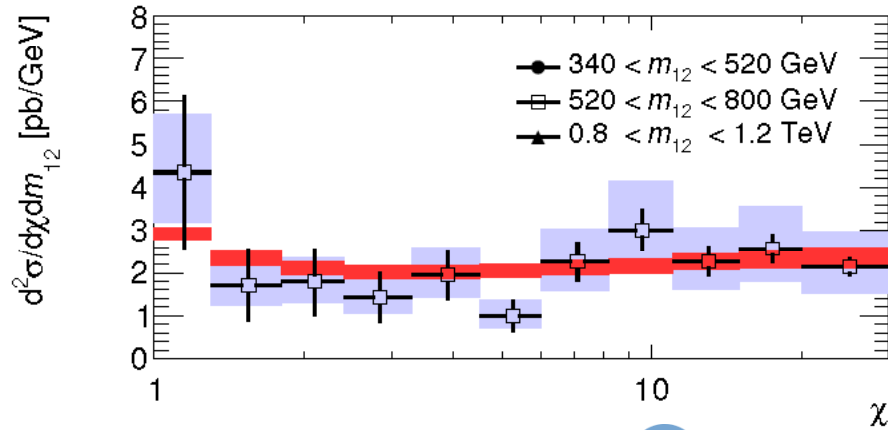
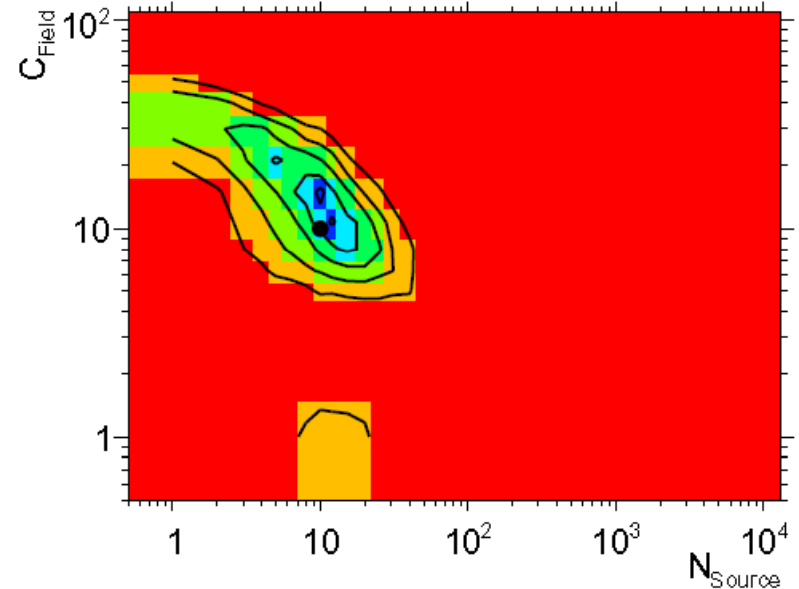


Analysis



V/SPA 

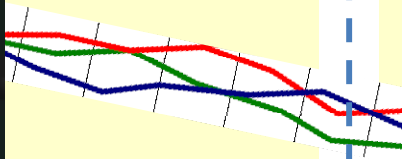


Prof. Dr. Martin Erdmann
RWTH Aachen University
9-Oct-2010

Astroparticle Tasks

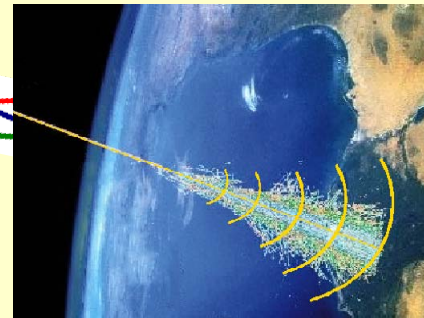
Theory

- Acceleration mechanism
- Sources
- Propagation
- Magnetic Fields



Experiment

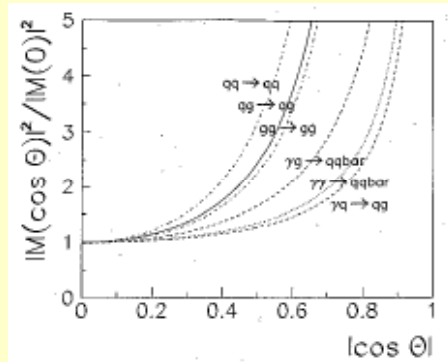
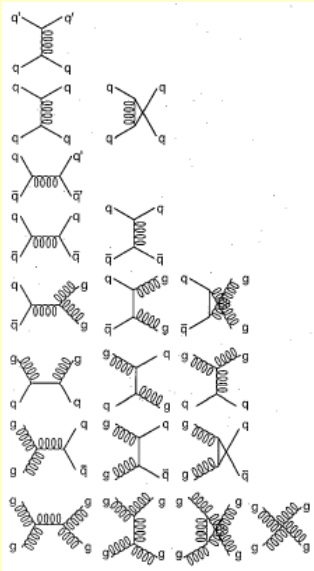
- UHECR detectors
- UHECR kinematics
- Data Distributions
- Observables



High Energy Physics

Theory

- Differential cross sections
- Monte Carlo Event Generators

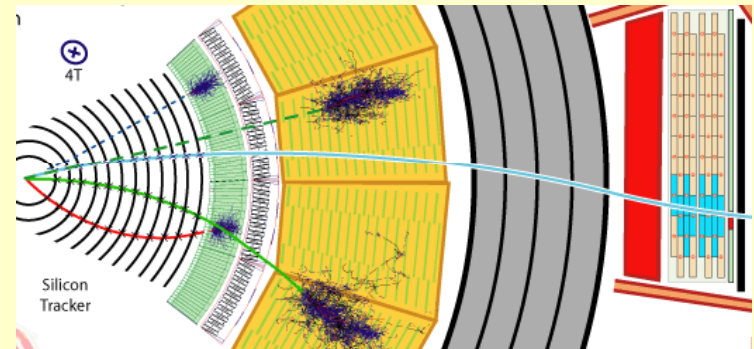


Interface C++ Classes

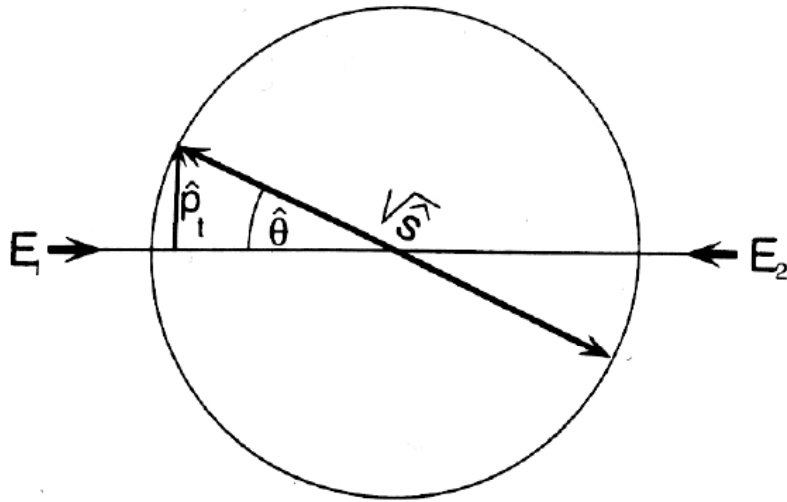
Experiment



- Accelerators
- Detectors
- Propagation
- Magnetic Fields



Distributions of Scattering Angle



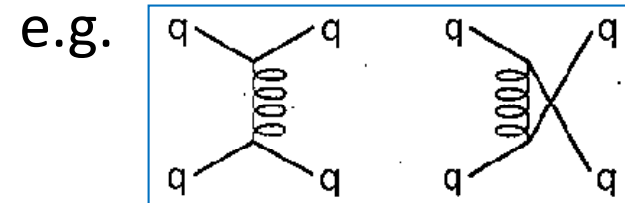
Mandelstam Variables

$$\hat{s} = 4 \cdot E_1 \cdot E_2$$

$$\hat{t} = -\frac{\hat{s}}{2} (1 - \cos \hat{\theta})$$

$$\hat{u} = -\frac{\hat{s}}{2} (1 + \cos \hat{\theta})$$

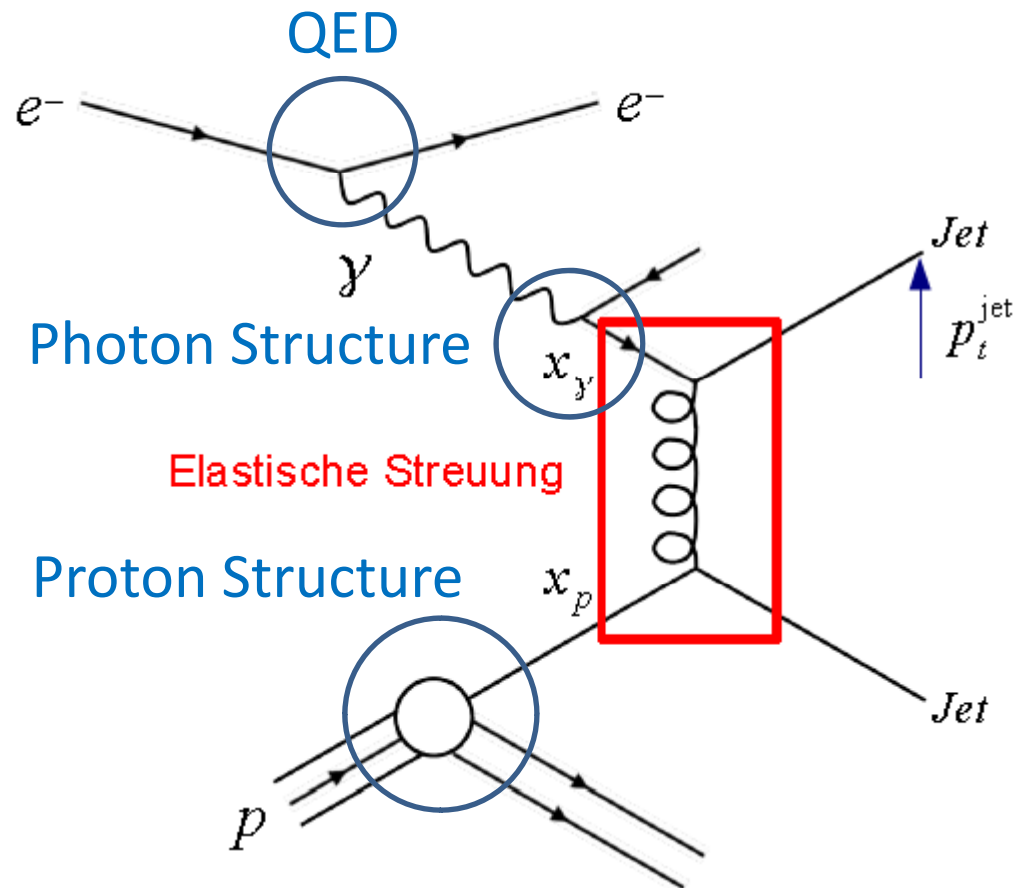
QCD: parton cross sections
-> angular distributions



$$\frac{d \hat{\sigma}}{d \hat{t}} = \frac{|M|^2}{16 \pi \hat{s}^2}$$

$$\frac{|M|^2}{\pi^2} = \frac{64}{9} \alpha_s^2 \left(\frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2} + \frac{\hat{s}^2 + \hat{t}^2}{\hat{u}^2} - \frac{2}{3} \frac{\hat{s}^2}{\hat{u} \hat{t}} \right)$$

