Angular Distribution of Gamma-rays from Up-to-date p-p Interactions

GLAST Science Lunch Talk
Aug 3, 2006

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Outline

- Recap
  - p-p interaction model
  - parameterization of gamma-ray spectra
- Angular distribution of gamma-rays - simulations
- Parameterization of angular distribution
- Final words, ideas, input!

p-p Interaction Model

- Kamae et al. (2005): previous models of inelastic proton-proton interaction lacked several key features:
  - diffraction dissociation process
  - violation of Feynman scaling
  - logarithmically rising inelastic p-p cross section

- Up-to-date model created
  - missing features included

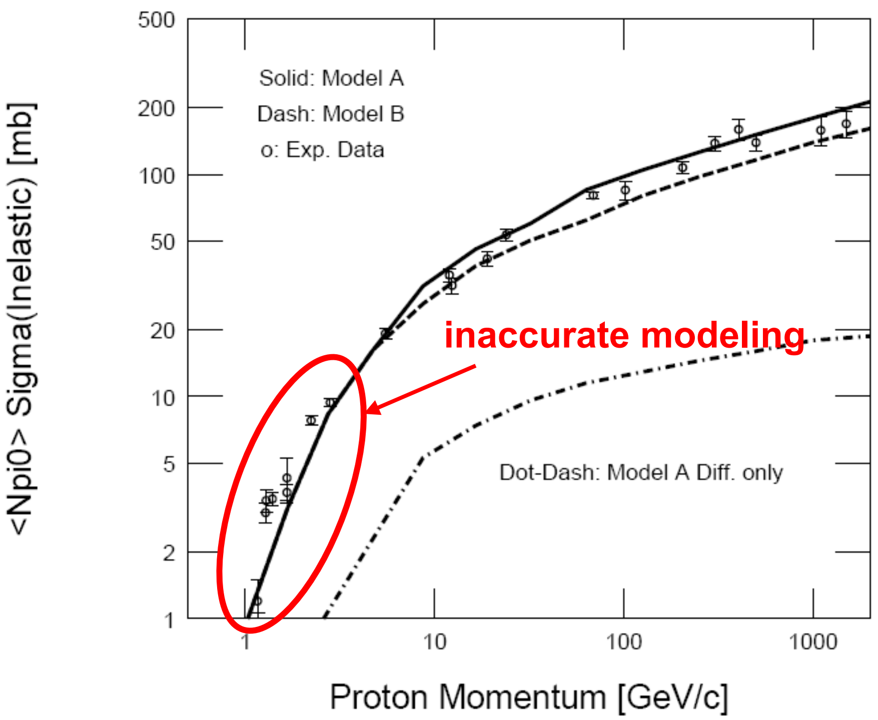
- Simulations show
  - 30%-80% more π^0 produced
  - gamma-ray spectrum harder than incident proton spectrum
  - Kamae et al. (2005) claimed to explain 50% of the GeV-excess in EGRET data

Inelastic Proton-Proton Interaction

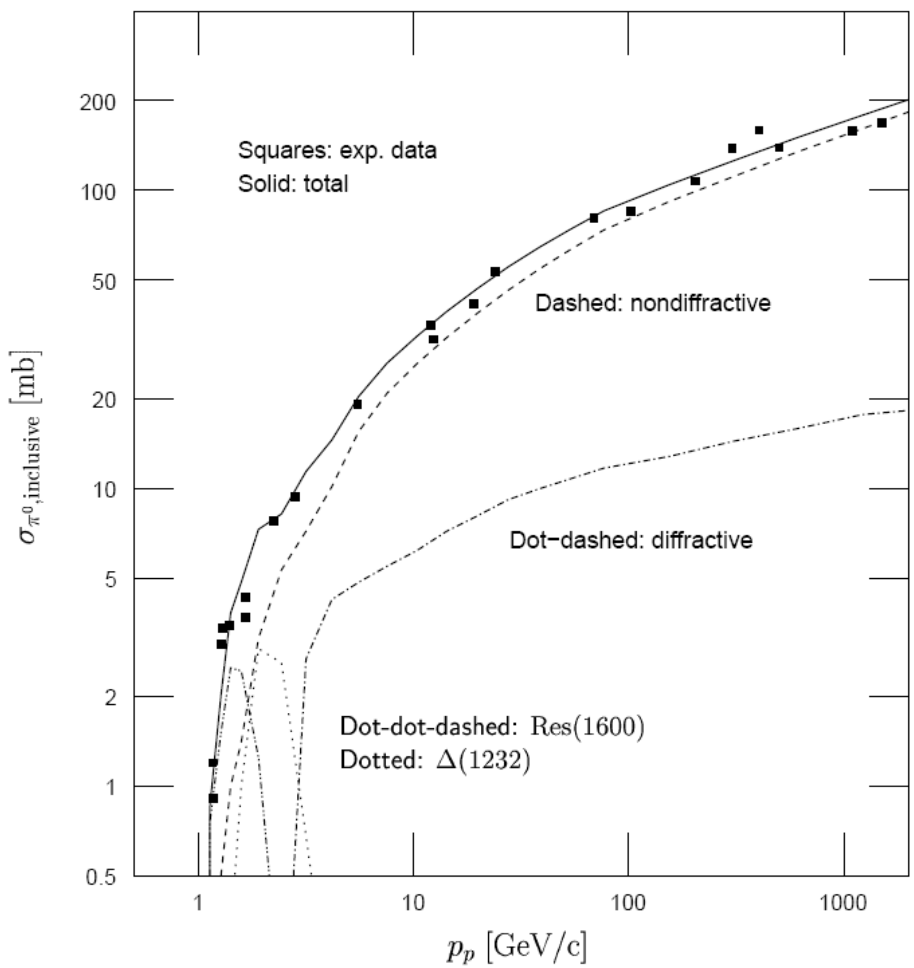
- Inelastic proton-proton interaction model:
  - non-diffractive interaction including violation of Feynman scaling
    - high energy ($T_p > 52.6$ GeV): simulated with Pythia 6.2
    - low energy ($T_p \leq 52.6$ GeV): parametric model of pion cross sections by Blattnig et al. (2000)
  - diffraction dissociation process
- Above not accurate enough near pion production threshold
  - add modeling of two baryon resonances
  - Δ(1232) and Res(1600)
- MC simulations for above processes
- Calculated inclusive cross sections for the stable secondary particles
  - γ-rays, electrons, positrons and four neutrino species

