Update of Gflash Lateral Shower Profile Tuning

Pedro A. Movilla Fernández (LBNL)

Jet Energy and Resolution Group Meeting

July 20, 2005

Introduction

- The hadronic lateral shower profile parameter values in Gflash in Gen-5 were tuned in the past using Minbias tracks within 0-2.5 GeV/c. These values are used for momenta up to 5 GeV/c.
- For higher momenta we have no tuning! We are still relying on the H1 default.
- Now we have considerably more single isolated tracks data from special jet calibration runs (~17M) which allows for a uniform tuning of the calorimeter up to ~20 GeV/c.

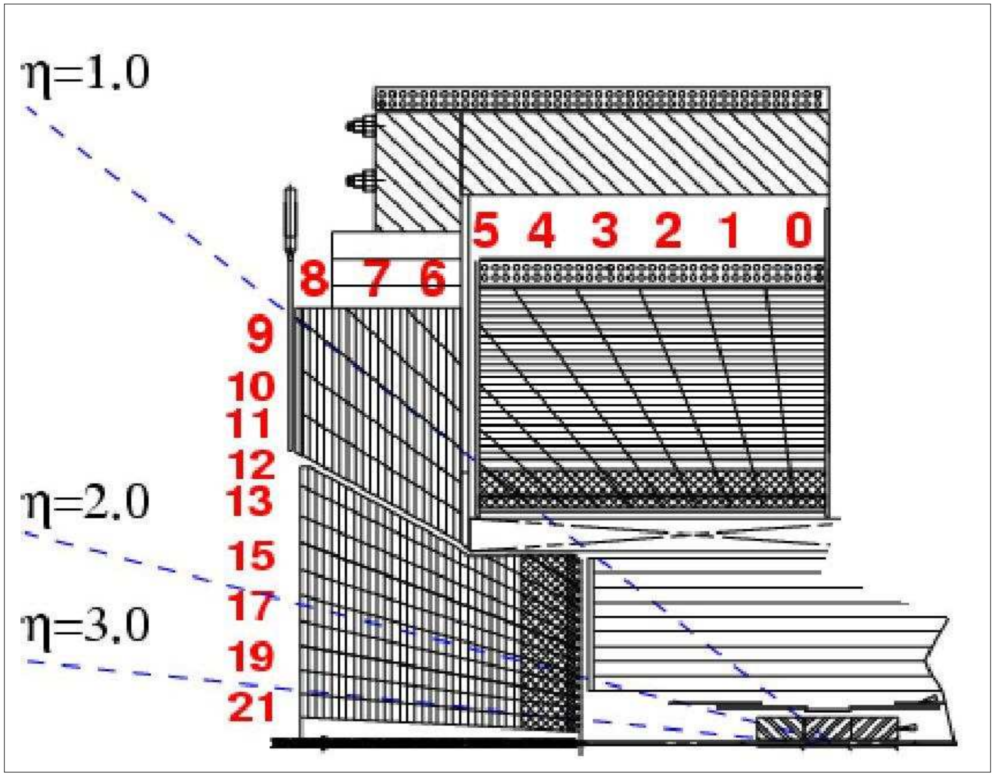
This talk:

- First tuning iteration in the central part.
- E/p measurement in the plug part.

See my JER talk of May 25, 2005 for details on the structure of hadronic lateral profiles.

Single Track Selection (Tower 0-11)

- Data sample: Jet calibration data gjtc0d (5.3.3_nt) ~ 16 M events
- MC samples: FakeEv, single track, flat spectrum
  Flavour mixture π/K/p = 60%/30%/10%
  E/p entries are weighted according to the data spectrum



Quality cuts:

N_{vertex}	$=$	1	← data only
z_{vertex}	$<$	60 cm	
z_0	$<$	60 cm	
d_0	$<$	1 cm	
7x7 iso			
CES iso			

tower	COT		Silicon		
	axial	stereo	axial	stereo	z
1-8	30	30	—	—	—
9	25	25	4	—	—
10-11	20	20	4	—	—