Calculation of γp Jet Cross Sections



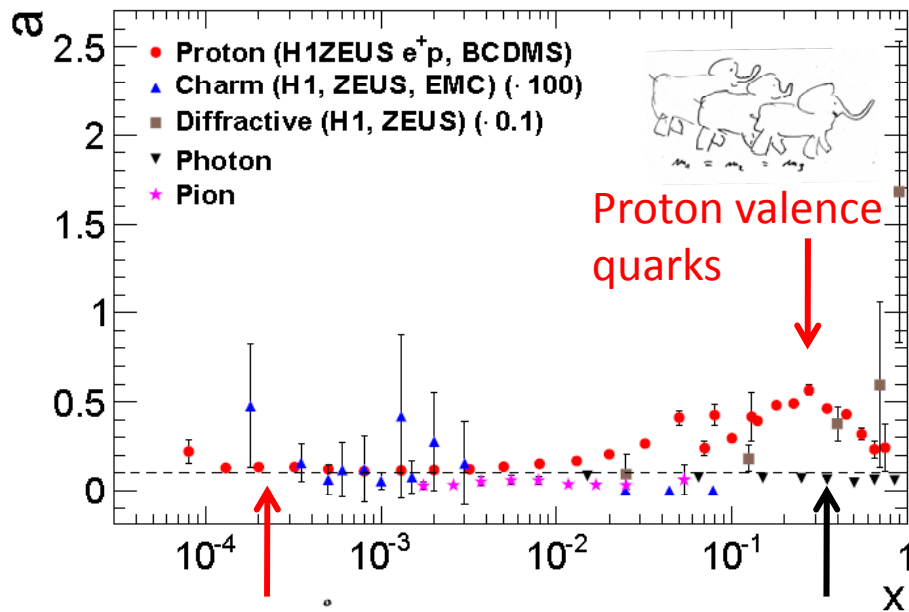
Blue marked ingredience: influence rate

Red: angular distributions are solid QCD predictions

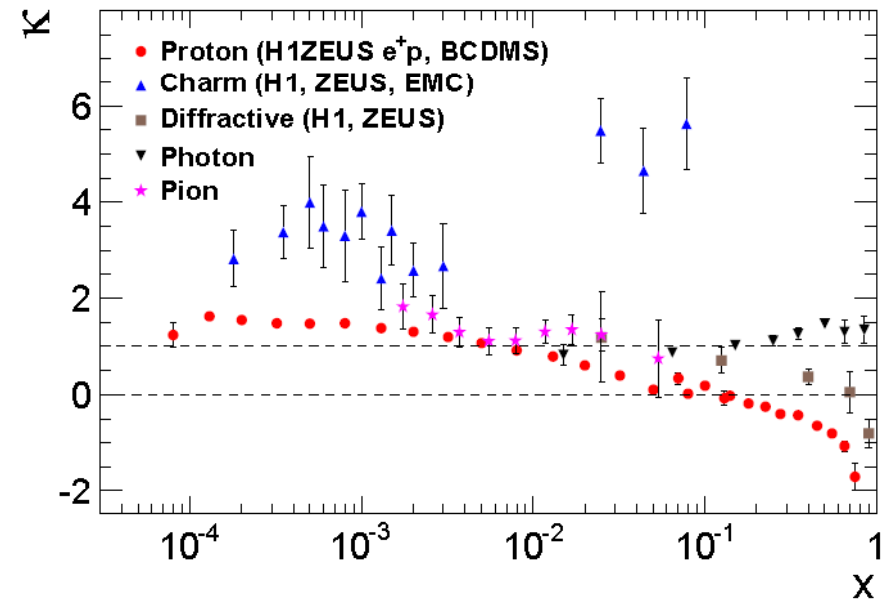
Proton & Photon Structure

$$F_2(x, Q^2) = a(x) \left[\ln \left(\frac{Q^2}{\Lambda^2} \right) \right]^{\kappa(x)}$$

hadronic structure



scaling violations

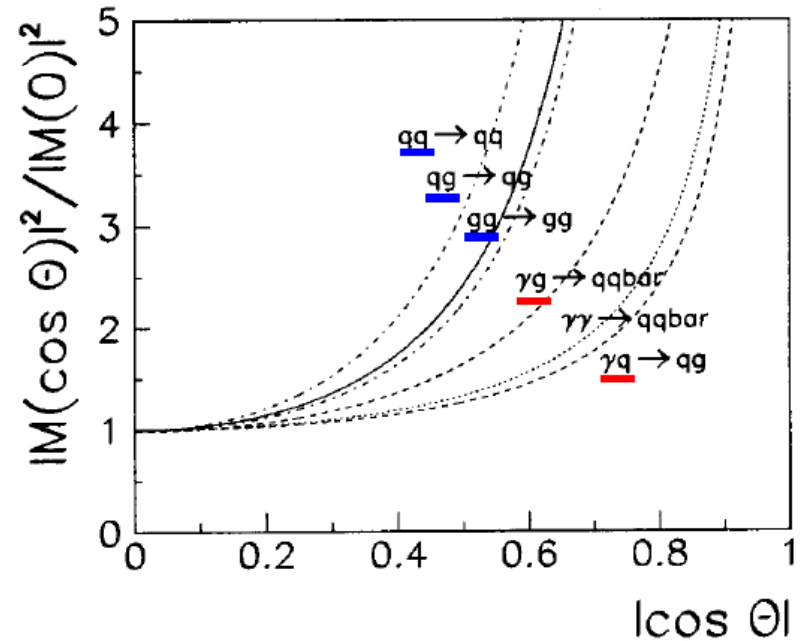
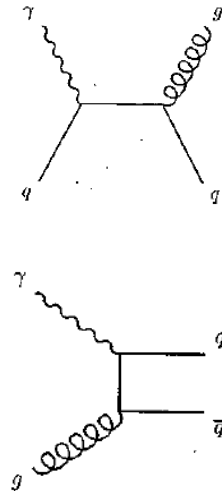
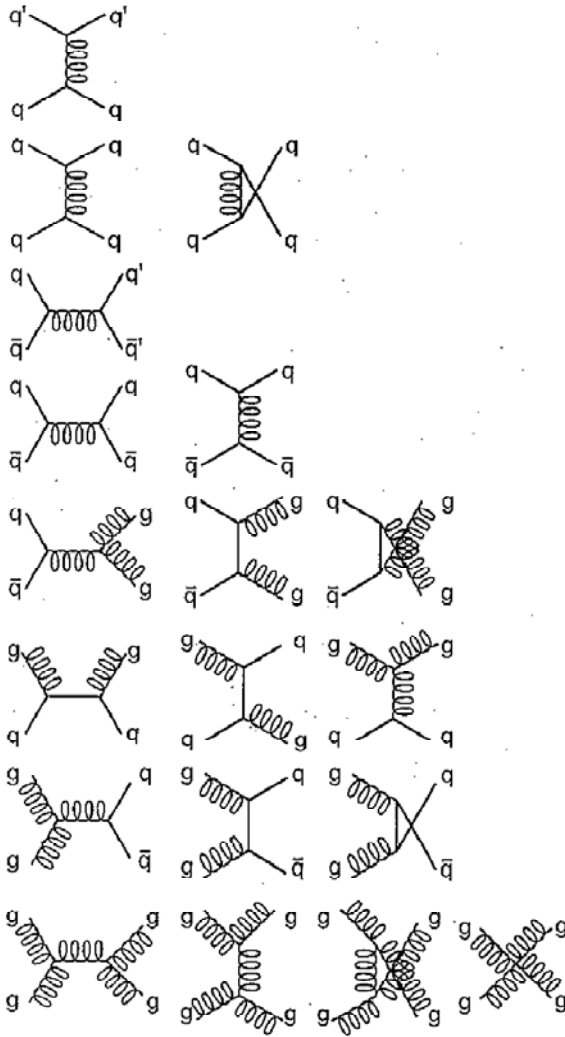


Many parton processes possible:

Resolved photon

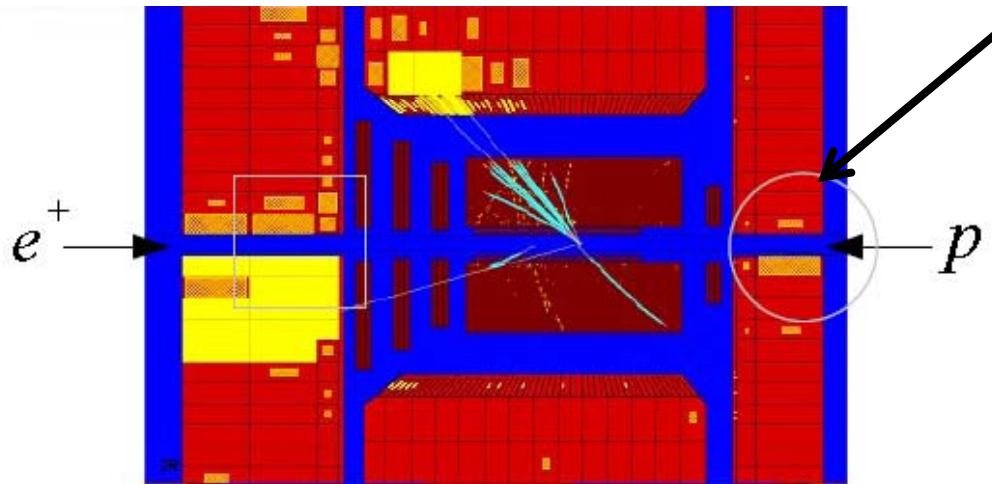
Direct photon

Angular Distributions

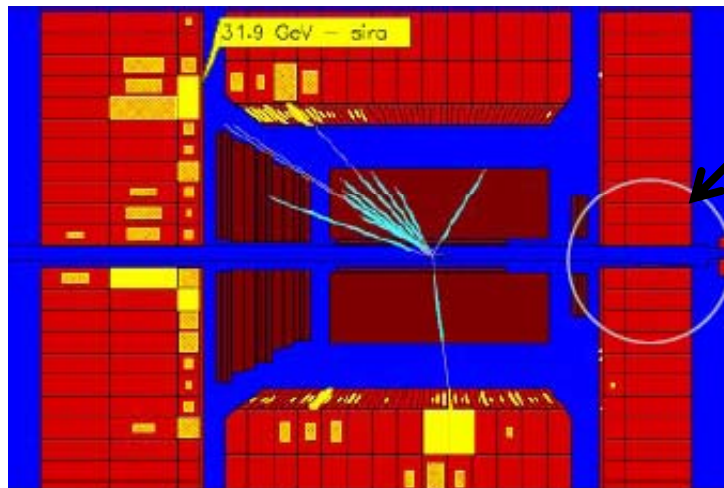
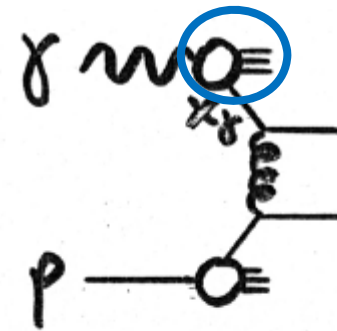


Direct / Resolved photon processes:
 Resolved γ angular distribution
 expected to be more steep.