π^0 Multiplicity

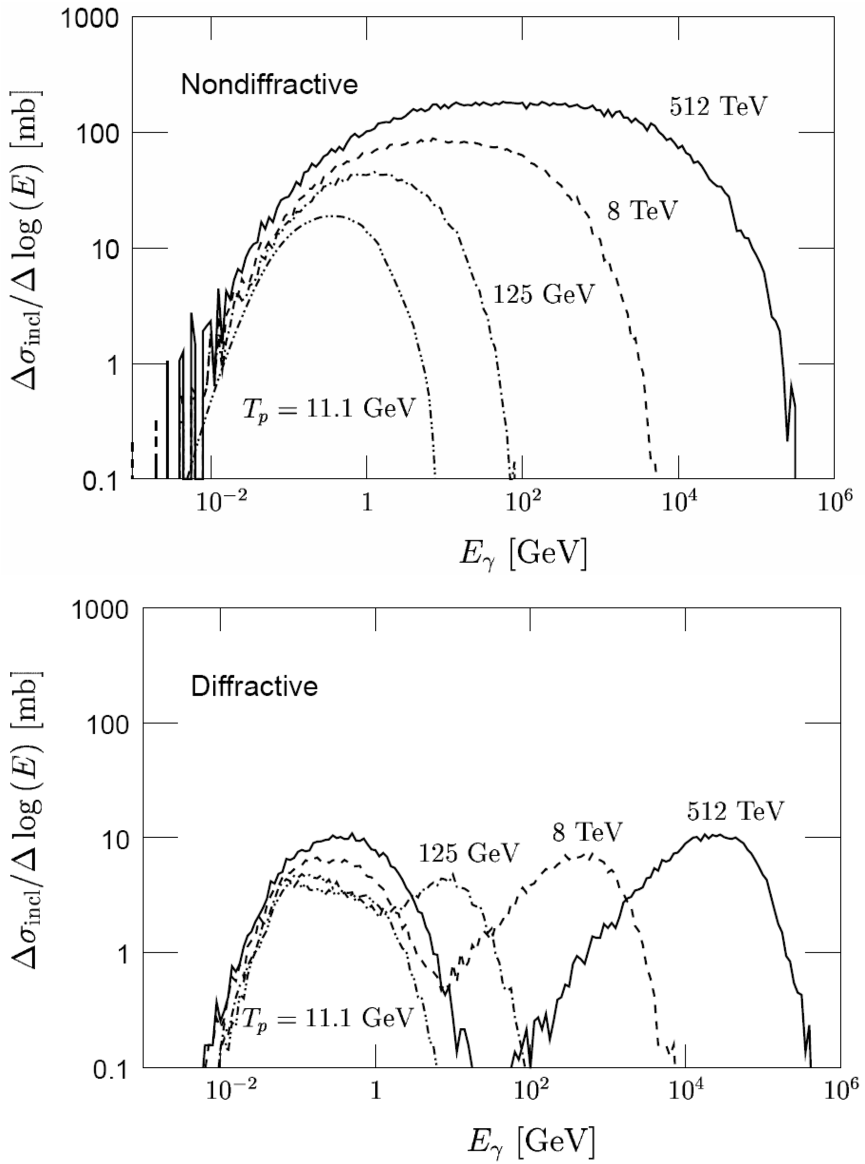
Without baryon resonances



With baryon resonances



Inclusive Gamma-ray Cross Sections



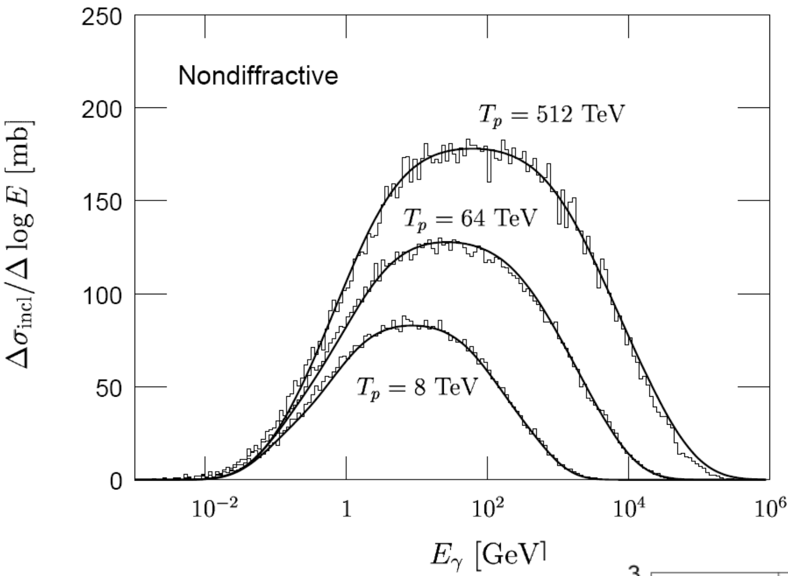
Parameterization of Incl. Cross Section

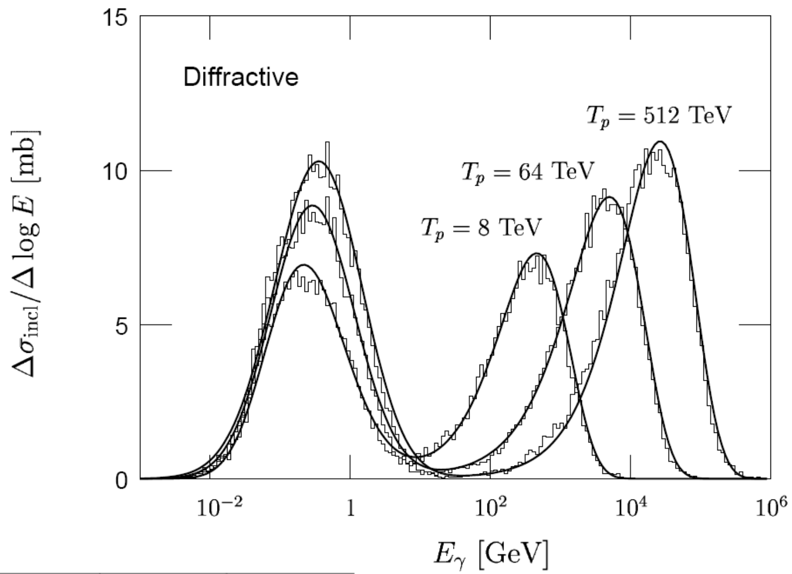
- Wanted: the inclusive cross section as a function of proton kinetic energy and photon energy

