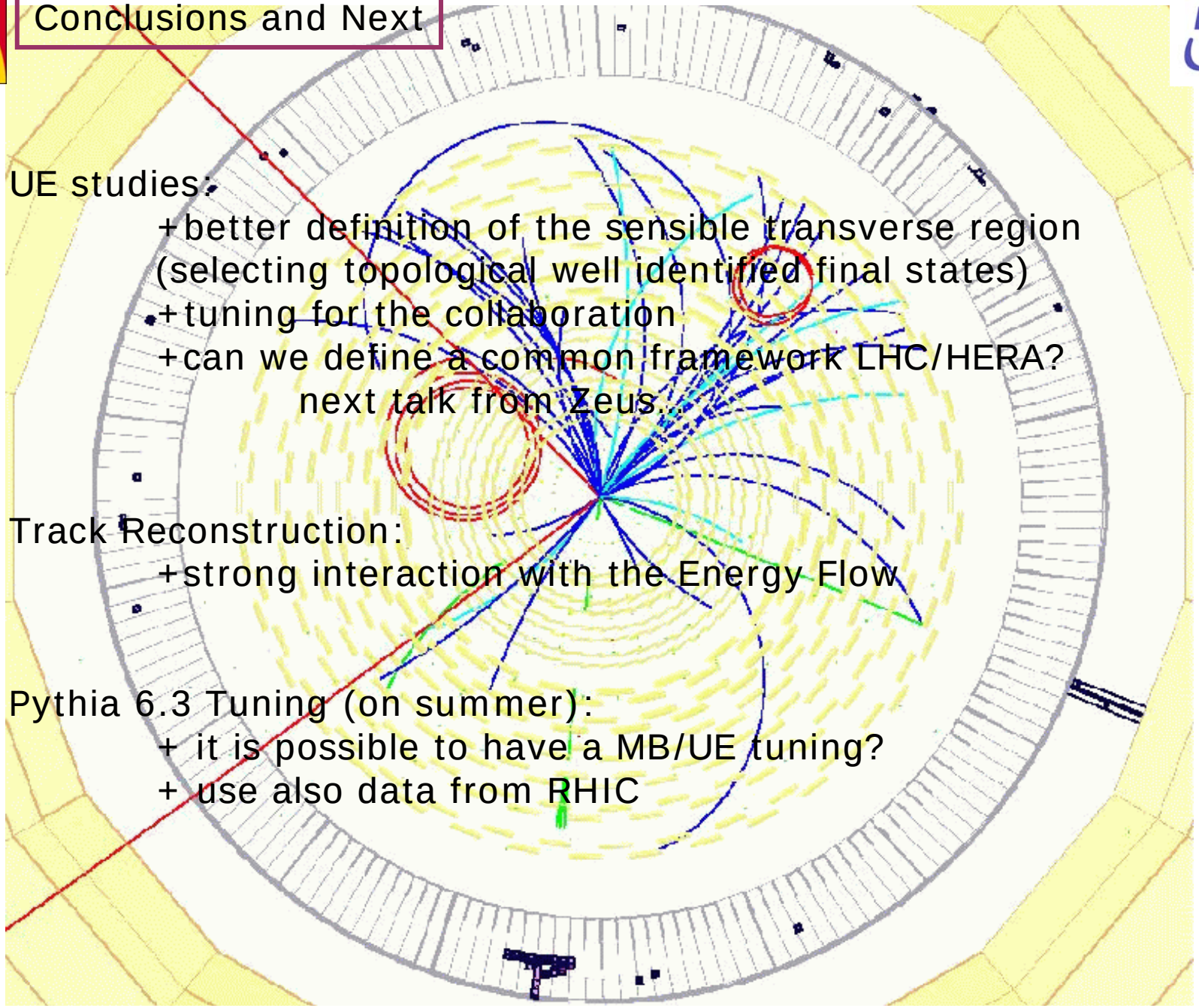
Isolated muons no tracks with PT>0.9 GeV in a cone of radius 0.3 in $\eta-\phi$ around the muon direction

(see talk from Alexey Drozdetskiy for UE/isolation correlation)

76.9% efficiency for DY-muon pairs

No QCD events passing these isolation cuts found (total statistics of 4M)

Conclusions and Next



UE studies:

+better definition of the sensible transverse region (selecting topological well identified final states)

+tuning for the collaboration

+can we define a common framework LHC/HERA?

next talk from Zeus...