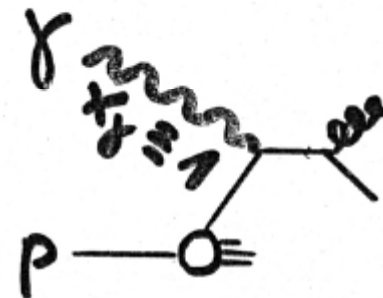
Direct/Resolved Photon Interactions



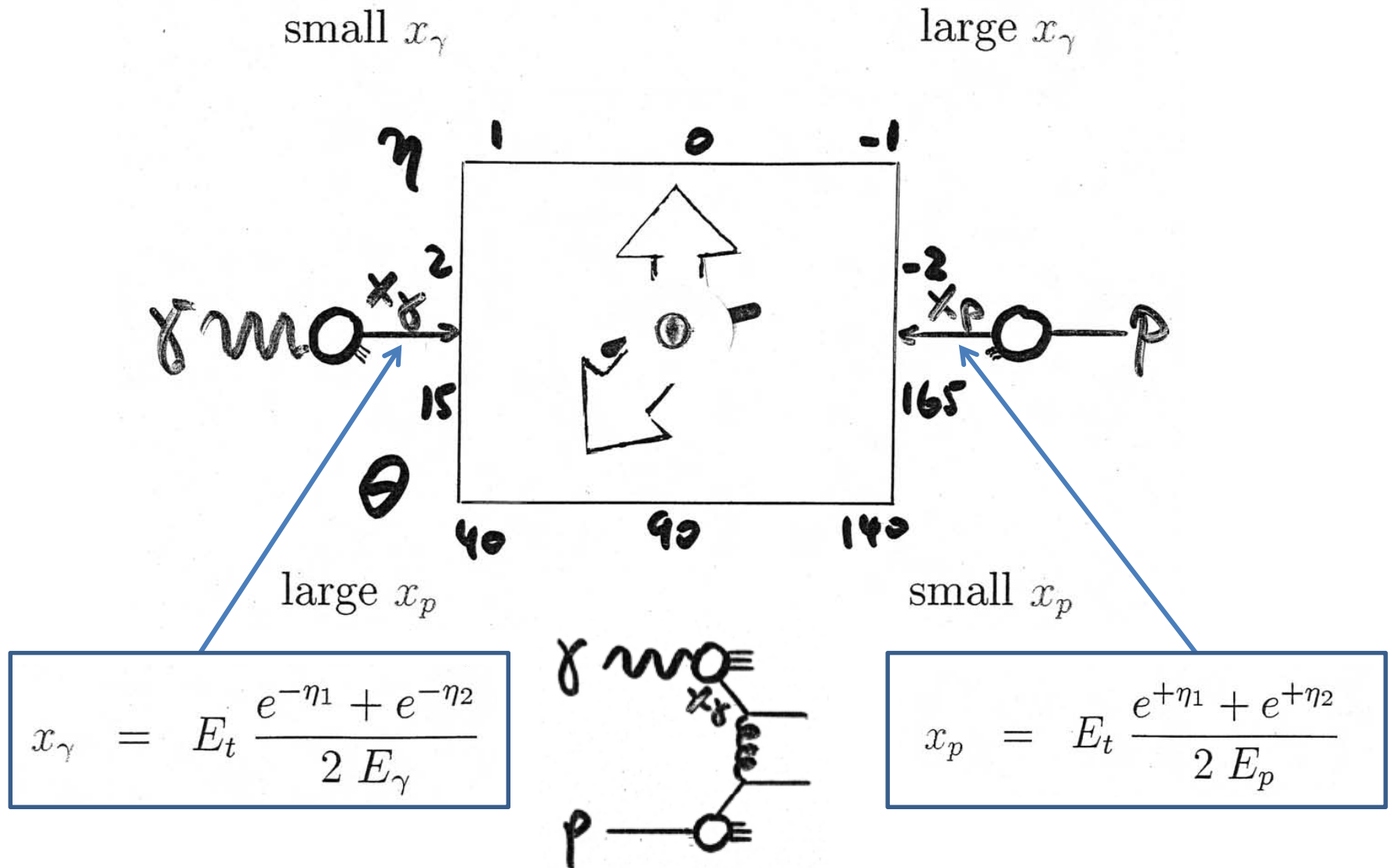
Energy from photon remnant



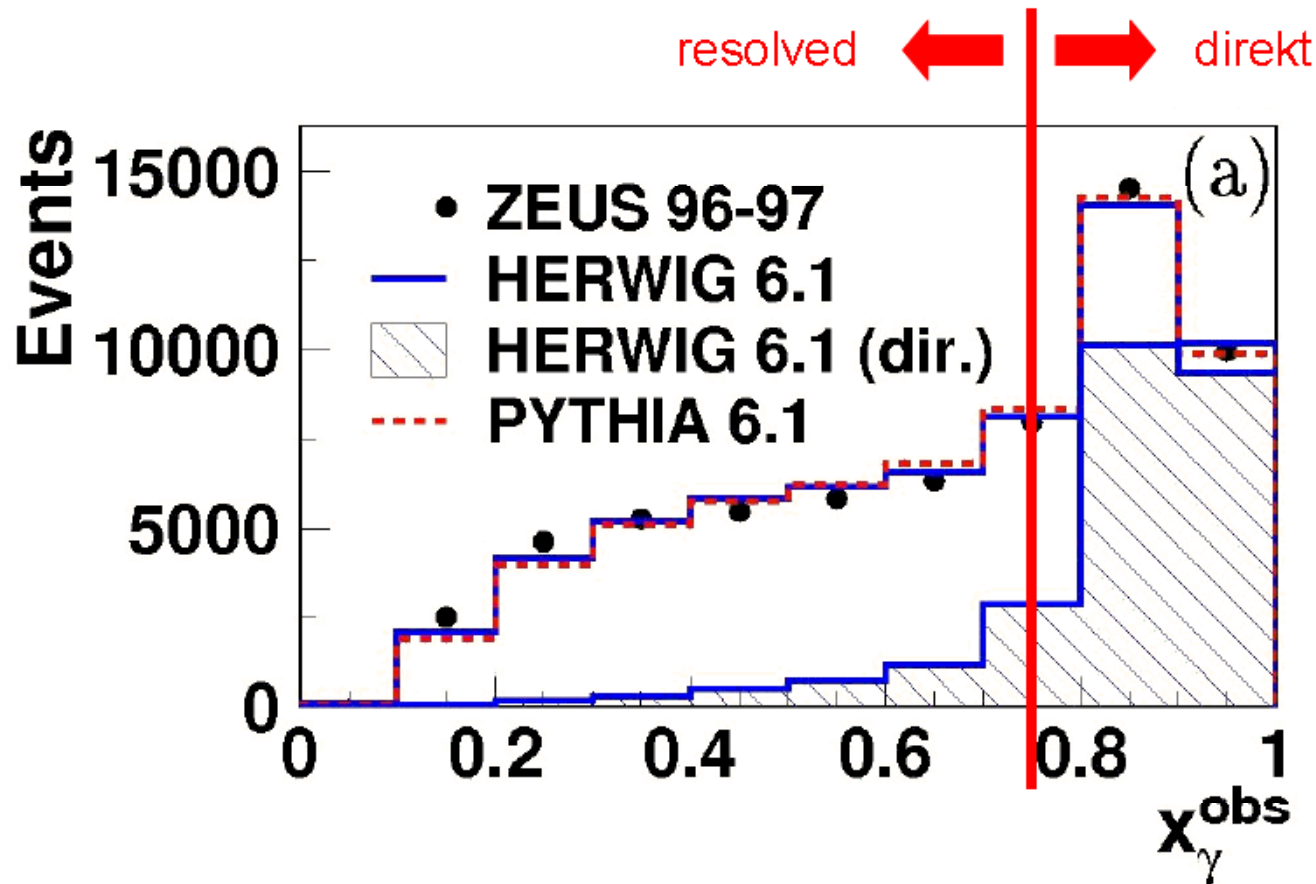
No energy in photon direction



Reconstruct initial Parton Momenta

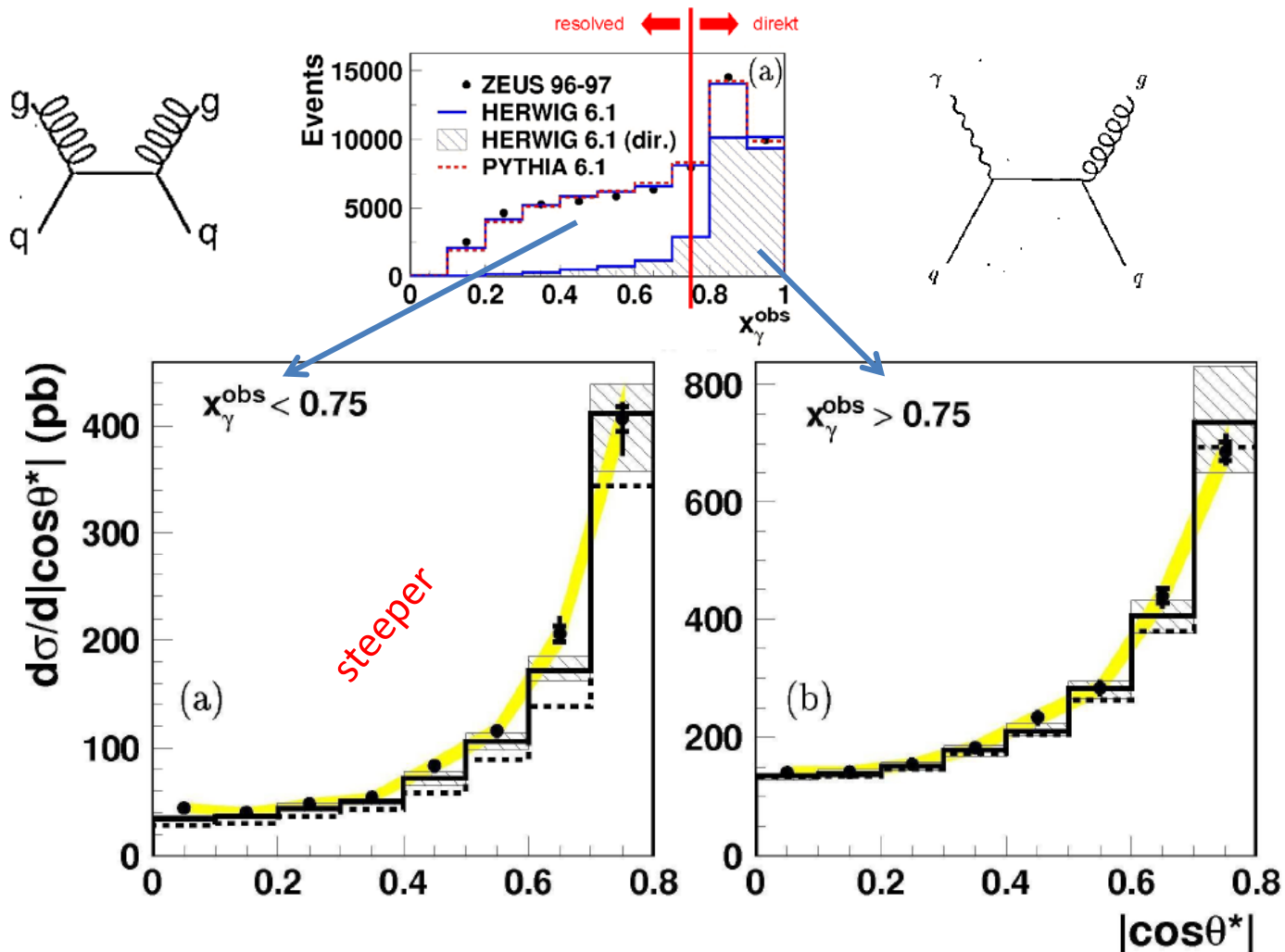


Separate Direct/Resolved Photon Events



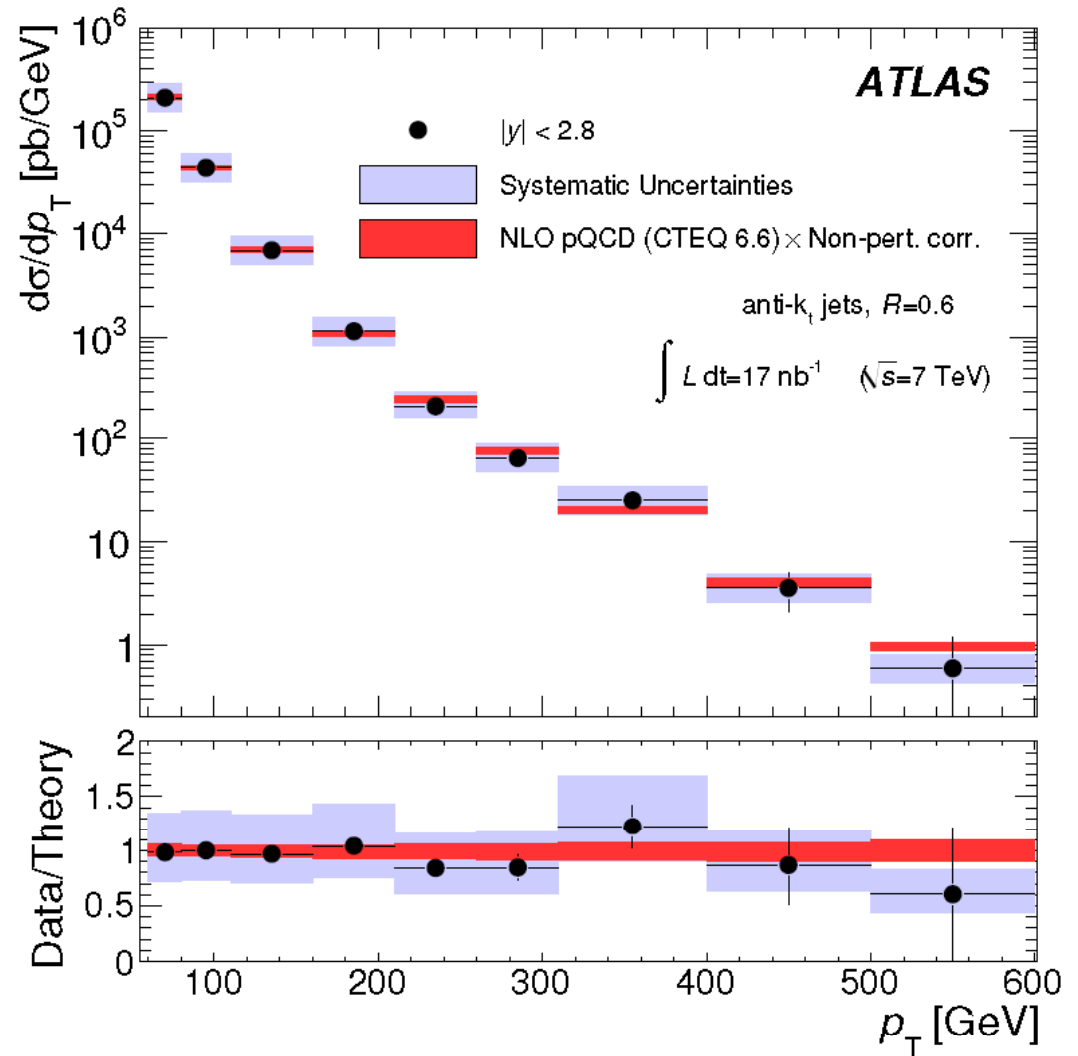
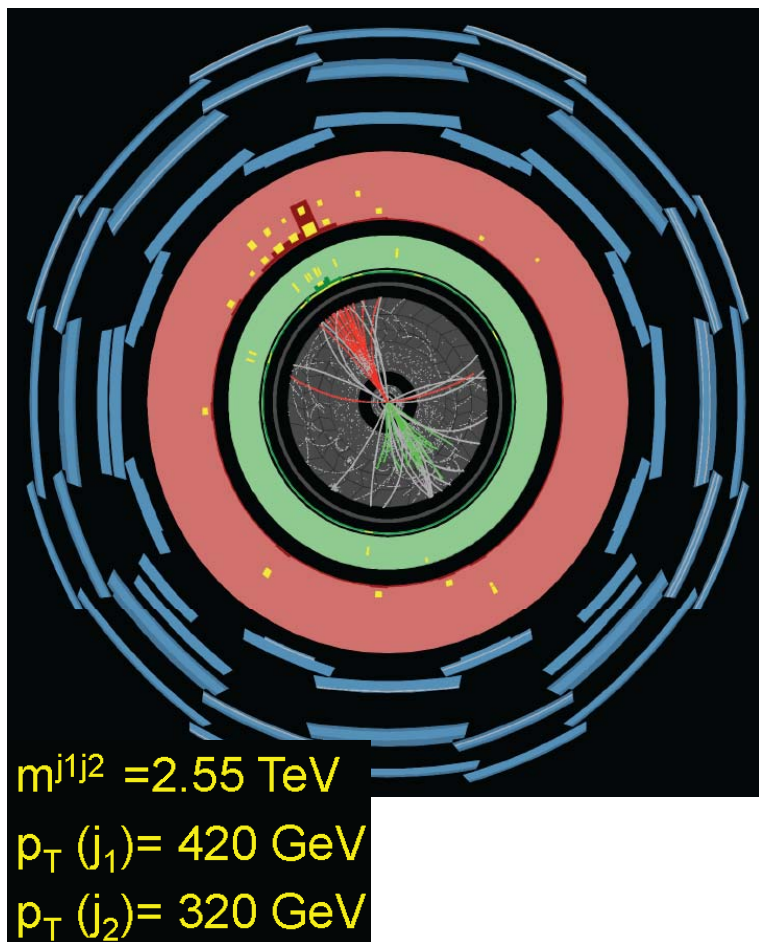
measure x_γ event-by-event