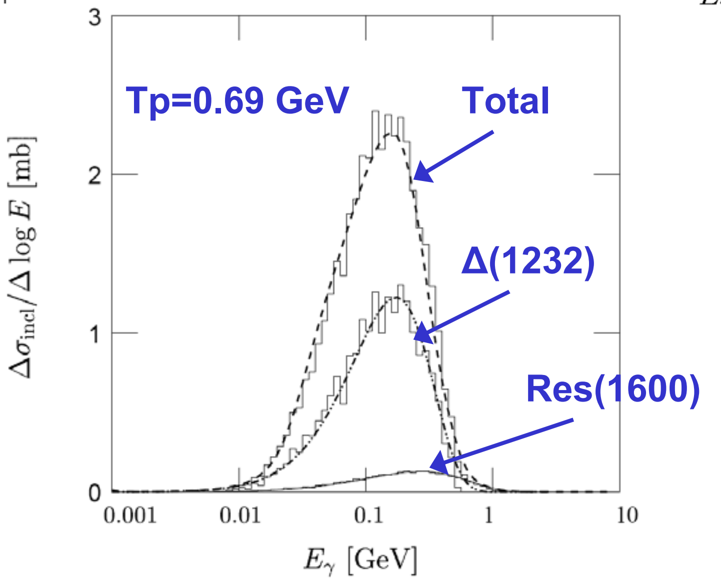
- For each of the four components:
  - fit to common function forms (functions of $\log(E_{sec})$), one form for each component
    $\rightarrow$ set of parameters for each Tp
  - then fit these parameters as functions of Tp

- Parameterization has been completed for all stable secondary particles
  - γ-rays, electrons, positrons and four neutrinos

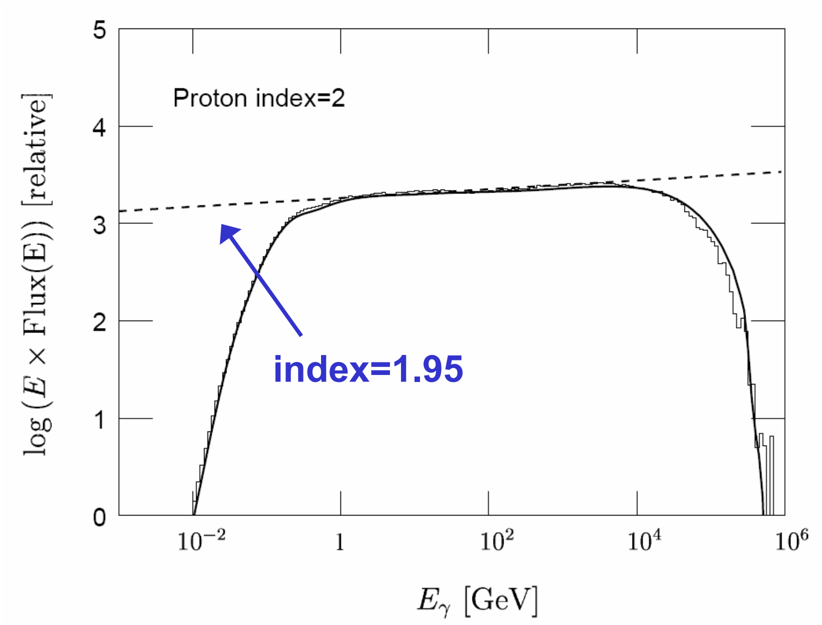
Comparison: MC vs Parametric model





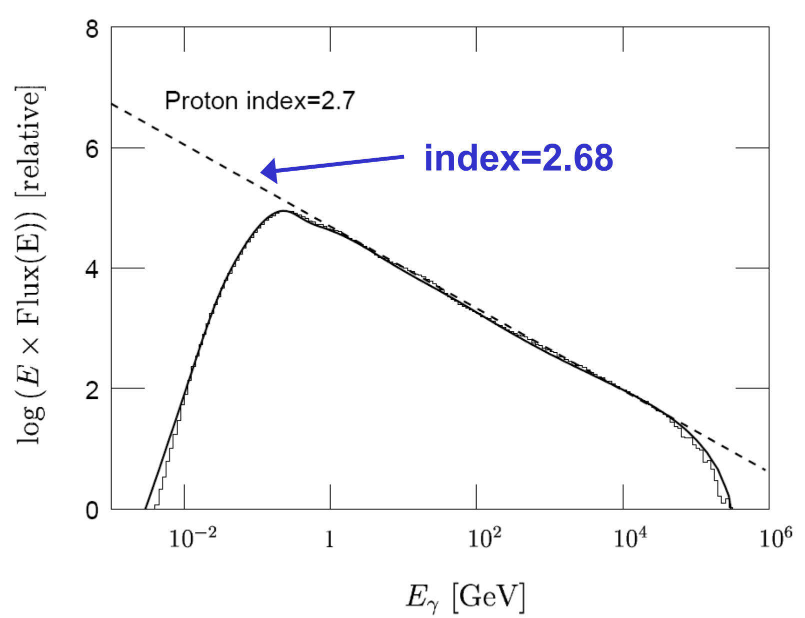


Gamma-ray Spectrum



Histograms: Monte Carlo simulations
Solid lines: calculations with parametric model
Dashed lines: asymptotic power-law

(no absolute normalization!)



Angular Distribution - Simulations

- **Assumptions:**
  - **stationary target experiment**
  - **projectile proton along z-axis**

- **For each event**
  - **calculate p_T (GeV/c) and θ (arcmin)**
  - **bin in 2D histograms**

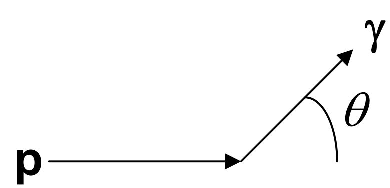
    pixel size: Δp_T=10MeV/c, Δθ=2 arcmin