Track Reconstruction:

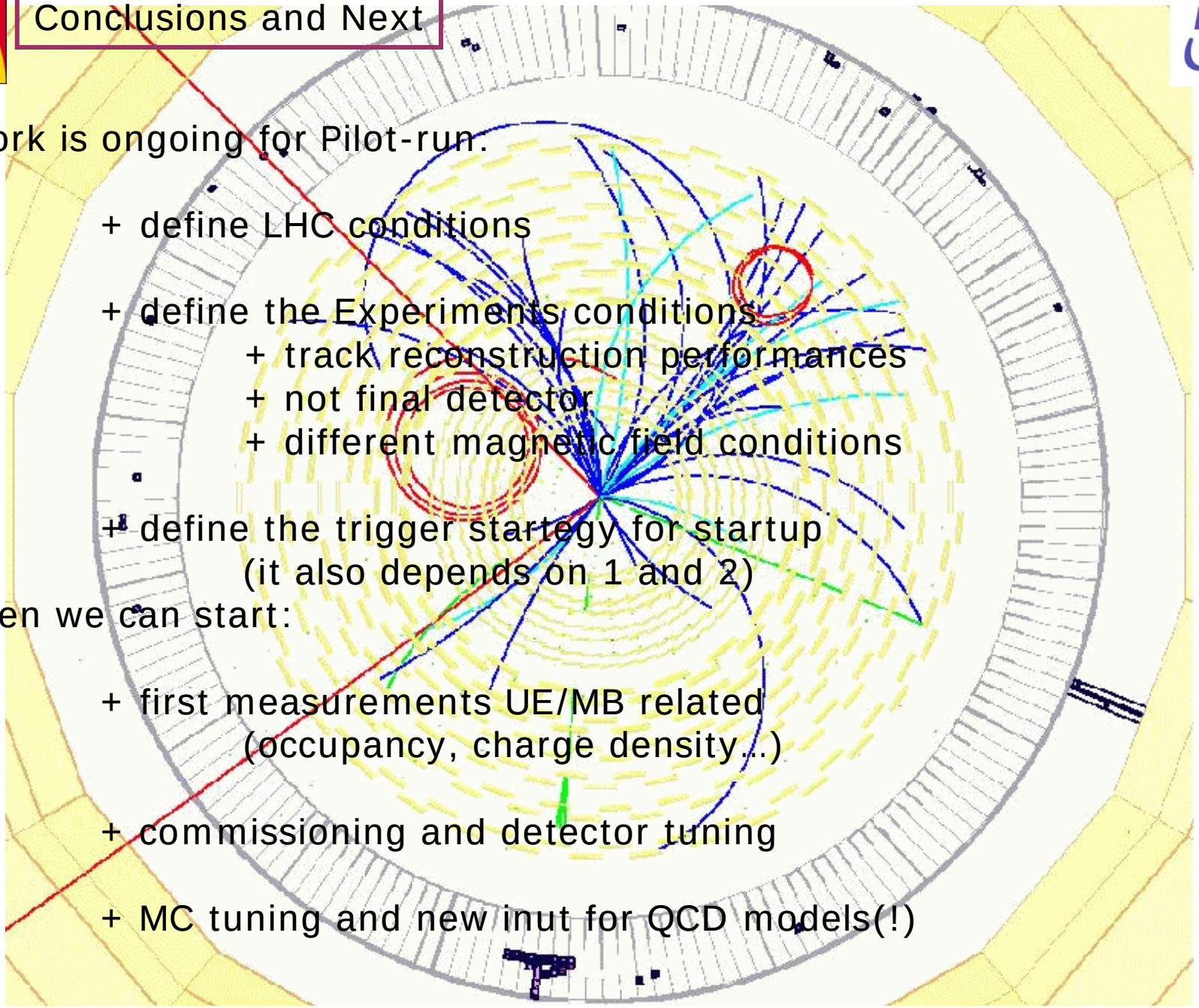
+strong interaction with the Energy Flow

Pythia 6.3 Tuning (on summer):

+ it is possible to have a MB/UE tuning?