Measured Angular Distributions



QCD correctly predicts the angular distributions

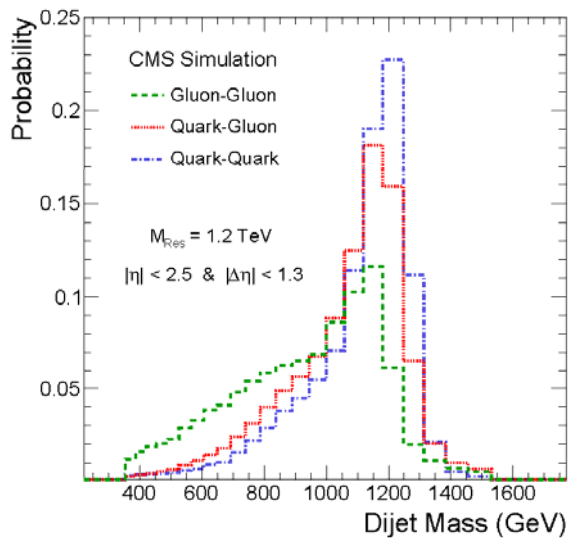
Atlas: Jet Cross Section



Good description of the NLO QCD calculations

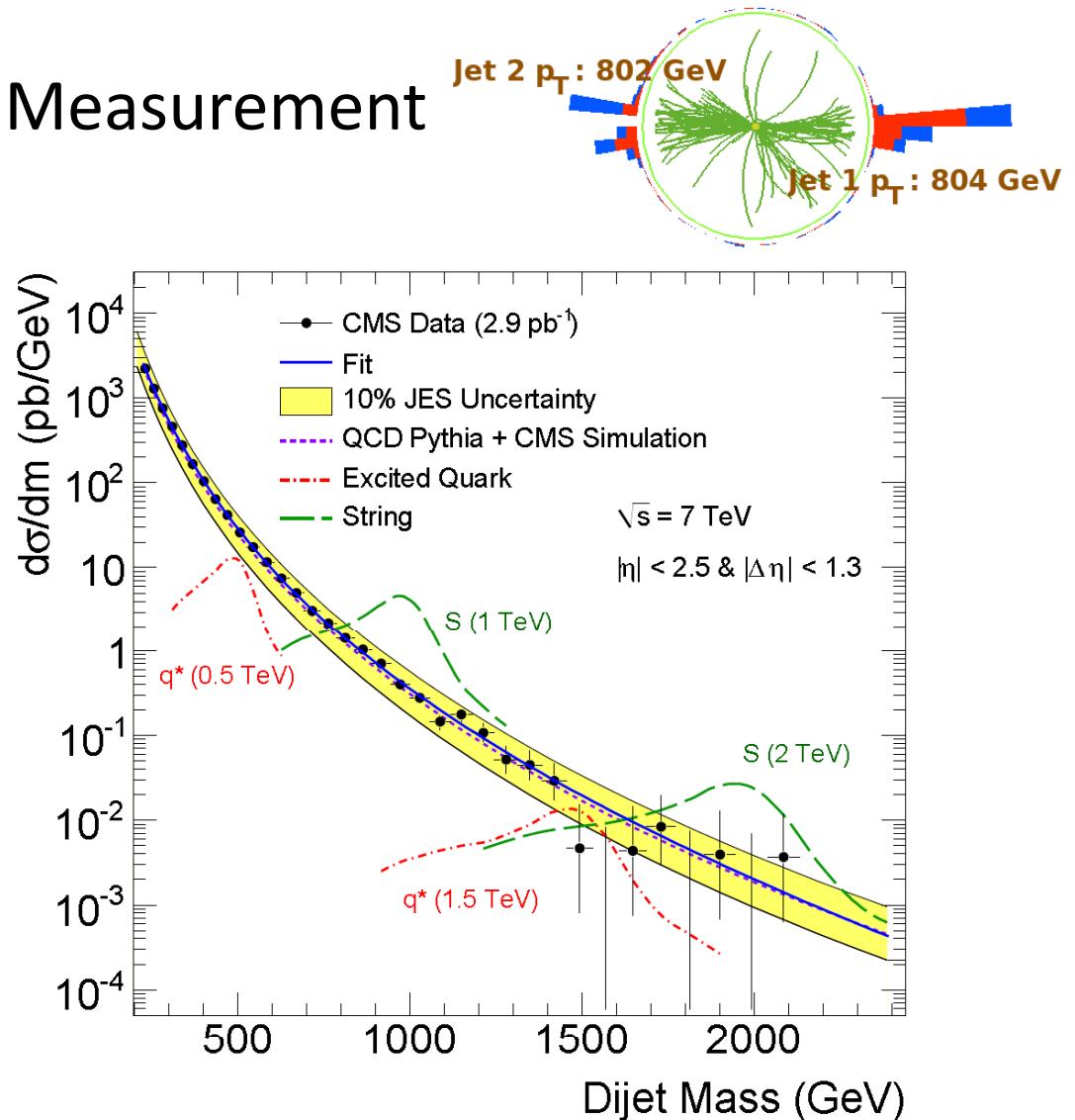
CMS: Search for New Heavy Particles

Simulation



No resonance (yet)

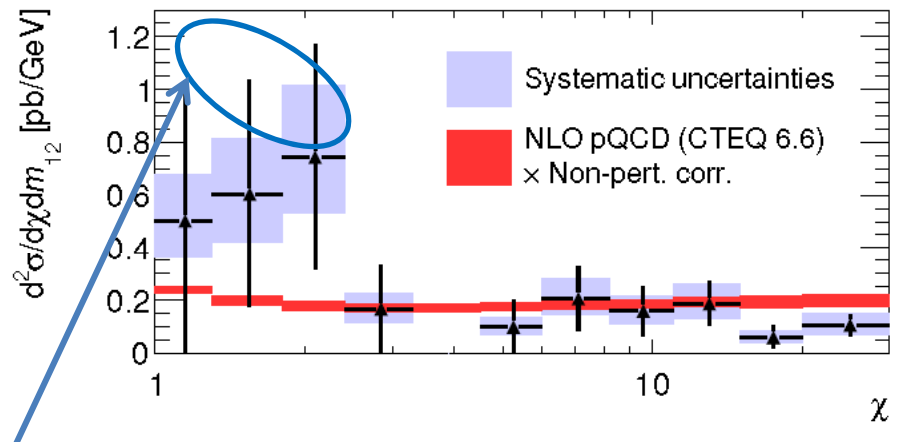
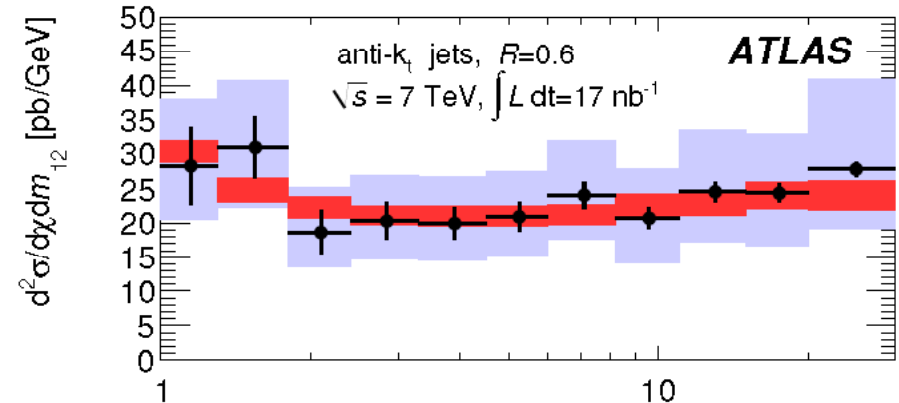
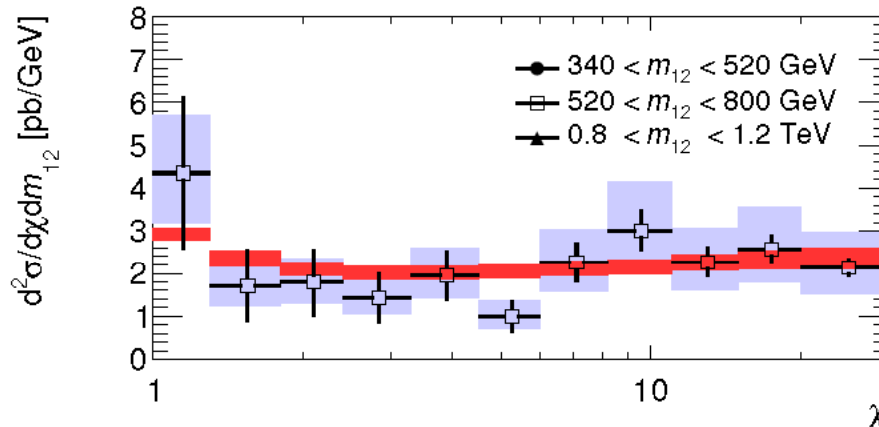
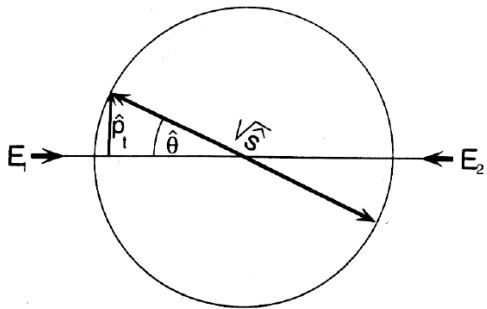
Measurement



Atlas: Dijet Angular Distributions

$$\chi = \exp(|y_1 - y_2|) \approx \frac{1 + \cos \theta^*}{1 - \cos \theta^*}$$

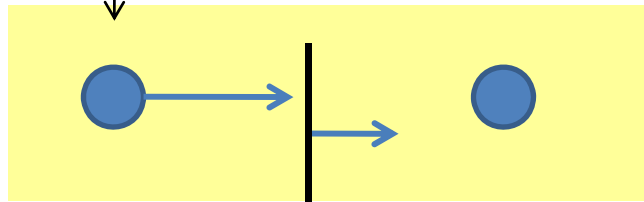
: Rutherford scattering appears flat



no sign (yet) of heavy particle decaying into two jets

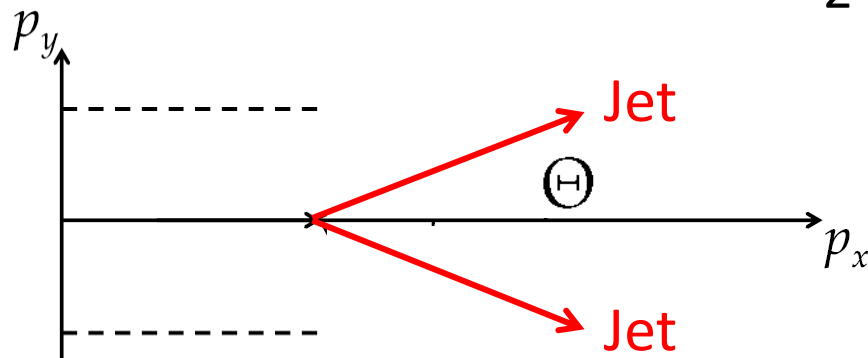
Jets from Air Showers?