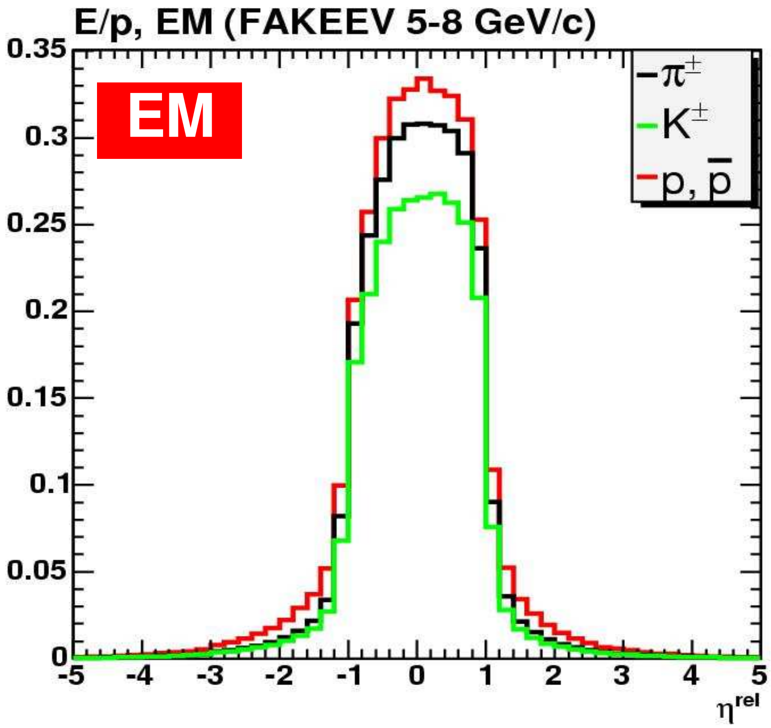
Single Track Statistics (Tower 0-11)

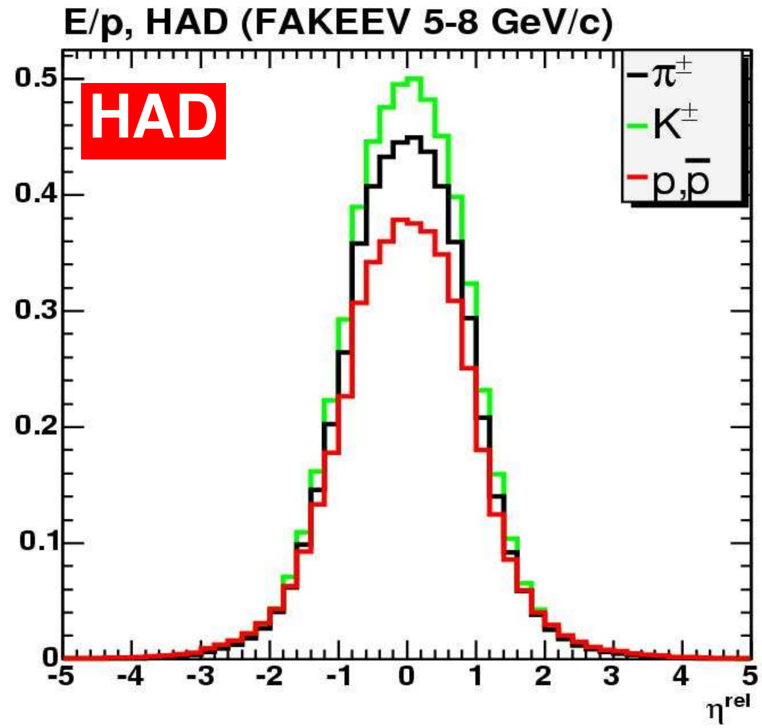
Number of selected tracks:

tower number	momentum range (GeV/c) ≥ 2	0.5-2	2-3	3-5	5-8	8-12	12-16	16-24	>24
0	101906	329537	11846	64676	16578	8015	629	116	45
1	109072	345385	12726	68439	17704	9262	754	147	39
2	114259	359959	13951	69419	18595	11170	914	169	41
3	115352	365974	15181	65847	19720	13125	1195	245	37
4	114795	366485	16870	59926	21898	14185	1582	280	52
5	118292	380410	20126	53818	26544	15038	2242	463	61
6	119588	388367	23670	47028	30777	14460	2977	597	76
7	126830	427403	30812	42726	34770	13728	3907	802	85
8	96483	445245	38401	26230	21509	7066	2636	566	72
9	55529	439577	38101	14241	2607	444	90	38	7
10	78510	501283	52699	21349	3754	570	94	32	8
11	121194	552756	78114	34826	6926	1050	195	65	13

- tower 1–4 define the “central part” used for the present tuning
- no adjacent tower w/ crack
- plug: see later