$$p = (p_x, p_y, p_z)$$

$$p_{abs} = \sqrt{p_x^2 + p_y^2 + p_z^2}$$

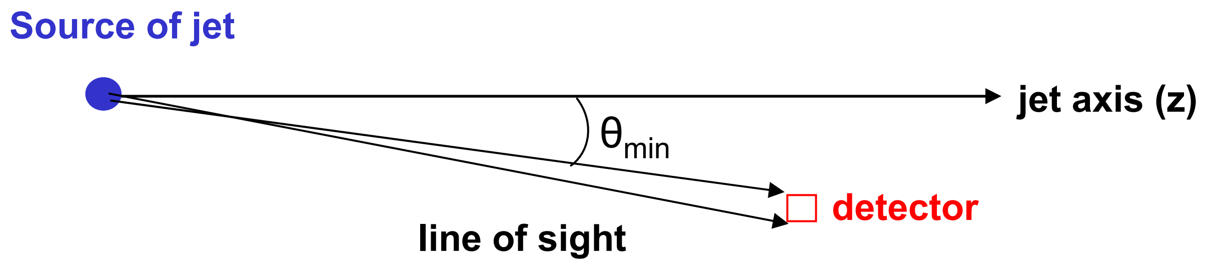
$$p_\perp = \sqrt{p_x^2 + p_y^2}$$

$$\theta = \arcsin\left(\frac{p_\perp}{p_{abs}}\right)$$

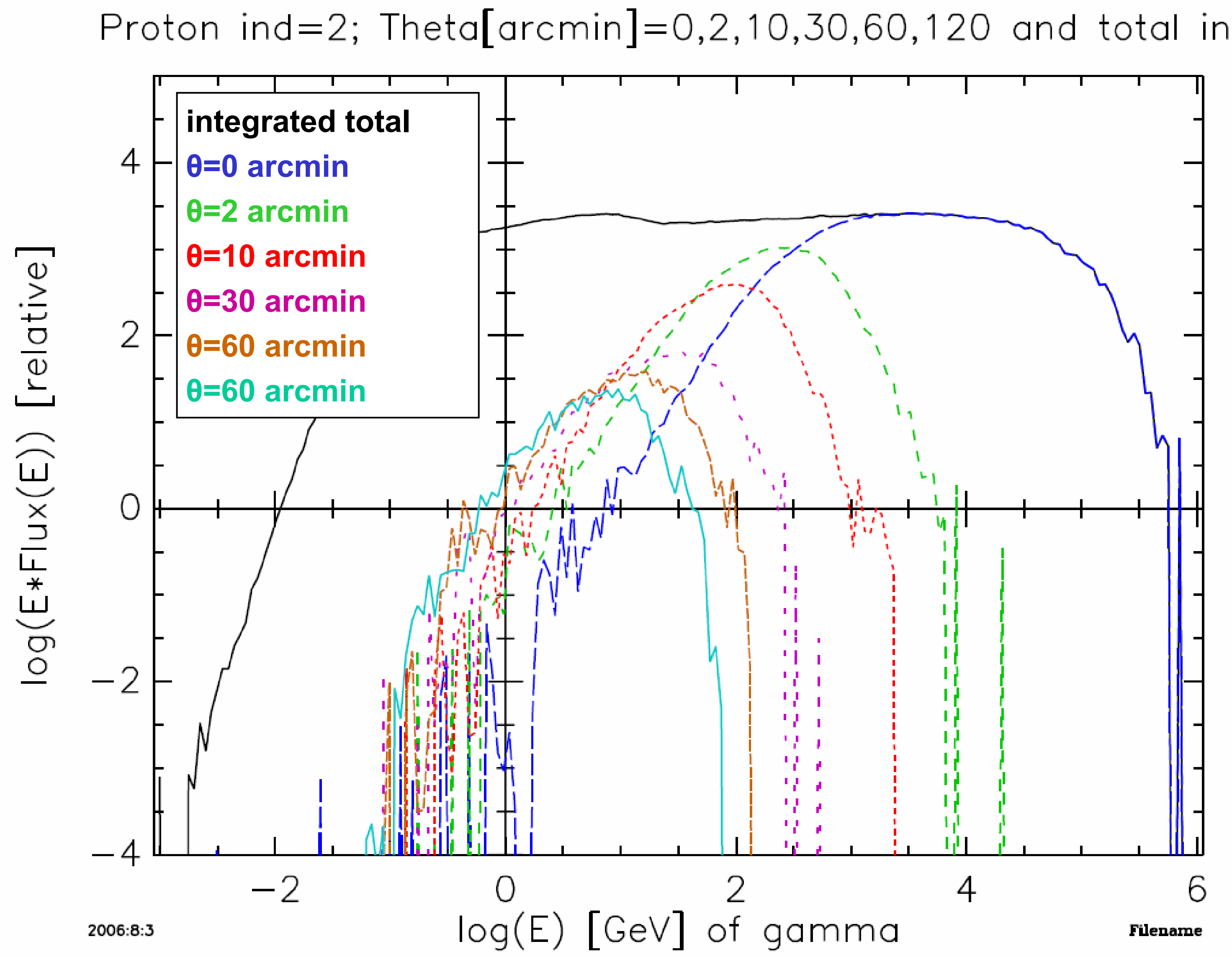


Pencil Proton Beam

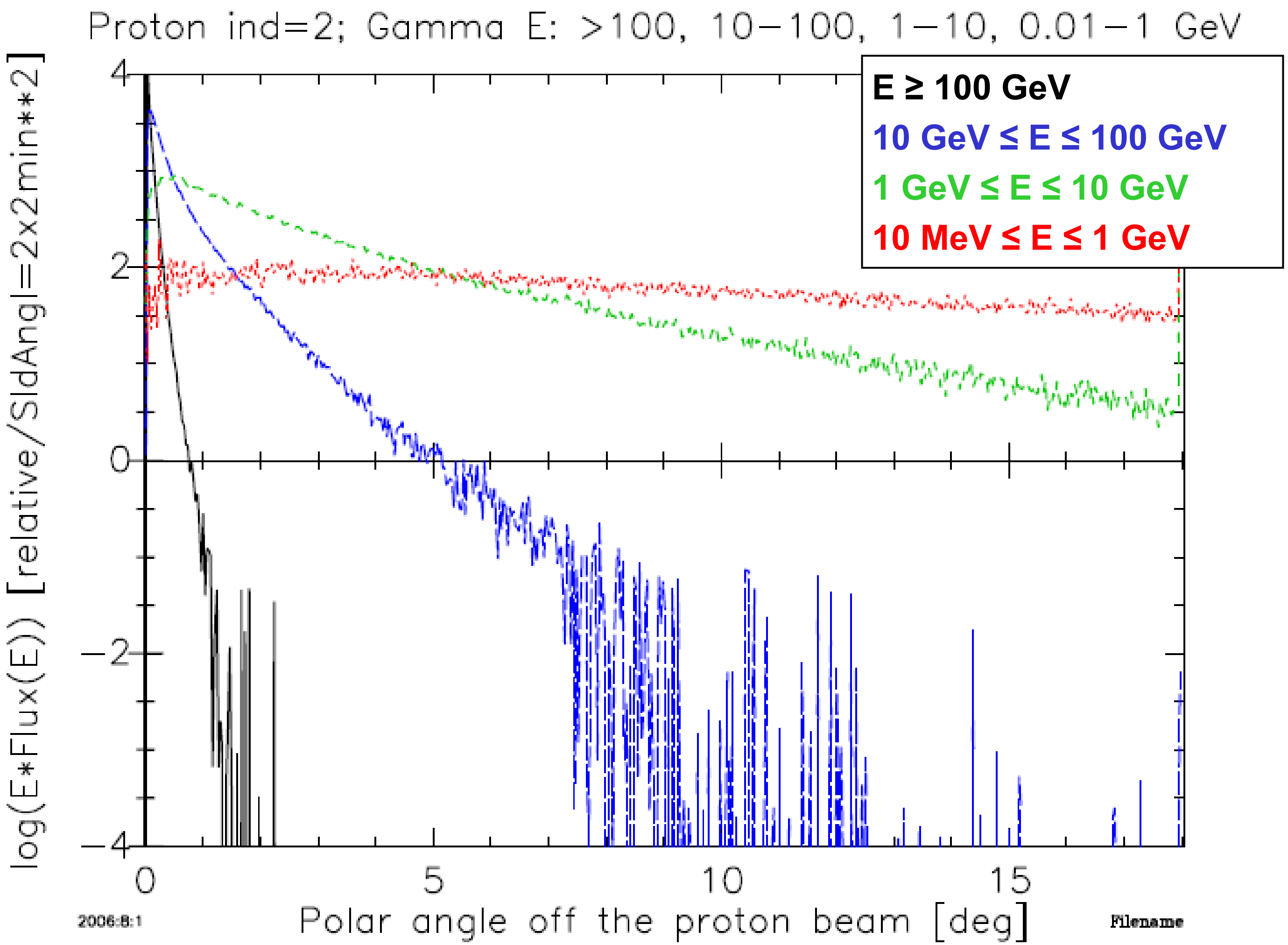
- Jet axis offset an angle θ from the line of sight
- How does the spectrum change with θ?
- Difference in angular distribution between energy bands?