+ use also data from RHIC

Conclusions and Next



Work is ongoing for Pilot-run:

+ define LHC conditions

+ define the Experiments conditions
  + track reconstruction performances
  + not final detector
  + different magnetic field conditions

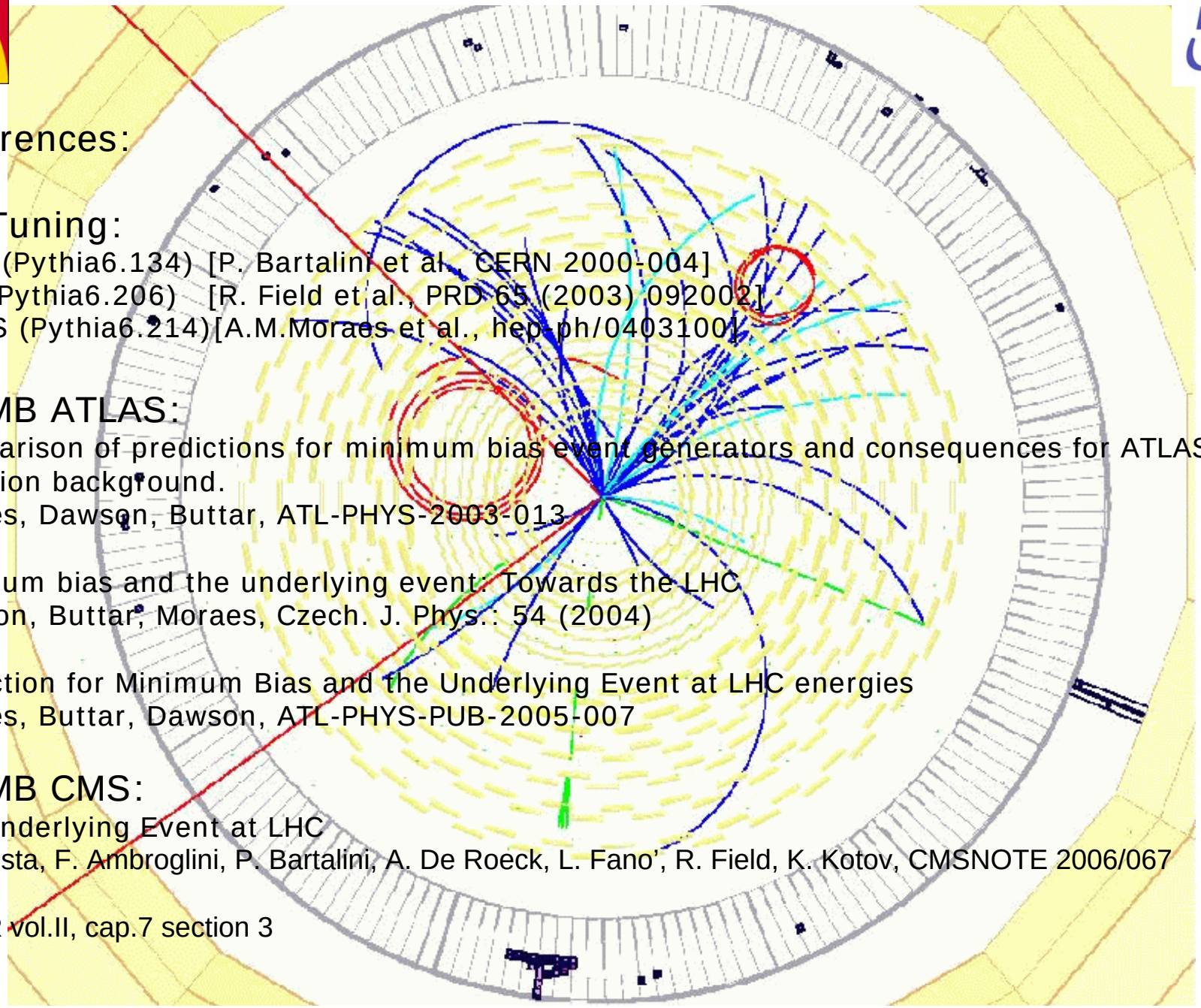
+ define the trigger startegy for startup
  (it also depends on 1 and 2)

Then we can start:

+ first measurements UE/MB related
  (occupancy, charge density...)

+ commissioning and detector tuning

+ MC tuning and new inut for QCD models(!)



References:

MC Tuning:

LHCb (Pythia6.134) [P. Bartalini et al., CERN 2000-004]
CDF (Pythia6.206) [R. Field et al., PRD 65 (2003) 092002]
ATLAS (Pythia6.214)[A.M.Moraes et al., hep-ph/0403100]

UE/MB ATLAS:

Comparison of predictions for minimum bias event generators and consequences for ATLAS radiation background.
Moraes, Dawson, Buttar, ATL-PHYS-2003-013

Minimum bias and the underlying event: Towards the LHC
Dawson, Buttar, Moraes, Czech. J. Phys.: 54 (2004)

Prediction for Minimum Bias and the Underlying Event at LHC energies
Moraes, Buttar, Dawson, ATL-PHYS-PUB-2005-007

UE/MB CMS:

The Underlying Event at LHC
D. Acosta, F. Ambroglini, P. Bartalini, A. De Roeck, L. Fano', R. Field, K. Kotov, CMSNOTE 2006/067

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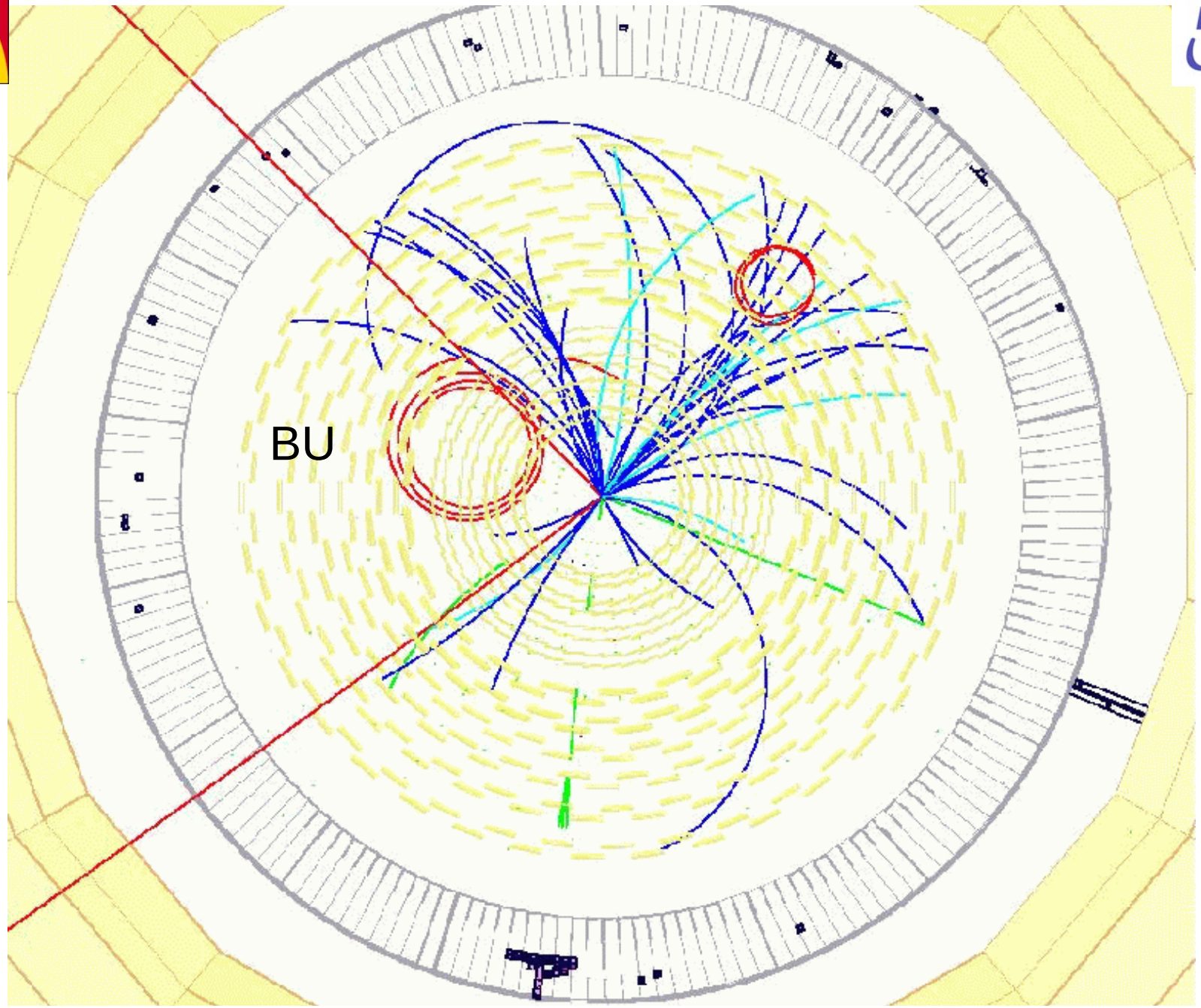
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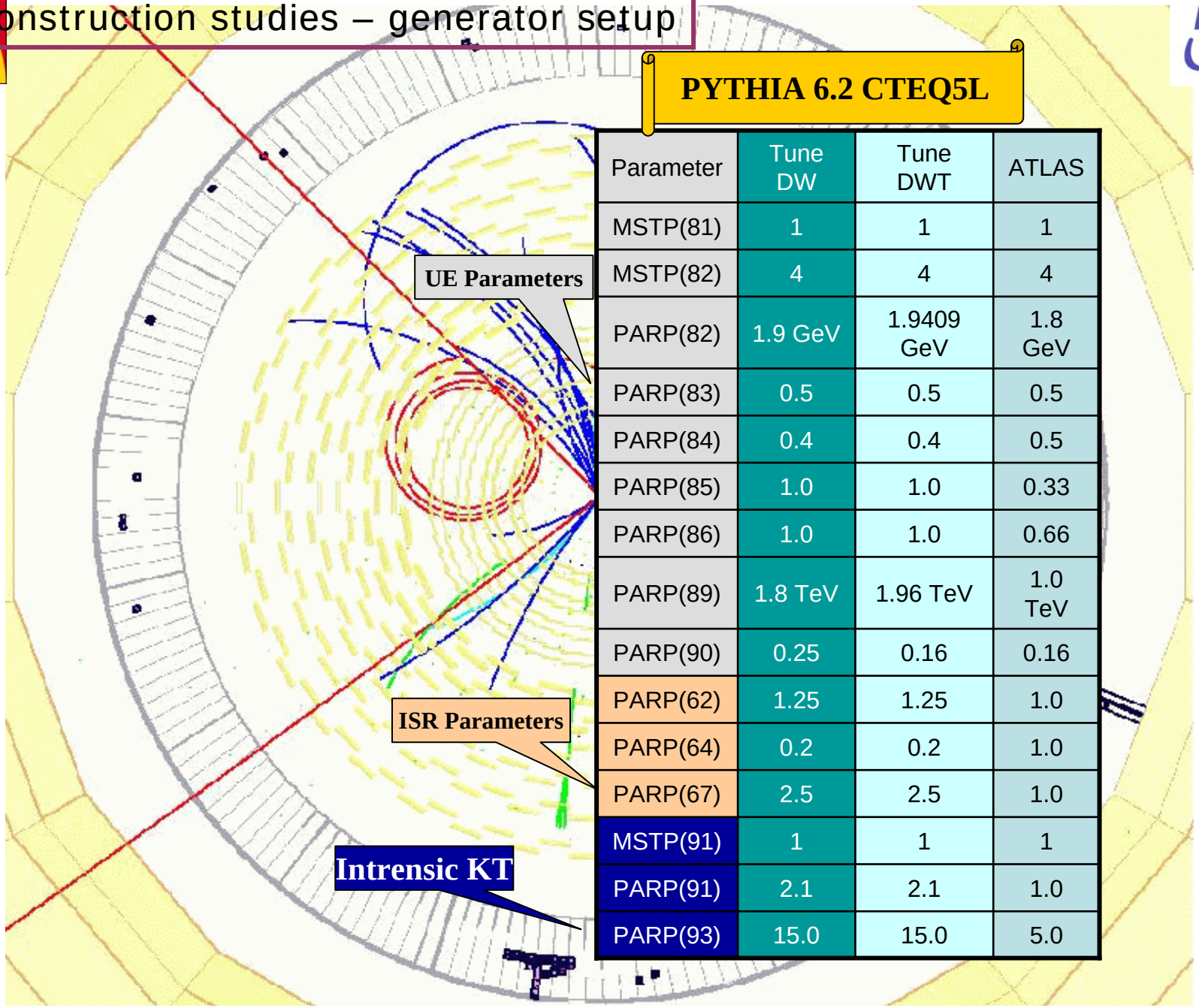
Reconstruction studies – generator setup