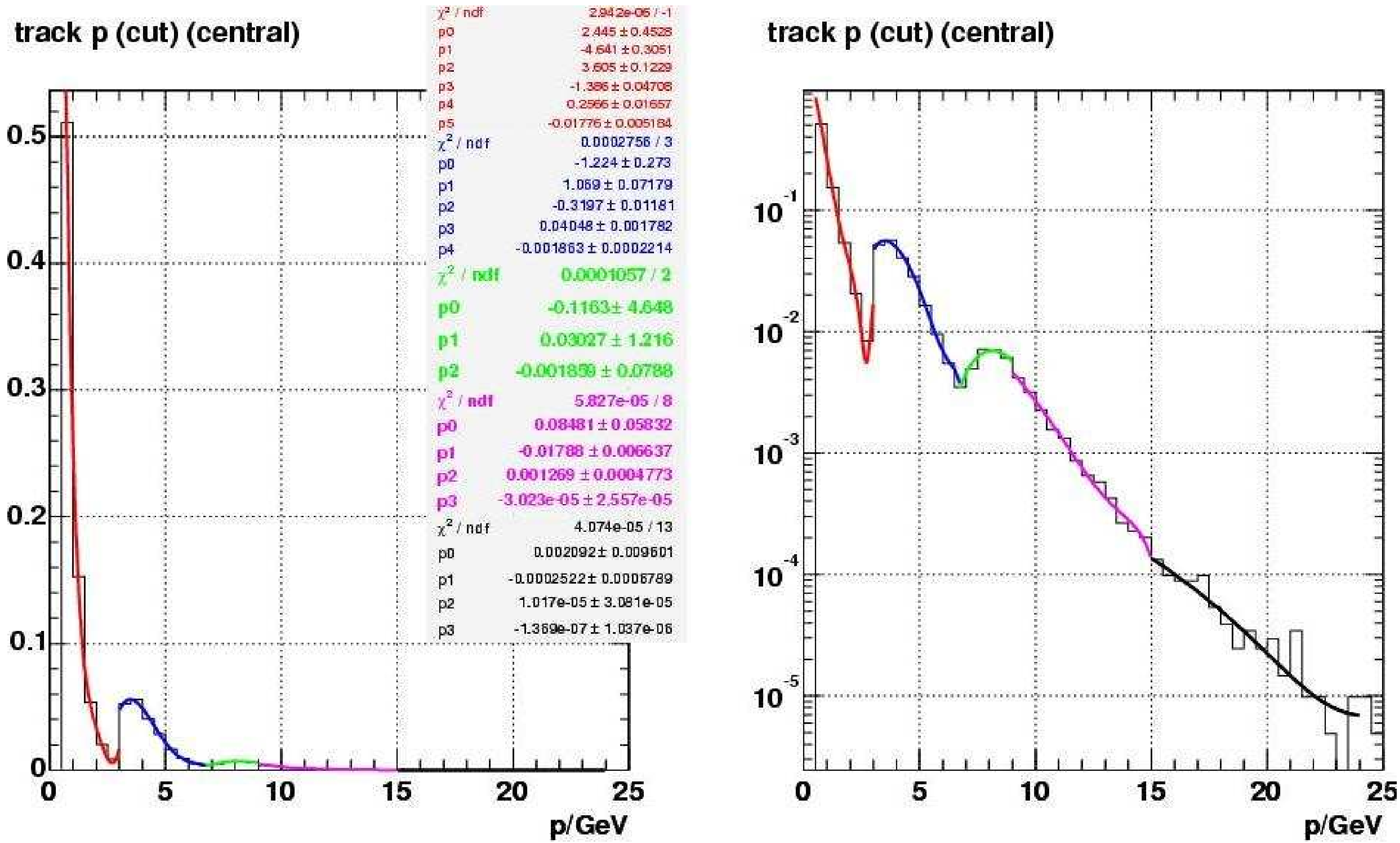
Dependence on Particle Type





- E/p (HAD): Kaons > Pions > Protons; E/p (EM): reverse
- But: shape is not too sensitive on flavor mixture.
- Here: adopt values used in the past: 60% $\pi^\pm$, 30% $K^\pm$, 10% $p/\bar{p}$