Pencil Proton Beam (cont.)



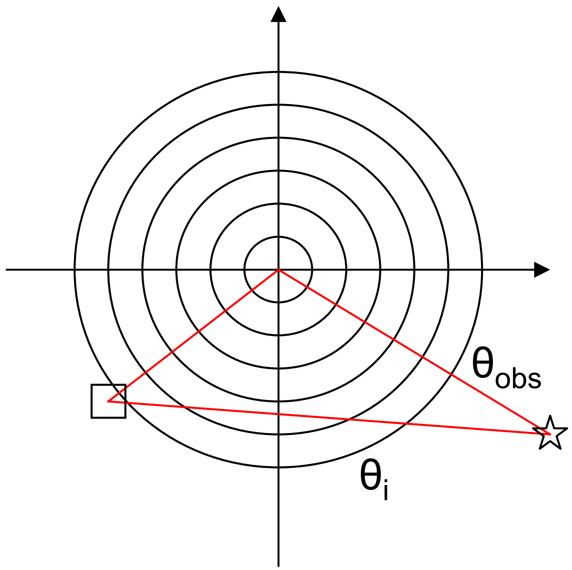
Pencil Proton Beam (cont.)



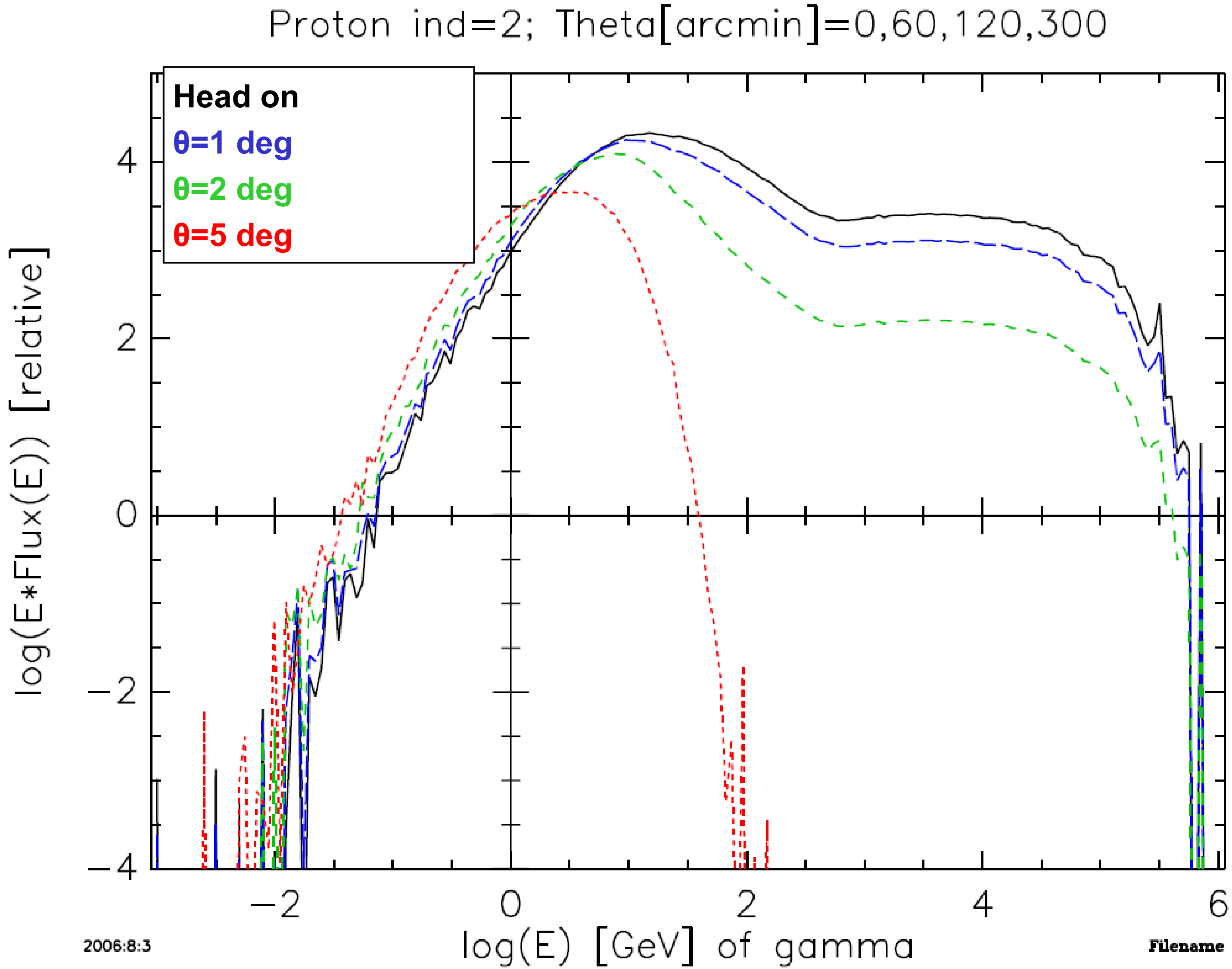
Gaussian Proton Beam

- Beam has a Gaussian (2D) profile
  - FWHM 2 deg → $\sigma \approx 1$ deg

- Convolve spectrum using beam profile
  - bin the profile in 5 arcmin bins
  - calculate relative angle to each bin
  - weight with profile of the beam
  - sum contributions from all bins



Gaussian Proton Beam (cont.)