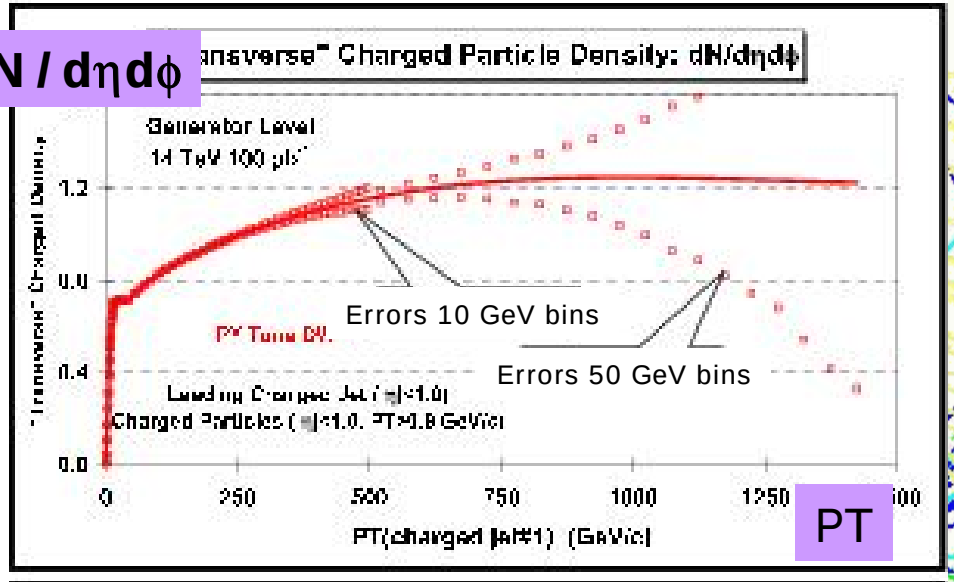


PYTHIA 6.2 CTEQ5L

Parameter	Tune DW	Tune DWT	ATLAS
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	1.9 GeV	1.9409 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.5
PARP(85)	1.0	1.0	0.33
PARP(86)	1.0	1.0	0.66
PARP(89)	1.8 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.25	0.16	0.16
PARP(62)	1.25	1.25	1.0
PARP(64)	0.2	0.2	1.0
PARP(67)	2.5	2.5	1.0
MSTP(91)	1	1	1
PARP(91)	2.1	2.1	1.0
PARP(93)	15.0	15.0	5.0

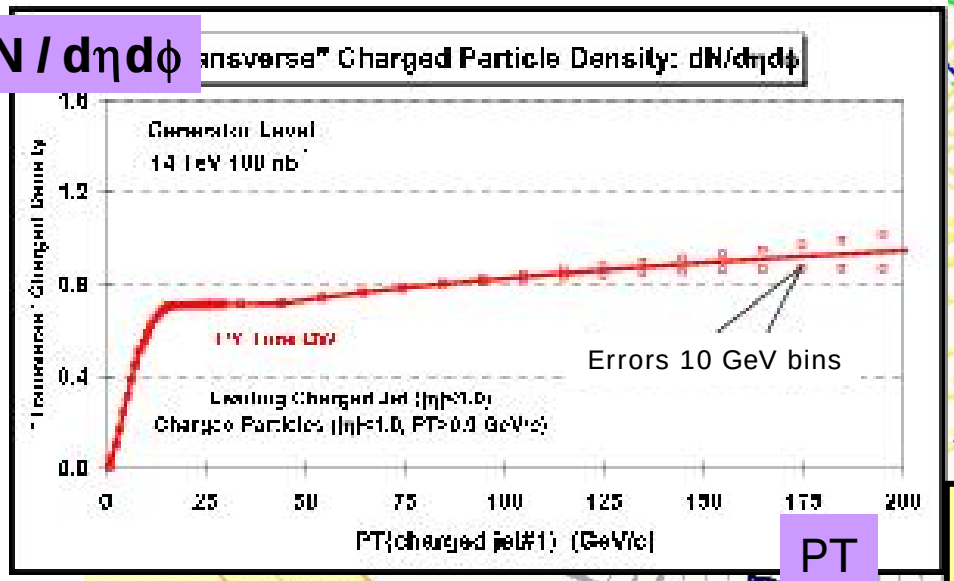
Generator level studies – charged jet – statistical errors

dN / dηdφ



PT

dN / dηdφ



PT

Pythia tune DW

100 pb^{-1}
of integrated luminosity

up to 1 TeV (~10%)

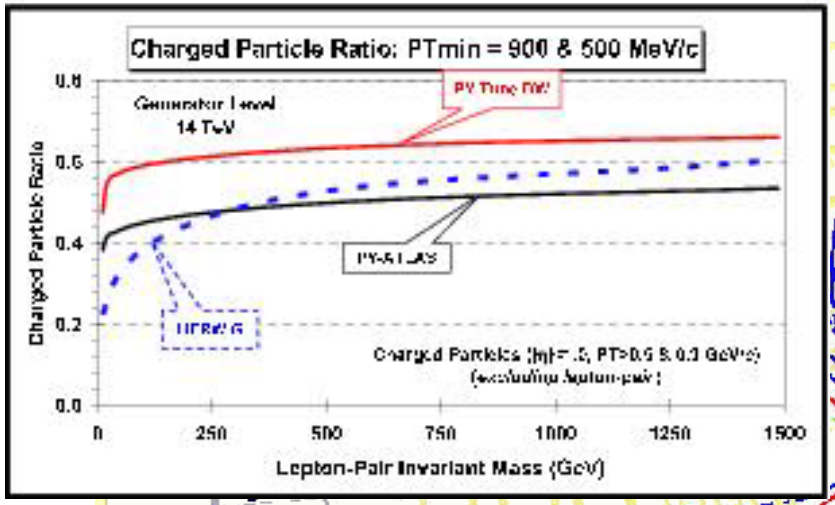
Doesn't take into account prescaling and trigger efficiency!