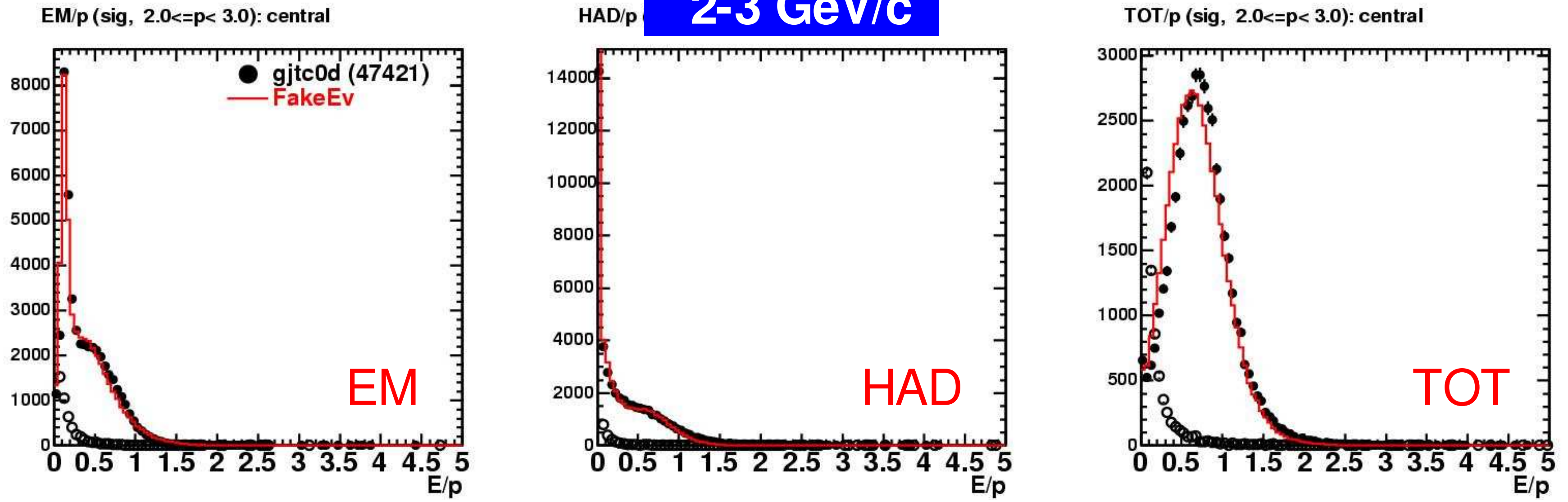
Momentum Spectrum (Central)



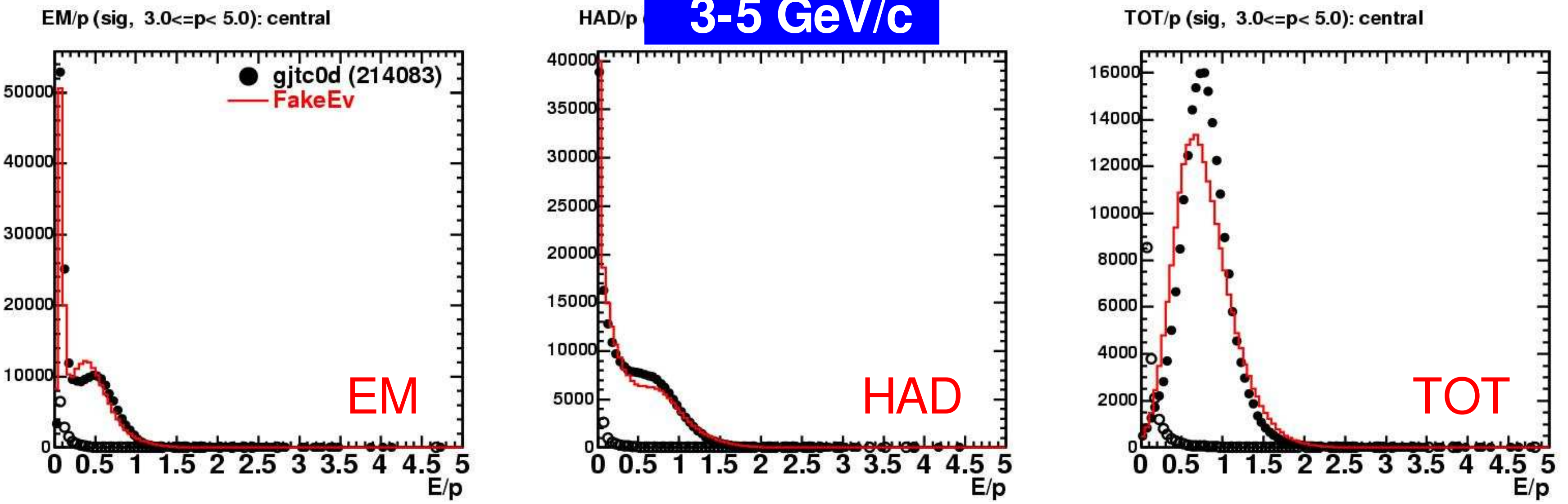
- Parametrization used to weigh E/p from FakeEv (individually for each detector region)