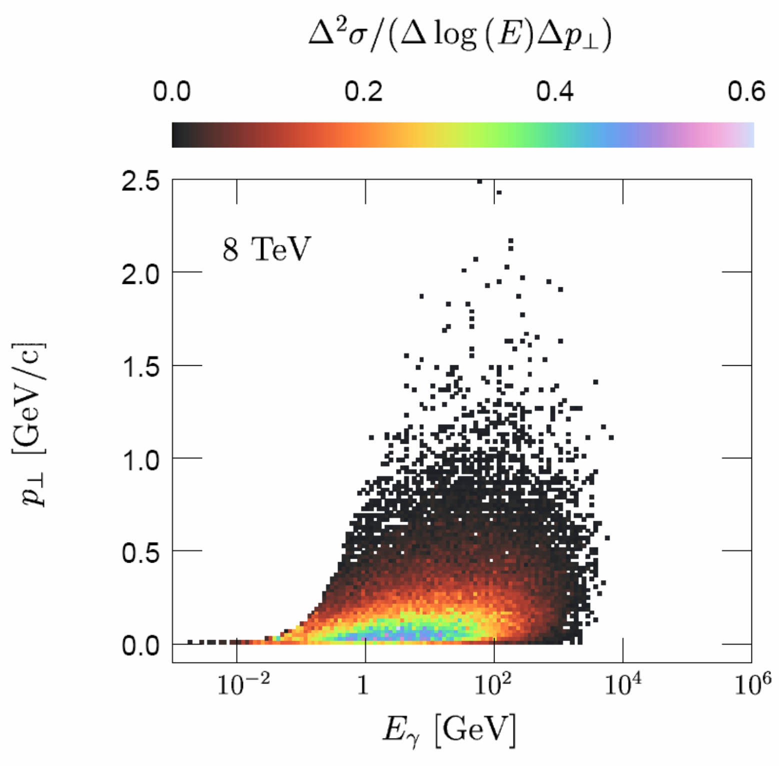


Parameterization of Angular Distribution

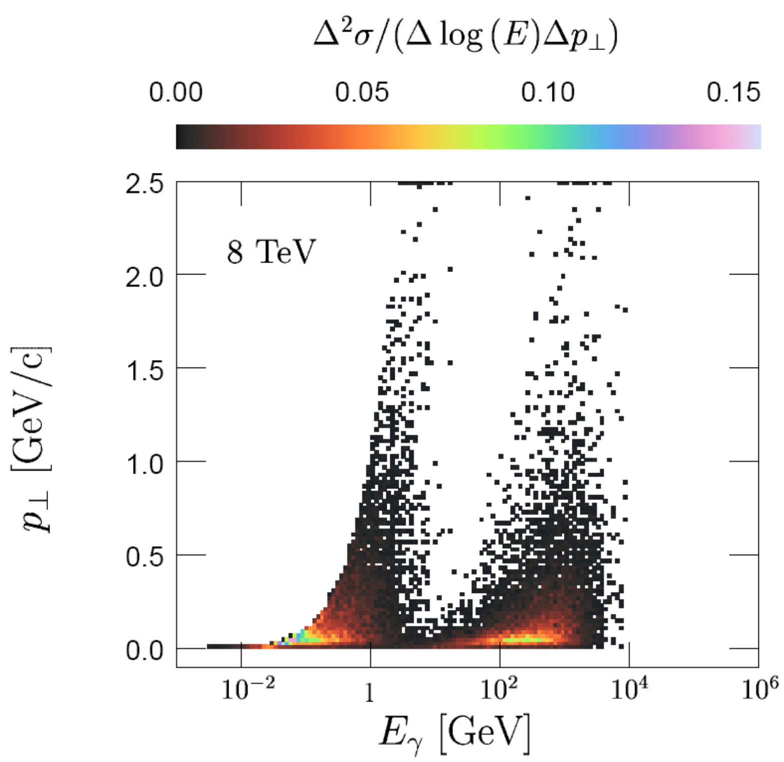
- Same idea as for total inclusive cross section
- Work with transverse momentum not angle
- Only gamma-rays worth while
- For each component
  - parameterize p_T distribution as functions of E_γ and p_T
  - first, for every Tp, fit p_T for each bin of E_γ $\rightarrow$ set of parameters
  - fit parameters as 2D functions of E_γ and Tp
  - work in phase space: $\rho = N/p_T$