$$y_{\text{UHECR}} = \ln \frac{E_p + p_p}{m_p} = \ln \frac{2 \cdot 10^{18}}{10^9} = \ln(2 \cdot 10^9)$$



$$y_{\text{CM}} = \frac{y_{\text{UHECR}}}{2} = \ln \sqrt{2 \cdot 10^9}$$

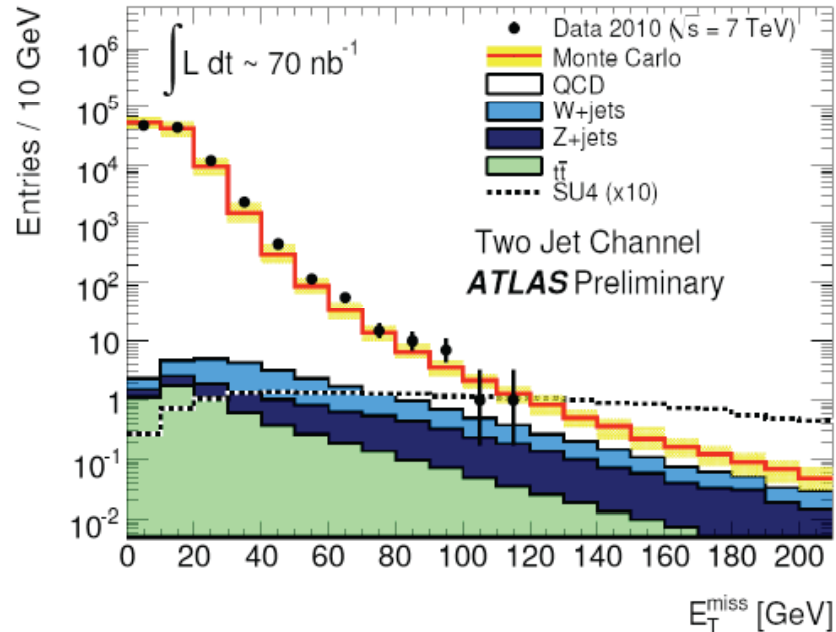
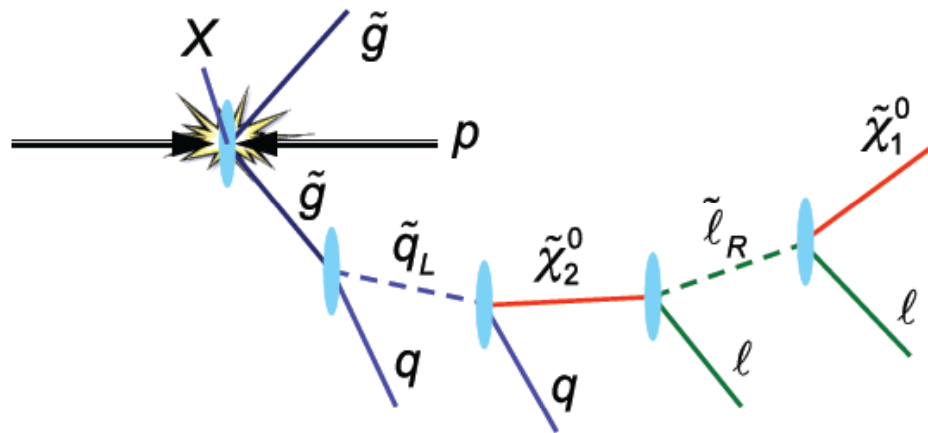
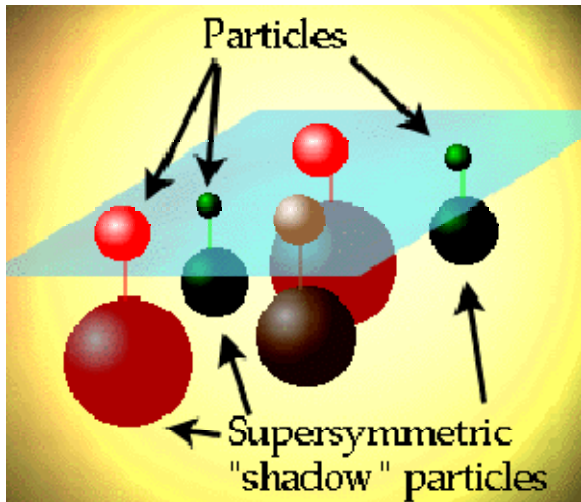
$$\gamma_{\text{CM}} = \cosh y_{\text{CM}} \sim \frac{e^{y_{\text{CM}}}}{2} = \frac{\sqrt{2 \cdot 10^9}}{2} \sim 2 \cdot 10^4$$



$$\ominus \approx \frac{1}{\gamma} = 0.5 \cdot 10^{-4} = \frac{0.5 \text{ m}}{10 \text{ km}}$$

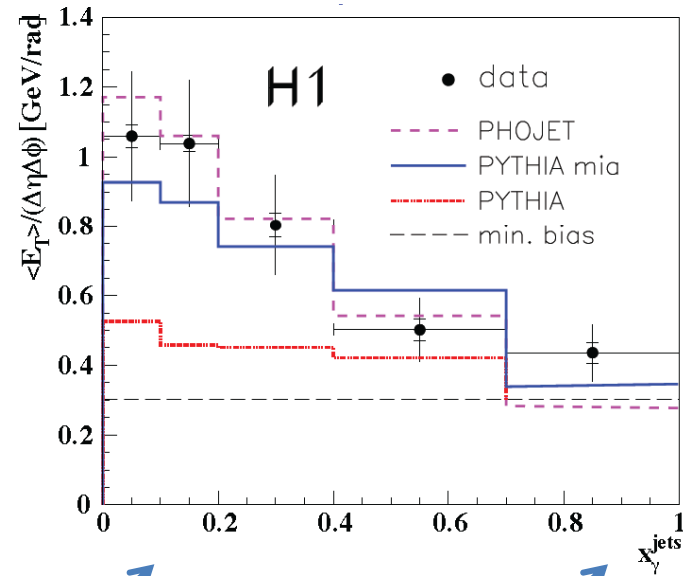
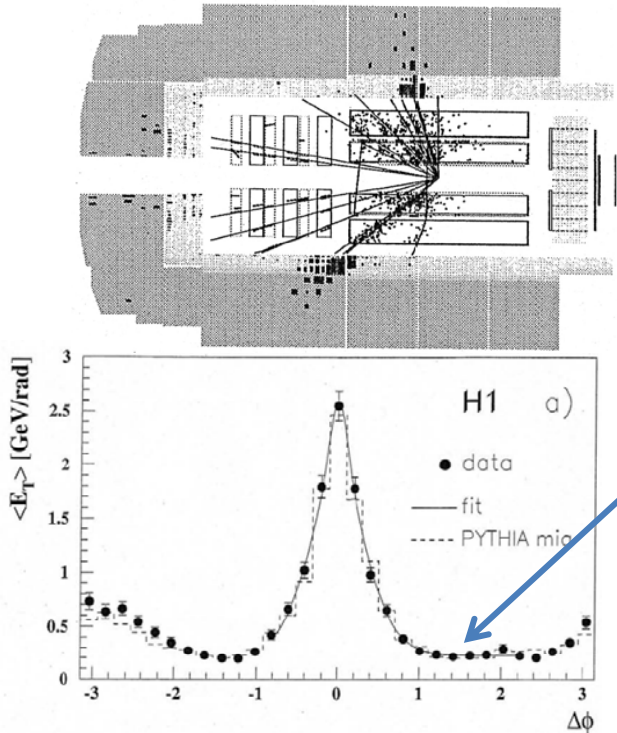
impossible to separate the jets

Atlas: Searches for Supersymmetry

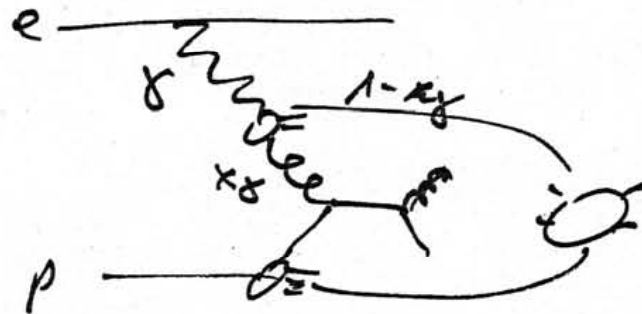


No sign (yet)

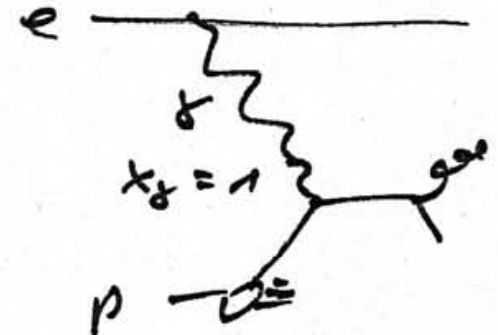
H1: Underlying Event Energy



Resolved photon interactions



Direct photon interactions

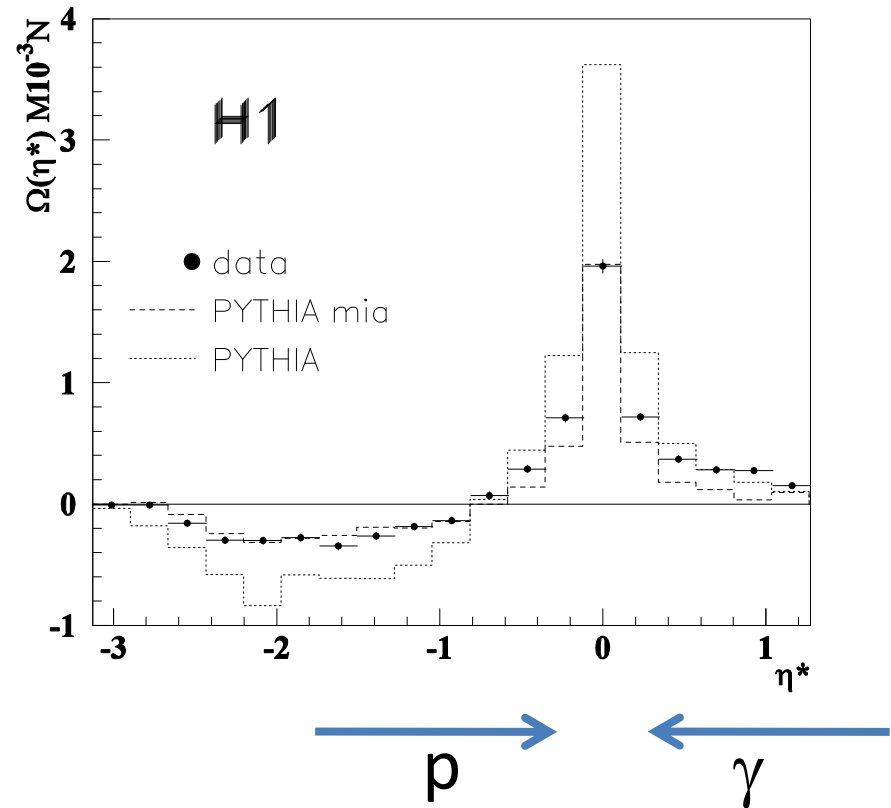
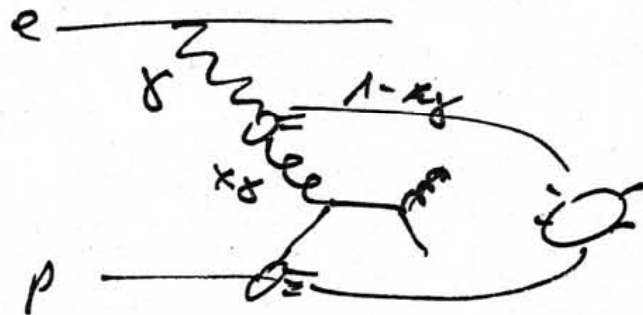
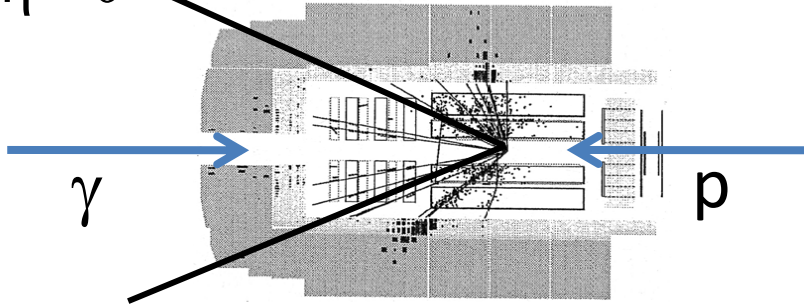


Multiple Parton Interactions

H1: Multiple Parton Interactions

$$\Omega(\eta^*) = \frac{1}{N_{ev}} \sum_{i=1}^{N_{ev}} \frac{(\langle E_{T,\eta^*=0} \rangle - E_{T,\eta^*=0,i}) (\langle E_{T,\eta^*} \rangle - E_{T,\eta^*,i})}{(E_T^2)_i}$$

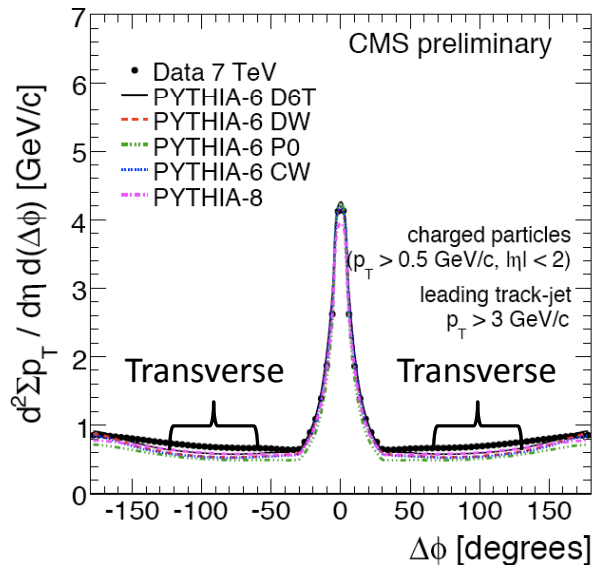
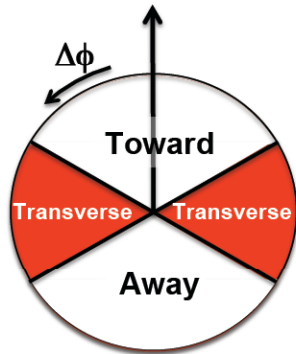
γp center-of-mass system
 $\eta^*=0$