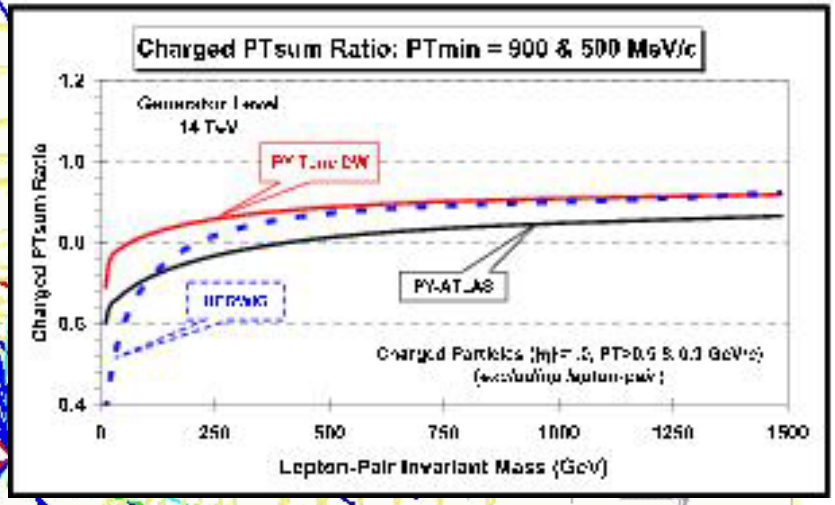
100 nb^{-1}
of integrated luminosity

up to 200 GeV (~10%)

PT>0.9
|η|<1

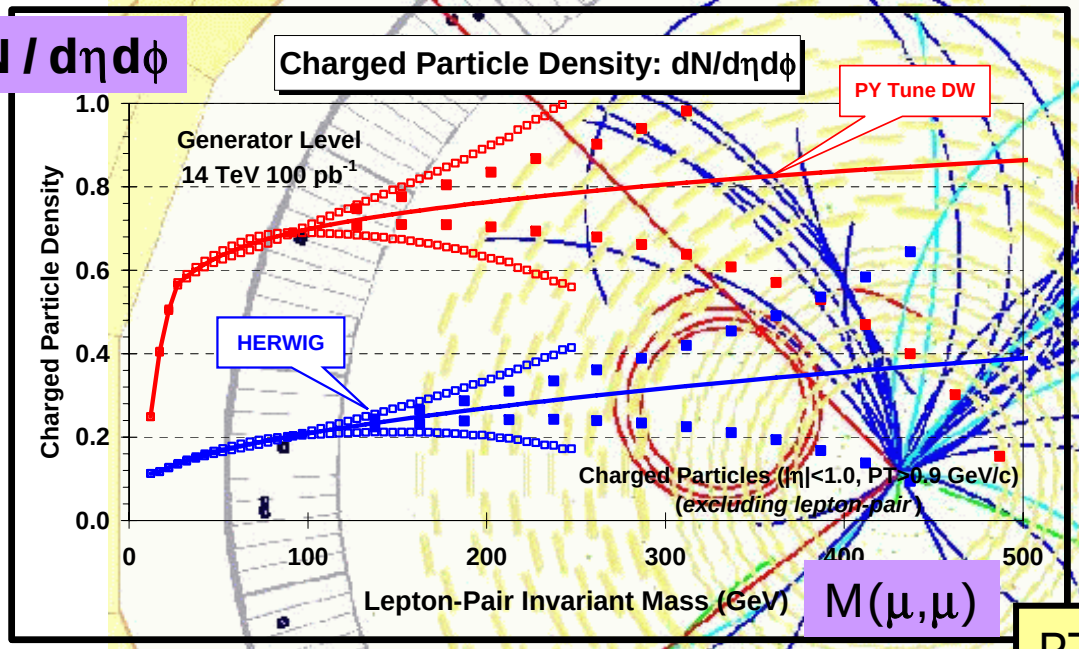
Generator level studies – DY – particles ratio