Gamma-ray pT Distributions

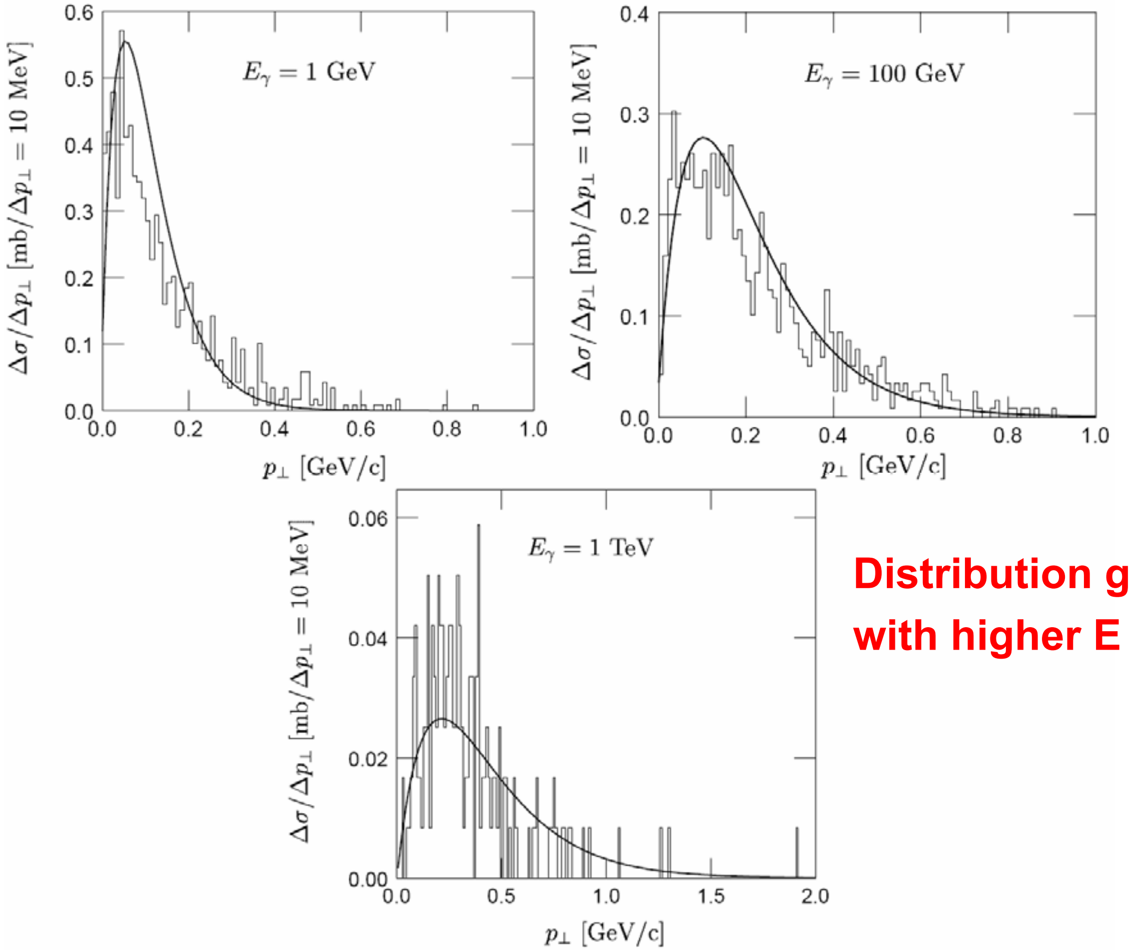
Non-diffractive interaction



Diffraction dissociation

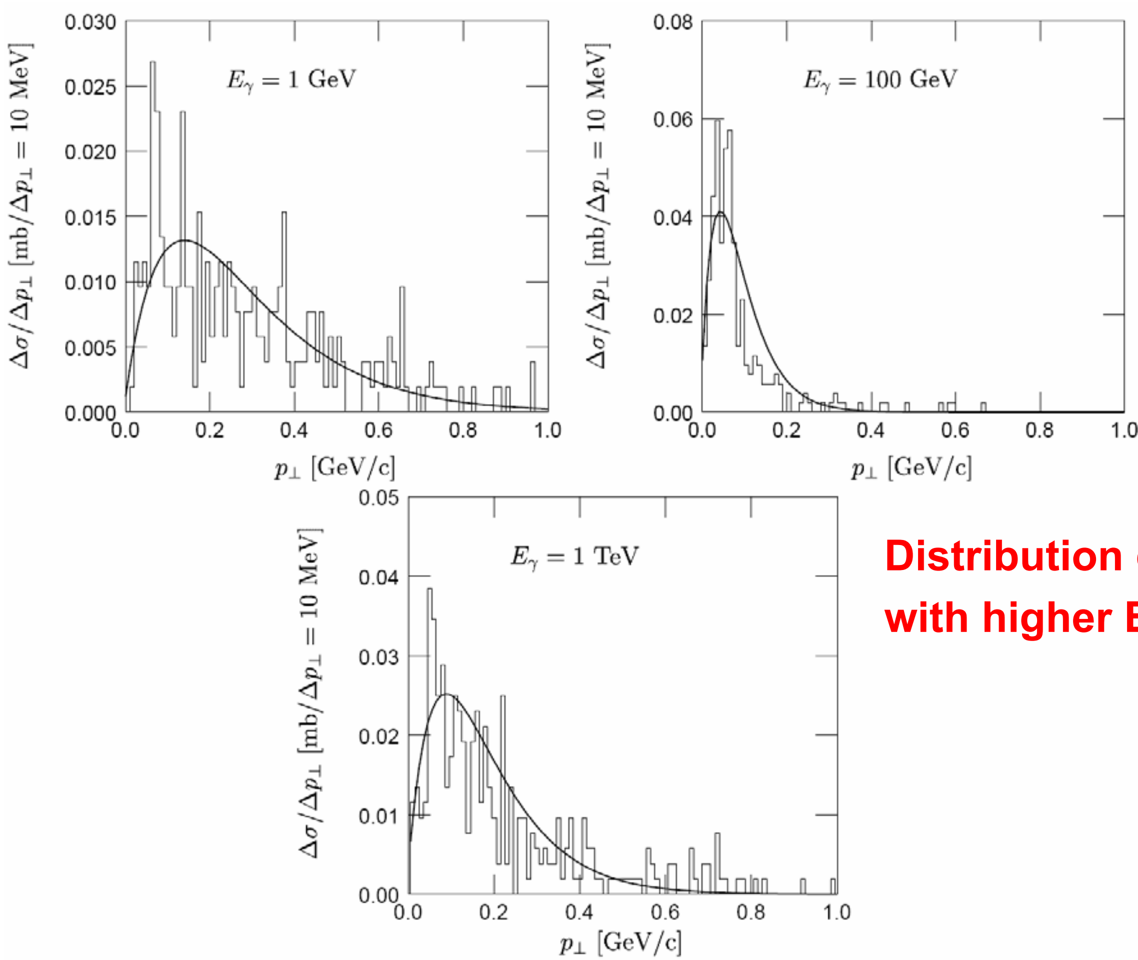


Fits: Non-diffractive Interaction



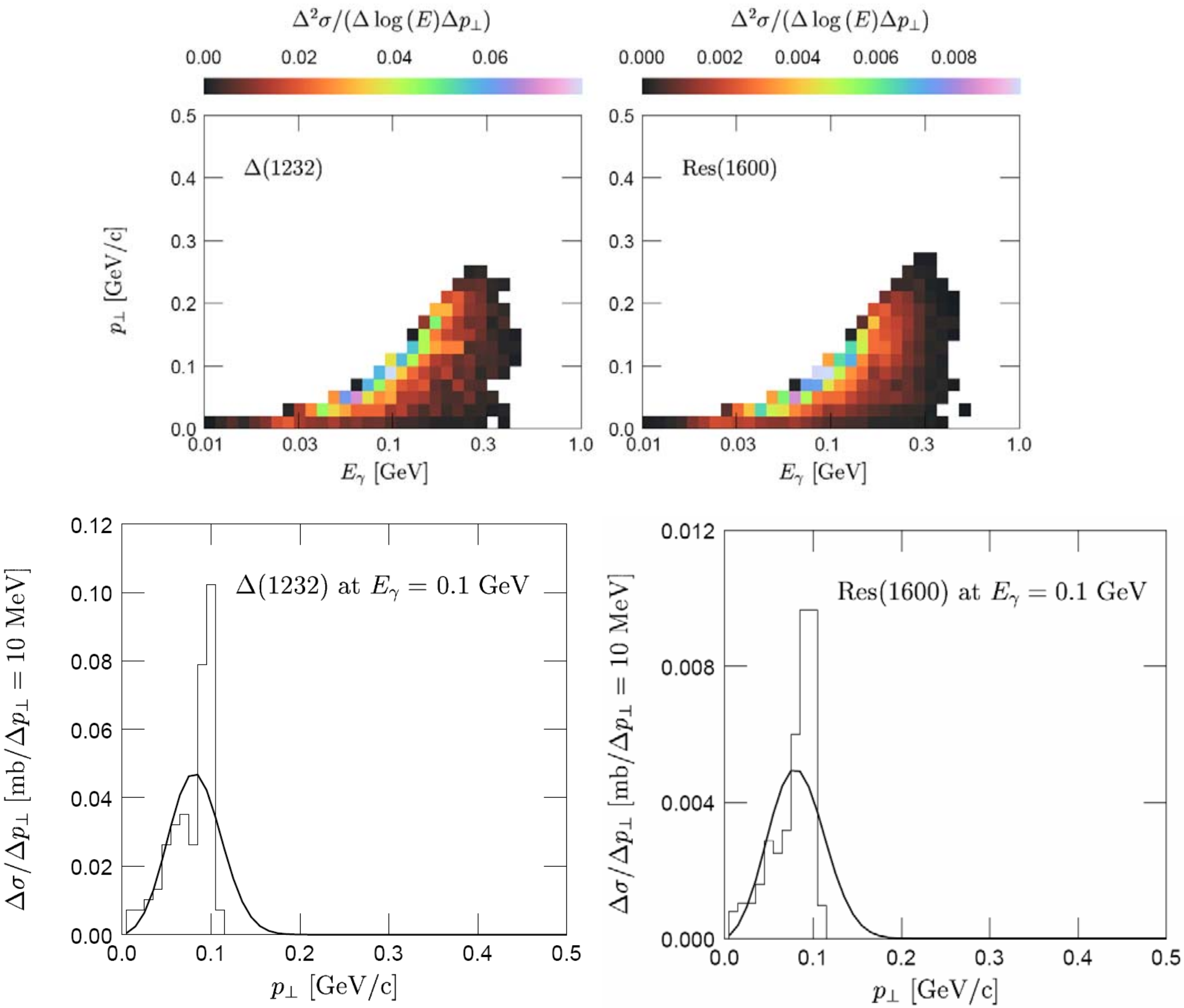
Distribution gets wider with higher E

Fits: Diffraction Dissociation



Distribution gets wider with higher E

Fits: Baryon Resonances

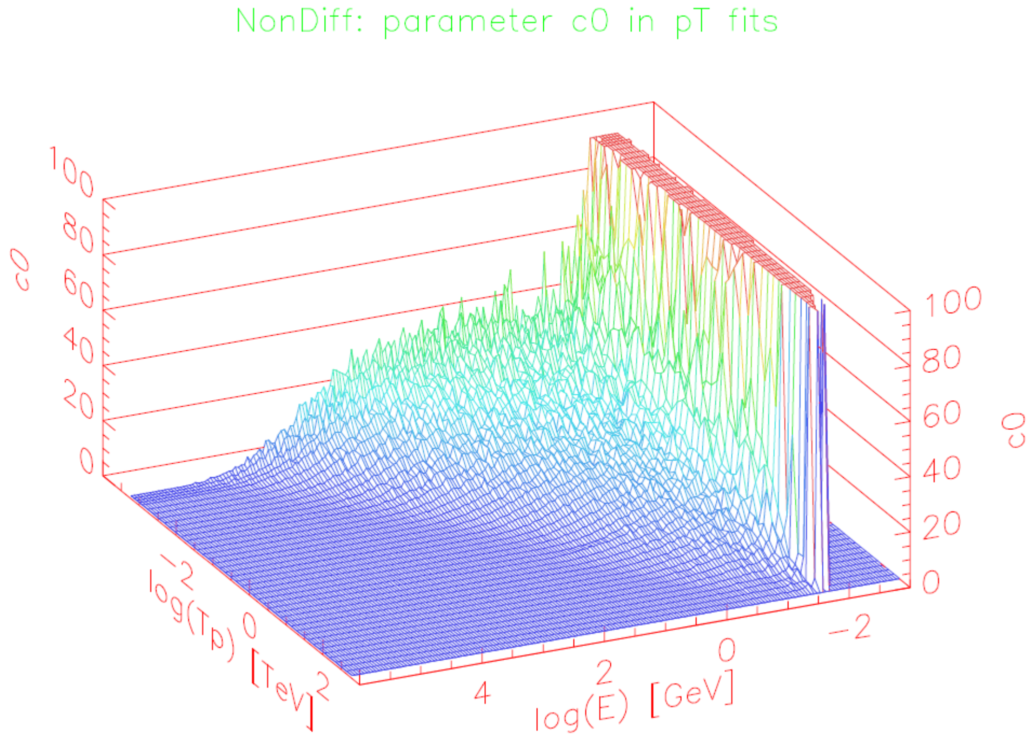


Final Step – Fit Parameters

- Parameters depend on both E and Tp
  - non-diff and diffraction: 2 parameters
  - baryon resonances: 3 parameters

- Find a way to parameterize these

- Artifacts from binning must be taken care of



Final words

- Up-to-date p-p inelastic model important
- Parameterization of secondary particle spectra very successful
  - paper to be published in ApJ
- Gamma-rays from anisotropic relativistic outflows might be detectable even if jet is viewed off-axis
- Parameterization of angular distribution for gamma-rays started
  - looks promising
  - paper is being prepared
- The two parameterizations gives us a great tool for modeling anisotropic relativistic outflows from SNRs, AGNs and GRBs