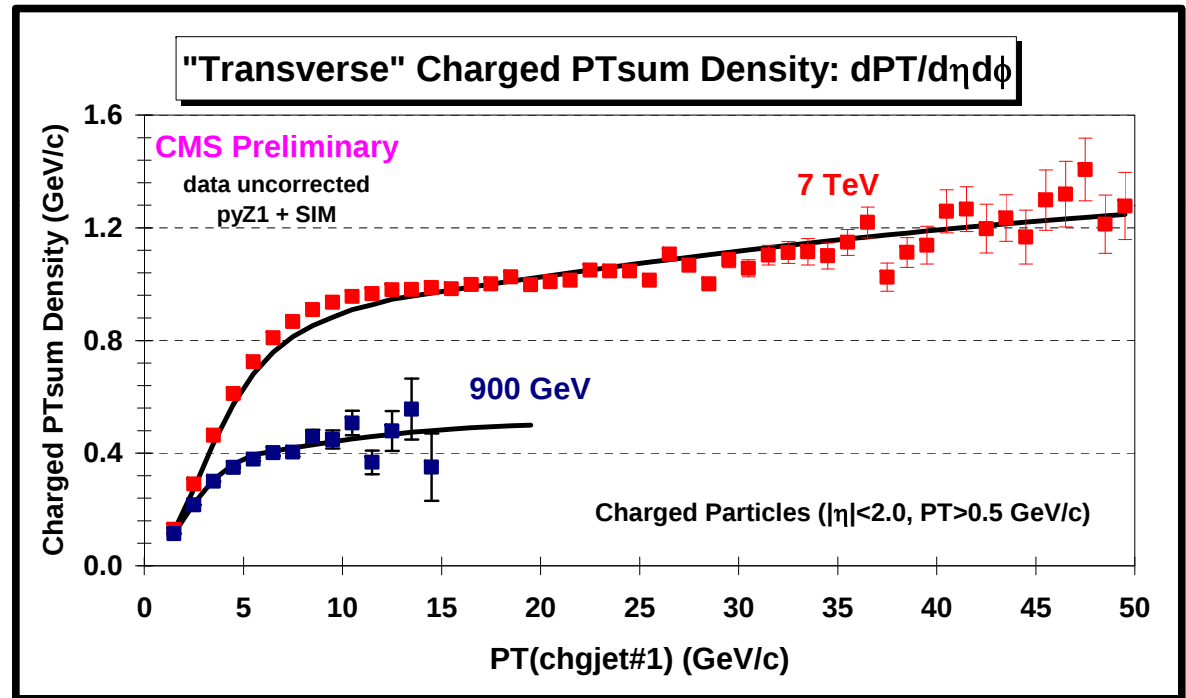
Uncorrelated additional interactions next to the hard parton scattering

CMS: Underlying Event

Leading Track Jet direction

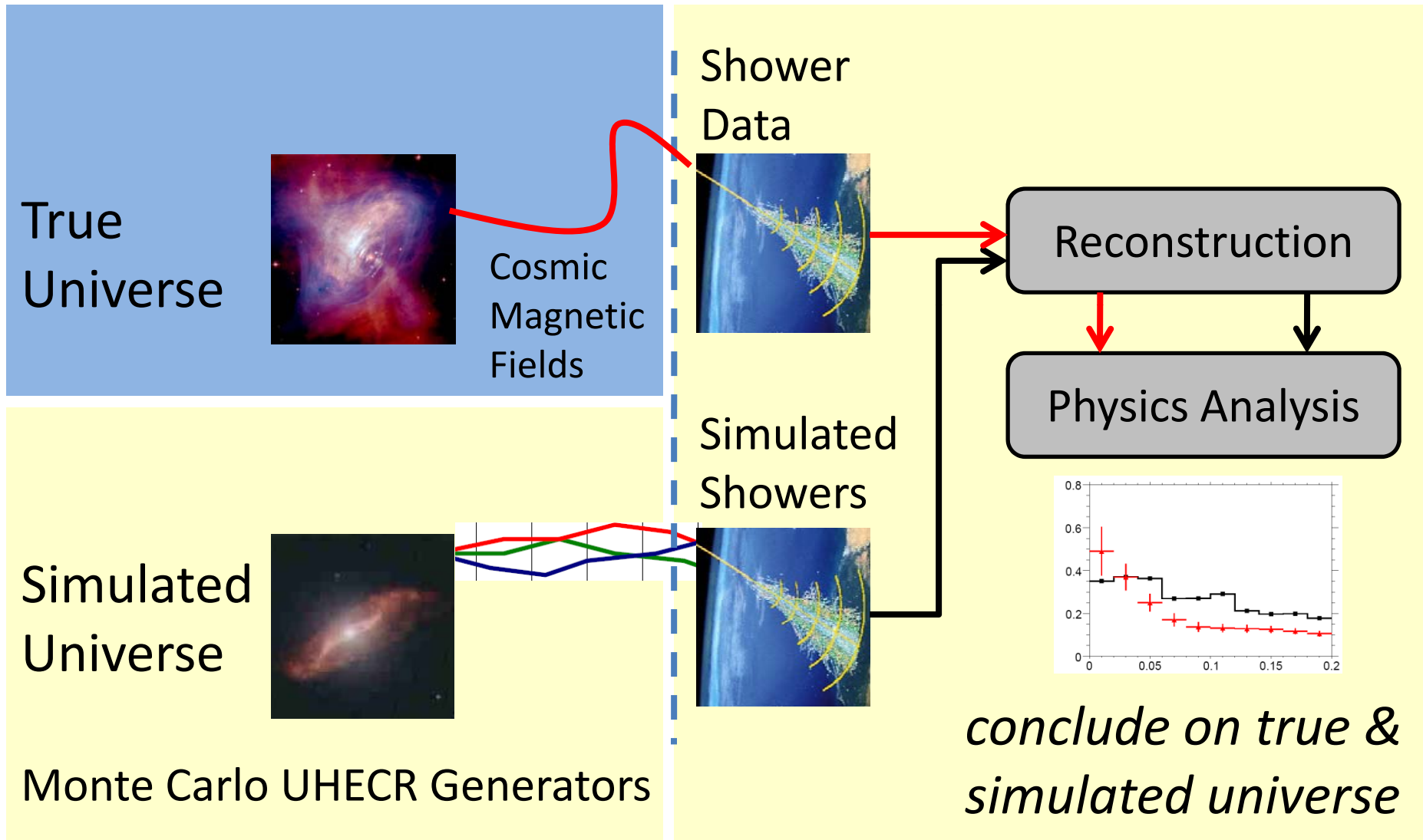


PYTHIA 6.4 tune p_T -ordered parton showers,
new Multiple Parton Interaction model



Charged energy
per unit rapidity-azimuth $E_{UE} \sim 1 \text{ GeV}$

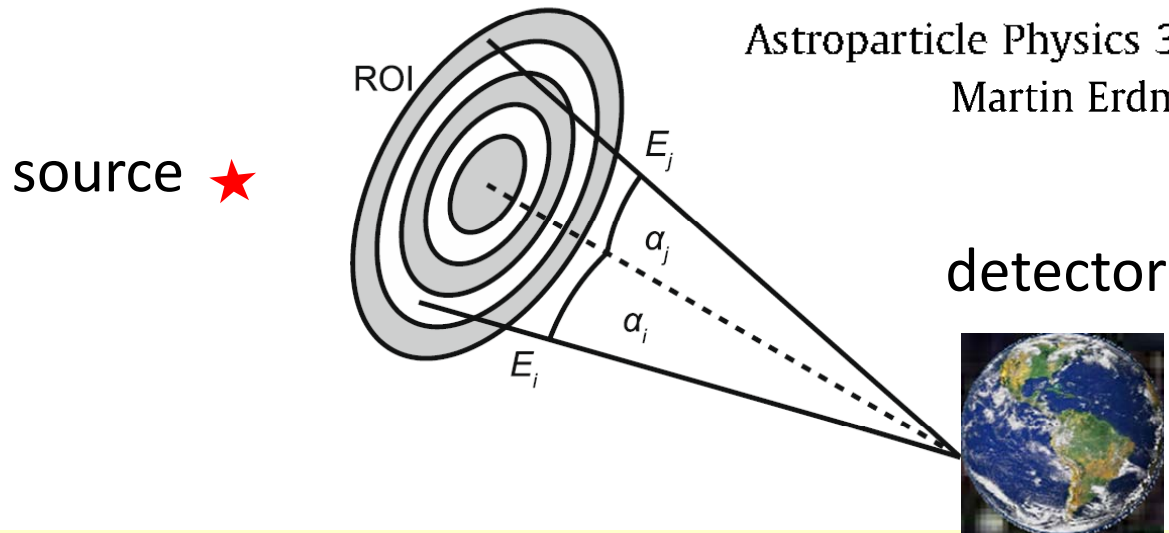
Astroparticle Physics Analysis



Advanced Autocorrelation Method

Astroparticle Physics 33 (2010) 201–205

Martin Erdmann, Peter Schiffer

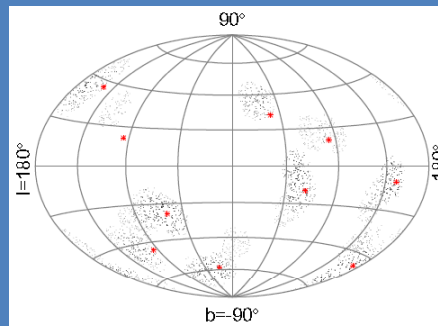
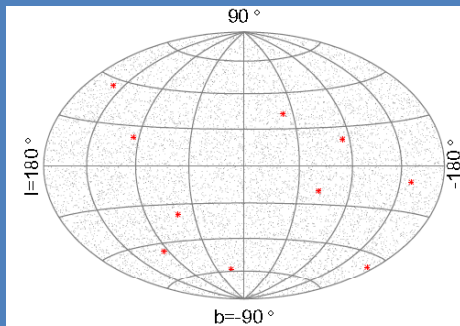
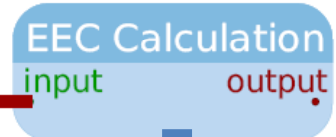
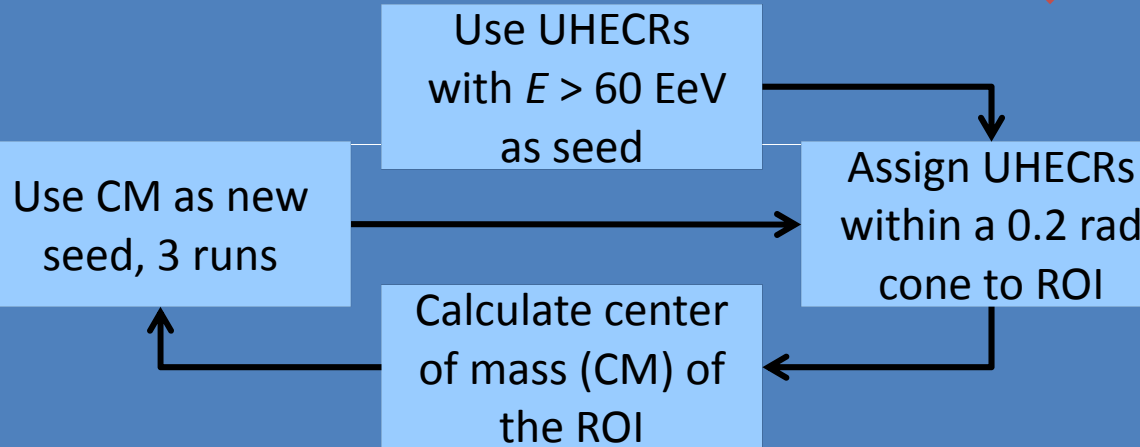
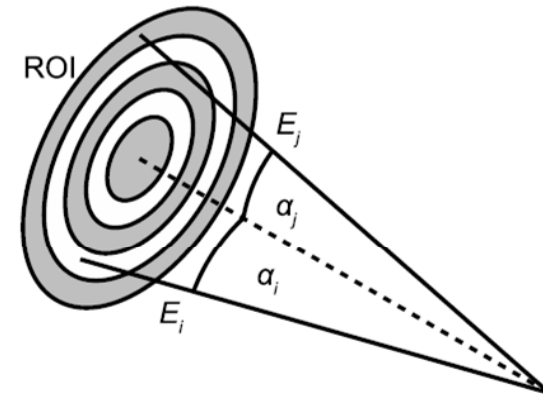
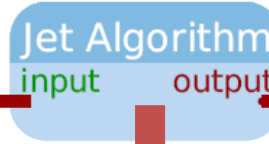
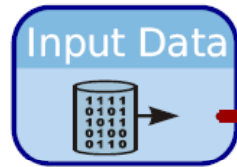


Energy-Energy-Correlations

$$\Omega_{ij} = \frac{(E_i(\alpha_i) - \langle E(\alpha_i) \rangle) (E_j(\alpha_j) - \langle E(\alpha_j) \rangle)}{E_i(\alpha_i) E_j(\alpha_j)}$$