Generator level studies – DY – statistical errors

dN / dηdϕ



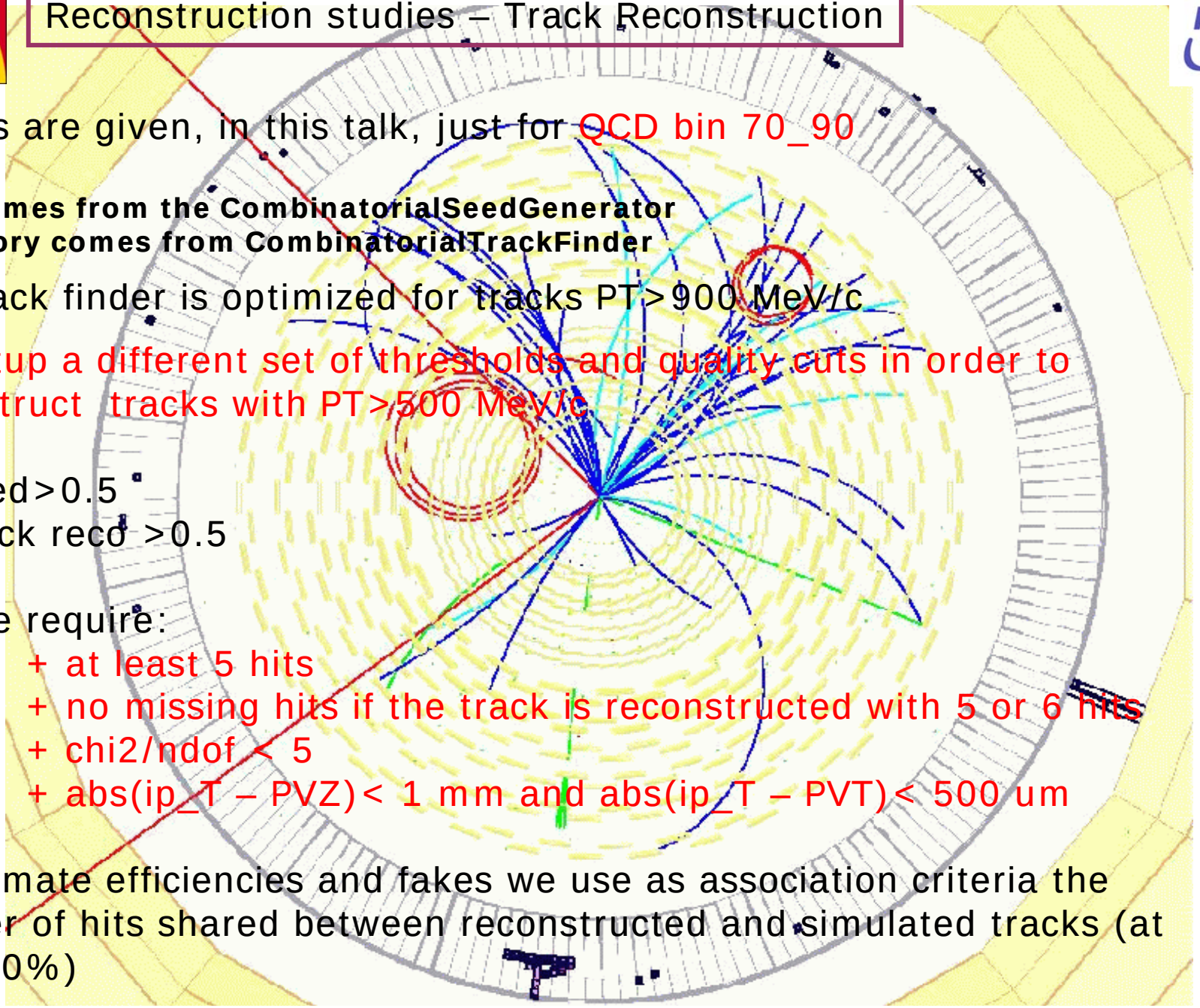
100 pb^{-1} of integrated luminosity

(up to 150 GeV ~10%)

PT>0.9
|η|<1

Doesn't take into account prescaling and trigger efficiency!

Reconstruction studies – Track Reconstruction



Results are given, in this talk, just for QCD bin 70_90

Seed comes from the CombinatorialSeedGenerator
Trajectory comes from CombinatorialTrackFinder

The track finder is optimized for tracks PT>900 MeV/c

We setup a different set of thresholds and quality cuts in order to reconstruct tracks with PT>500 MeV/c

PT_seed>0.5
PT_track recd >0.5

And we require:

+ at least 5 hits
+ no missing hits if the track is reconstructed with 5 or 6 hits
+ chi2/ndof < 5
+ abs(ip_T – PVZ)< 1 mm and abs(ip_T – PVT)< 500 um

To estimate efficiencies and fakes we use as association criteria the number of hits shared between reconstructed and simulated tracks (at least 50%)