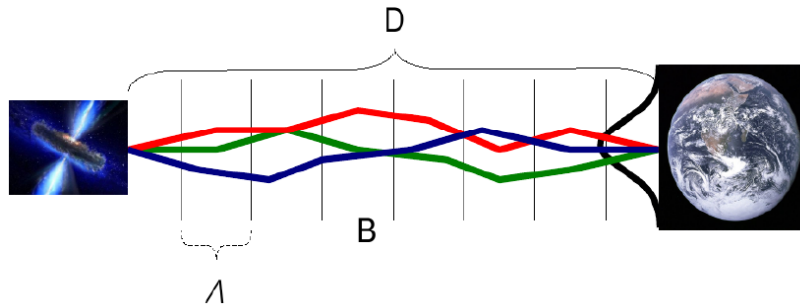
- Signal typically positive correlations $\langle \Omega \rangle > 0$
 - Background typically (naive) $\langle \Omega \rangle = 0$
- } expect mixture

Analysis Flow



$$\Omega_{ij} = \frac{(E_i(\alpha_i) - \langle E(\alpha_i) \rangle) \cdot (E_j(\alpha_j) - \langle E(\alpha_j) \rangle)}{E_i \cdot E_j}$$

Universe of Random Walk and coherent deflection



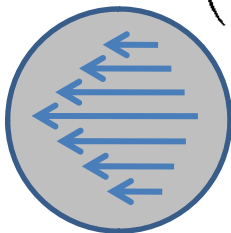
10 sources emitting
1000 protons each

$$\sigma_{\theta} \simeq 0.025 \text{ deg} \left(\frac{D}{\lambda} \right)^{1/2} \left(\frac{\lambda}{10 \text{ Mpc}} \right) \left(\frac{B}{10^{-11} \text{ G}} \right) \left(\frac{E}{10^{20} \text{ eV}} \right)^{-1}$$

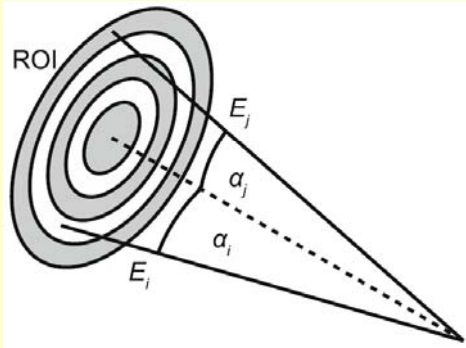
$$\sigma_{\theta} \simeq C_{\text{RandomField}} \left(\frac{E}{10^{18} \text{ eV}} \right)^{-1} \quad C_{\text{RandomField}} = 10 \text{ rad}$$

scenario, e.g. $D=50 \text{ Mpc}$, $\lambda=1 \text{ Mpc}$, $B=3 \text{ nG}$

$$\Delta \ell \simeq C_{\text{CoherentField}} \left(\frac{10^{18} \text{ eV}}{E} \right) \quad C_{\text{CoherentField}} = 10 \text{ rad, for } 60 \text{ EeV UHECR max. deflection } 10\text{deg, average deflection } 7.5\text{deg}$$

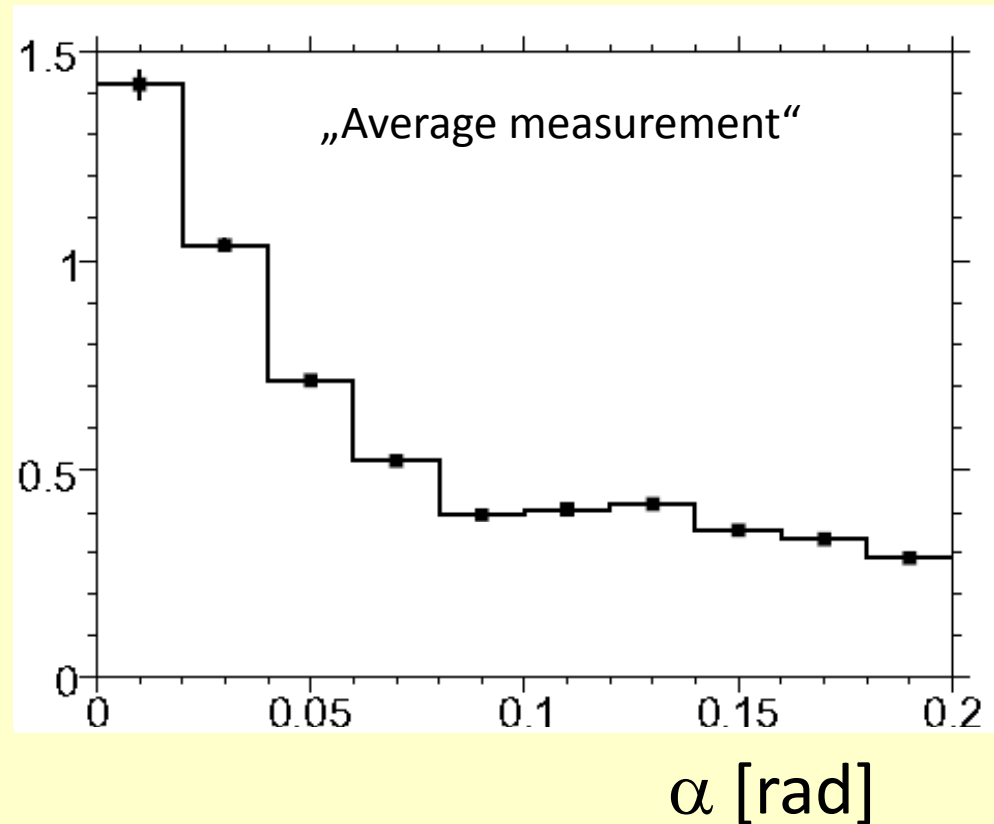


Energy-Energy-Correlation „Measurement“

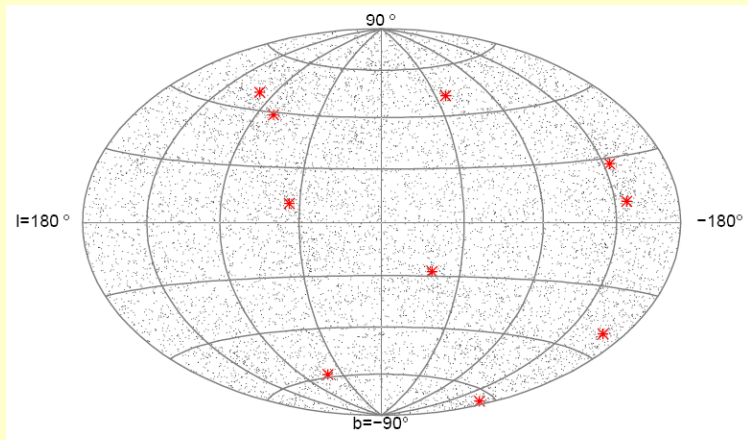


$$\Omega_{ij} = \frac{(E_i(\alpha_i) - \langle E(\alpha_i) \rangle) (E_j(\alpha_j) - \langle E(\alpha_j) \rangle)}{E_i(\alpha_i) E_j(\alpha_j)}$$

Ω



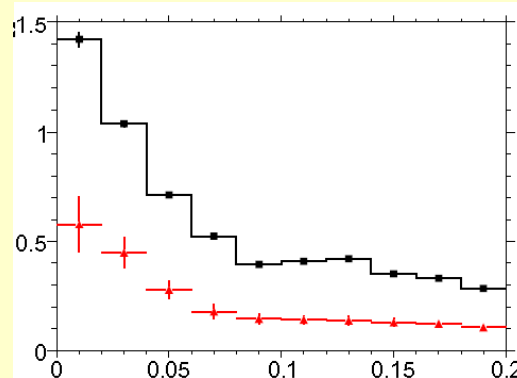
Interpretation of Measurement



Calculate many universes:

- **N sources**
each emits $10000/N$ UHECR
- **Random Magnetic field C**

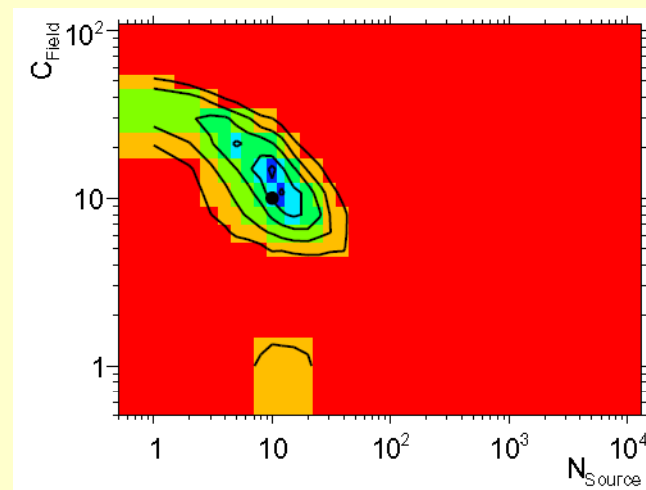
Ω



α [rad]

$C_{\text{Random Field}}$ [rad]

$C_{\text{Random Field}}$



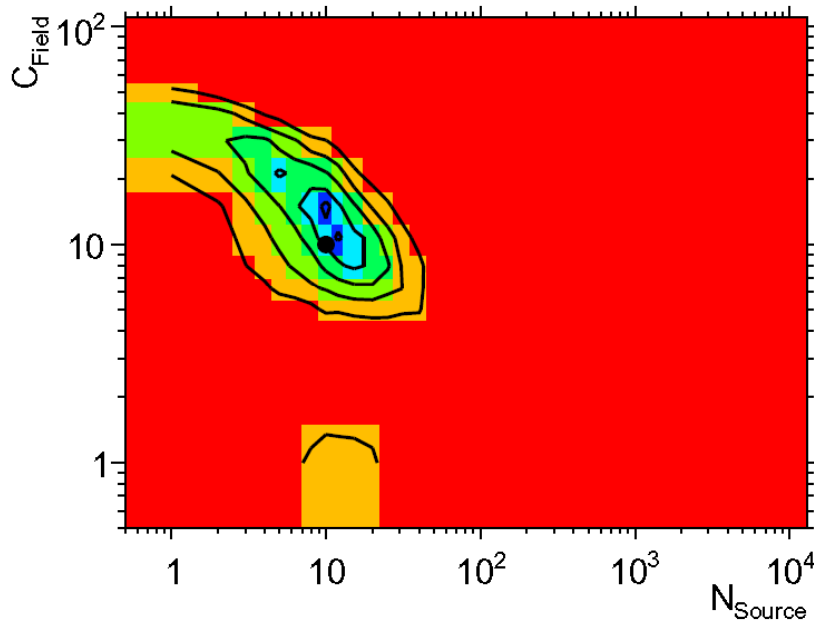
N

reject hypothesis in red region $>5 \sigma$

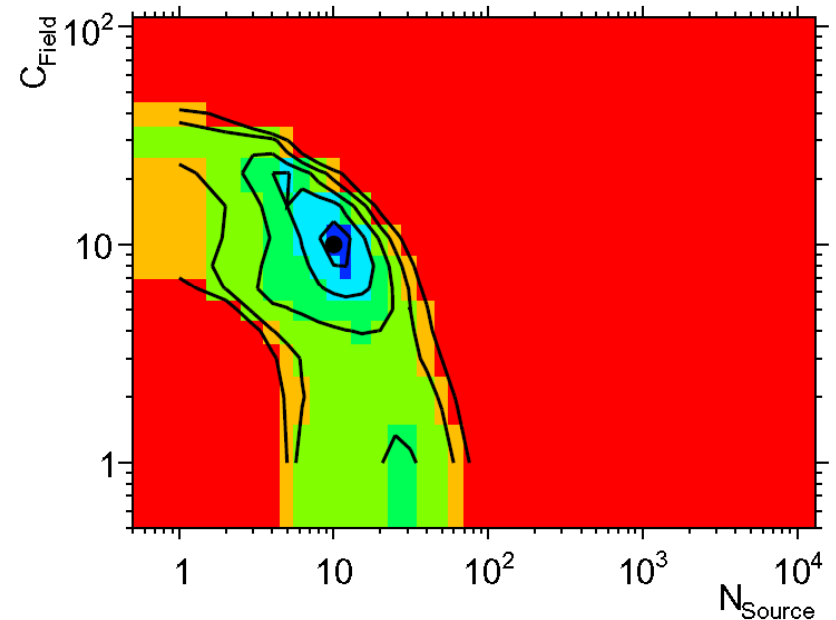
Successful reconstruction of universe $C_{\text{Random Field}}=10$ rad, $N_{\text{Source}}=10$

Systematic Check

Original single realization



100 Realizations using original parameter



No significant shift caused
by reconstruction method

Without knowing the sources: method constrains
phase space of the parameters of a universe model

Astroparticle Physics Analysis

True
Universe



Shower
Data



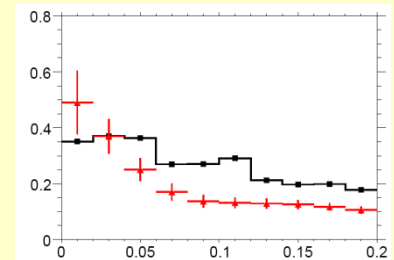
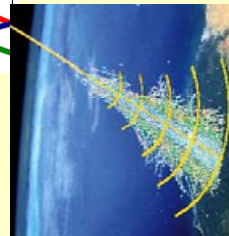
Reconstruction

Physics Analysis

Simulated
Universe



Simulated
Showers



Monte Carlo UHECR Generators

*conclude on true &
simulated universe*

Simulation of More Realistic Universes

10 EeV Proton

Trajectory calculated
with CRPropa

Constrained
simulation of
structure
formation
reproduces
local universe

K. Dolag et. al. Journ.
Cosm. and Astropart.
Phys. 2005



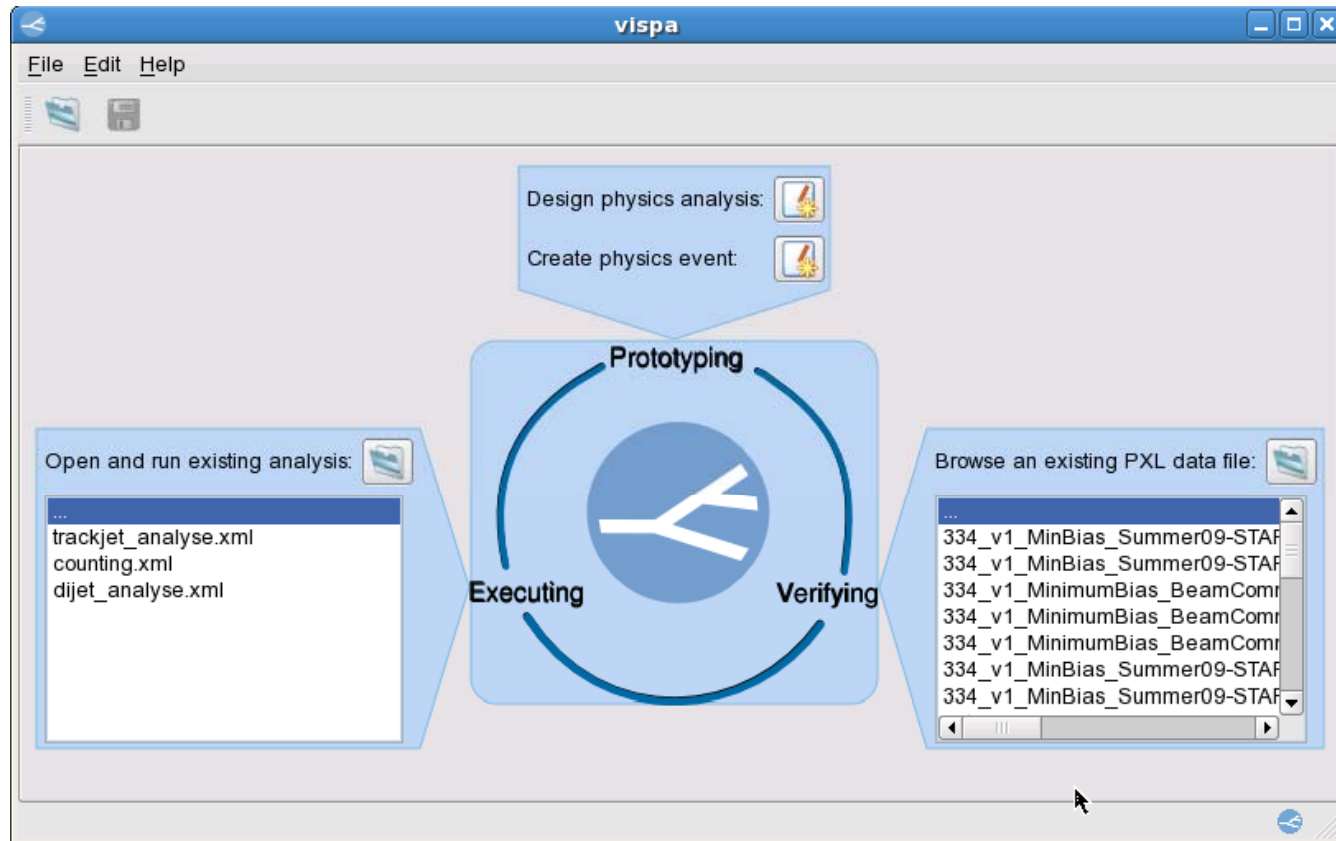
Preliminary

Gero Müller
Christoph Genreith
Tobias Winchen
David Walz
Peter Schiffer
Martin Erdmann

see contributed talk
by Gero Müller

110 Mpc

Graphische Entwicklungsumgebung für Physik Analysen



Astroteilchenphysik
Hochenergiephysik

Paradigmen {

- Objektorientiert
- Datenflussbasiert
- Grafisch

Analysis Designer

The screenshot shows the Analysis Designer interface with a workflow diagram in the center. The workflow starts with two input modules, 'MC' and 'DATA', which feed into a central 'selection_script.py' module. The output of this script is split into two paths: 'MC Selected Events' and 'DATA Selected Events'. The interface includes a menu bar (File, Edit, Analysis Designer, View, Help), a toolbar, and a sidebar with 'Available Modules' and 'Python Scripts'. The 'Available Modules' list includes PySwitch, PyModule, PyGenerator, PyDecide, PyAnalyse, File Output, File Input, GlobalModule, and AutoProcess. The 'Python Scripts' list includes withROOT, selection_script.py, count_script.py, zmumu_mc_10.pxl, split_3streams_scrip, zmumu_steering.pxl, rename_particles_s, sort_filter_particles, zmumu_mc_10_ren, zmumu_mc_10_sel, zmumu_mc_10_sel, zmumu_mc_10_stre, zmumu_mc_10_stre, zmumu_mc_10_stre, and zmumu_autoprocess. The 'Property' panel on the right shows the configuration for the 'MC' module, including its name, type, run index, filename, start, end, and additional files.

Module Skeletons

Python C++

Module Configuration

Analysis Flow (Interface!)

Property	Value
Main	
Name	MC
Type	File Input
runIndex	0
Options	
filename	_mc_10.pxl
start	0
end	-1
Additional fil...	['']

Opening file /home/home1/institut_3a/hinzmann/workspace/vispa-trunk/examples/AnalysisDesigner/selection.xml... done.

Data Browser

The screenshot shows the vispa Data Browser interface. The title bar indicates the file path: `vispa - /home/home1/institut_3a/hinzmann/workspace/vispa-trunk/examples/AnalysisDesigner/zmumu_mc_10.pxlio`. The interface is divided into three main panels:

- Tree View:** Located on the left, it shows a hierarchical structure of the event data. The 'Event' node is expanded, revealing 'Generator' (with sub-nodes 'd', 'Z', 'mu', 'mu') and 'Reconstructed' (with sub-nodes 'Muon', 'Muon', 'MET'). An arrow labeled 'data structure' points to this panel.
- Line Decay View:** Located in the center, it displays a diagram of the particle decay process. The 'Event' section shows a Z boson decaying into two muons (μ). The 'Reconstructed' section shows the corresponding reconstructed particles: two Muons and MET (Missing Transverse Energy). An arrow labeled 'data relations' points to this panel.
- Property View:** Located on the right, it displays a table of properties for the selected object (muon). The table has two columns: 'Property' and 'Value'.

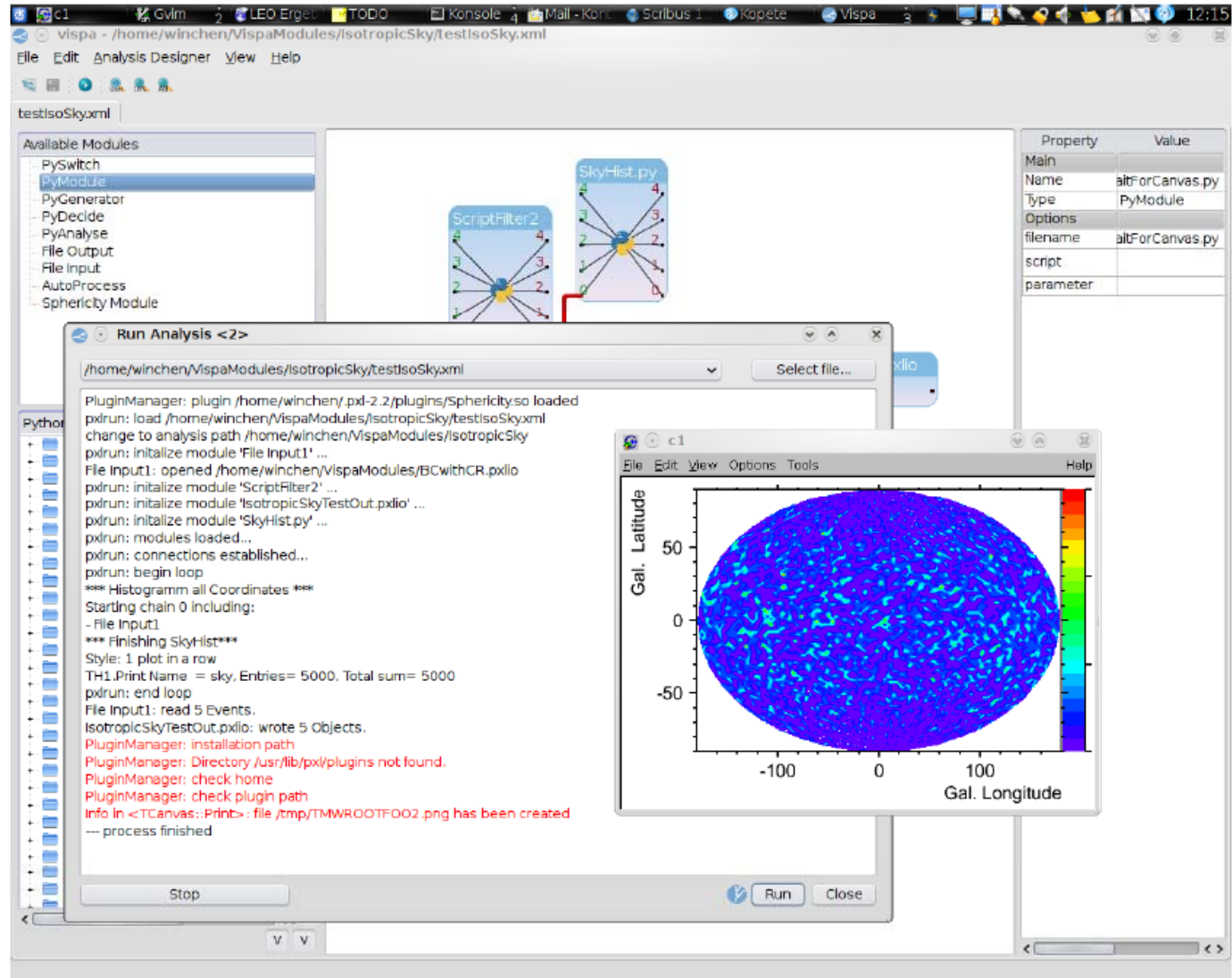
The Property View table contains the following data:

Property	Value
Object info	
Name	mu
Type	Particle
Charge	0
Id	64f-9ef3-1d7fce0d6f3b
Index	4
PdgNumber	-13
WorkFlag	0
Vector	
E	49.07673903
Px	-26.20675469
Py	-26.55011882
Pz	-31.88767024
Mass	0
Pt	37.30553311
Eta	-0.7748680099
Phi	-2.349686158
P	49.07673903
Et	37.30553311
Theta	2.278053417
SoftRelations	
UserRecord	
anticolour_in...	0
c_tau	0
colour_index	0

Arrows labeled 'inspect data' and 'user invented data' point to the 'Py' and 'anticolour_in...' rows, respectively. The status bar at the bottom indicates 'Updating property view... done.'

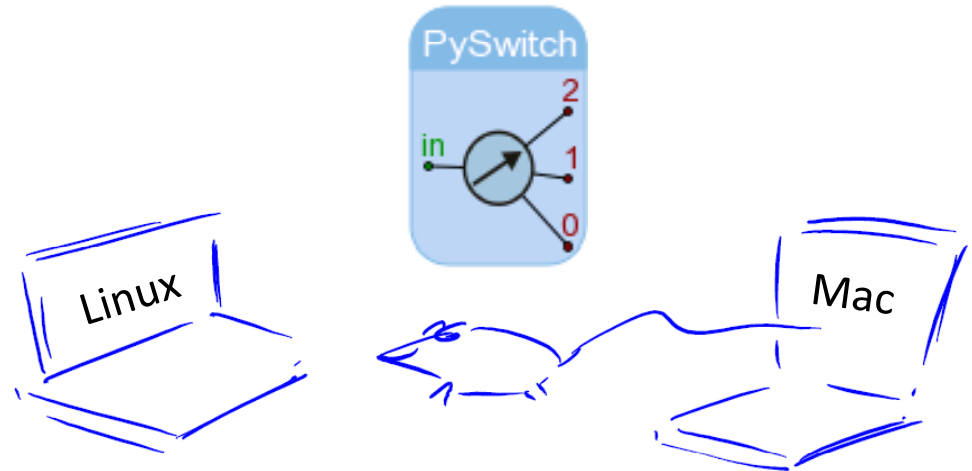
Application Astroparticle Physics

*Execute
Analysis
→
ROOT
Connection*



Team Work

*Do you have
a module which... Yes...*



Drag-in-and-Play

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<http://vispa.sourceforge.net>

Summary

- Parton Scattering correctly predicted by QCD
- Data Analysis at LHC with enormous progress
- Information on Cosmic Magnetic Fields through Correlations
- You may want to try VISPA for developing your analysis