E/p Distributions (1)

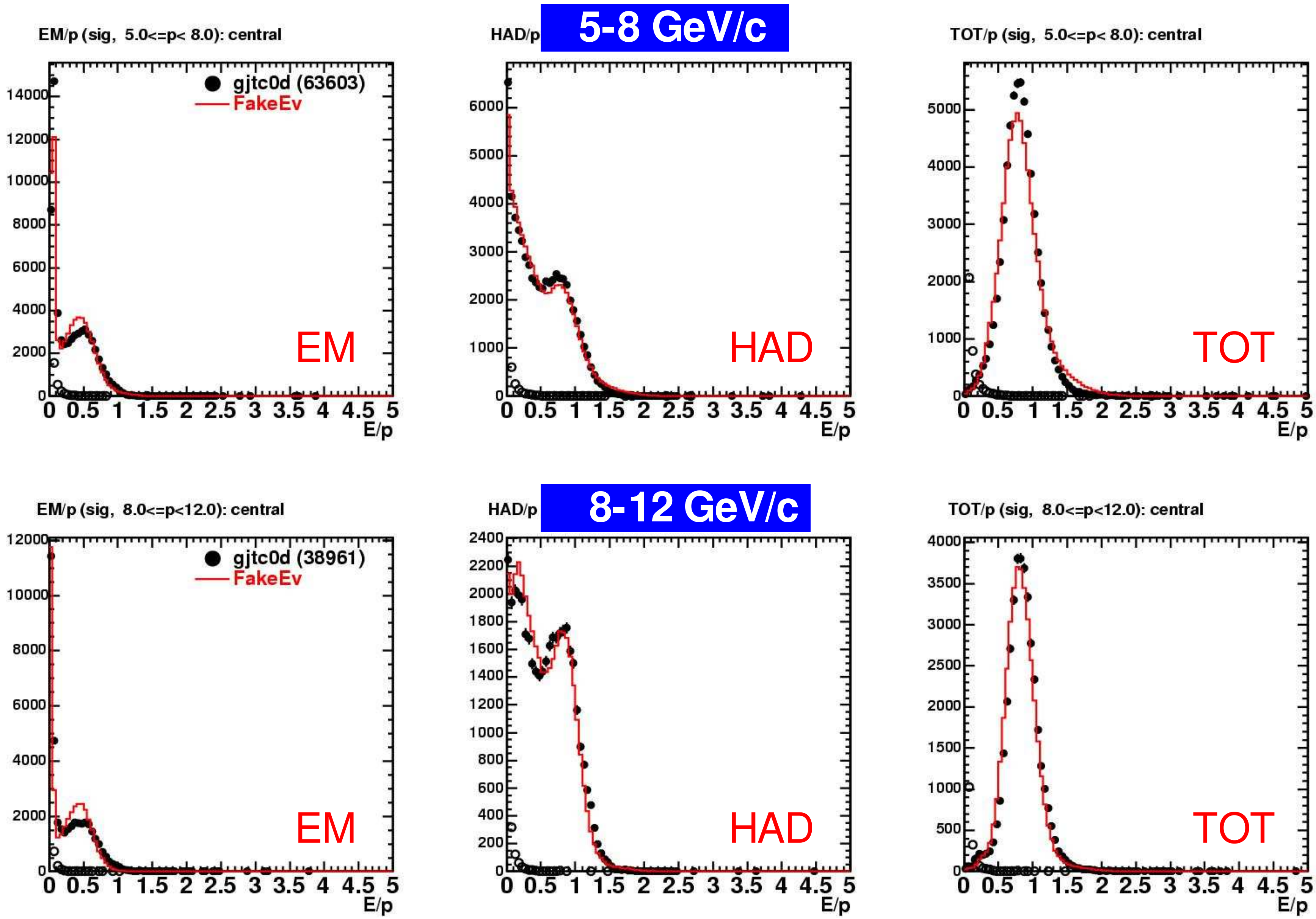
2-3 GeV/c



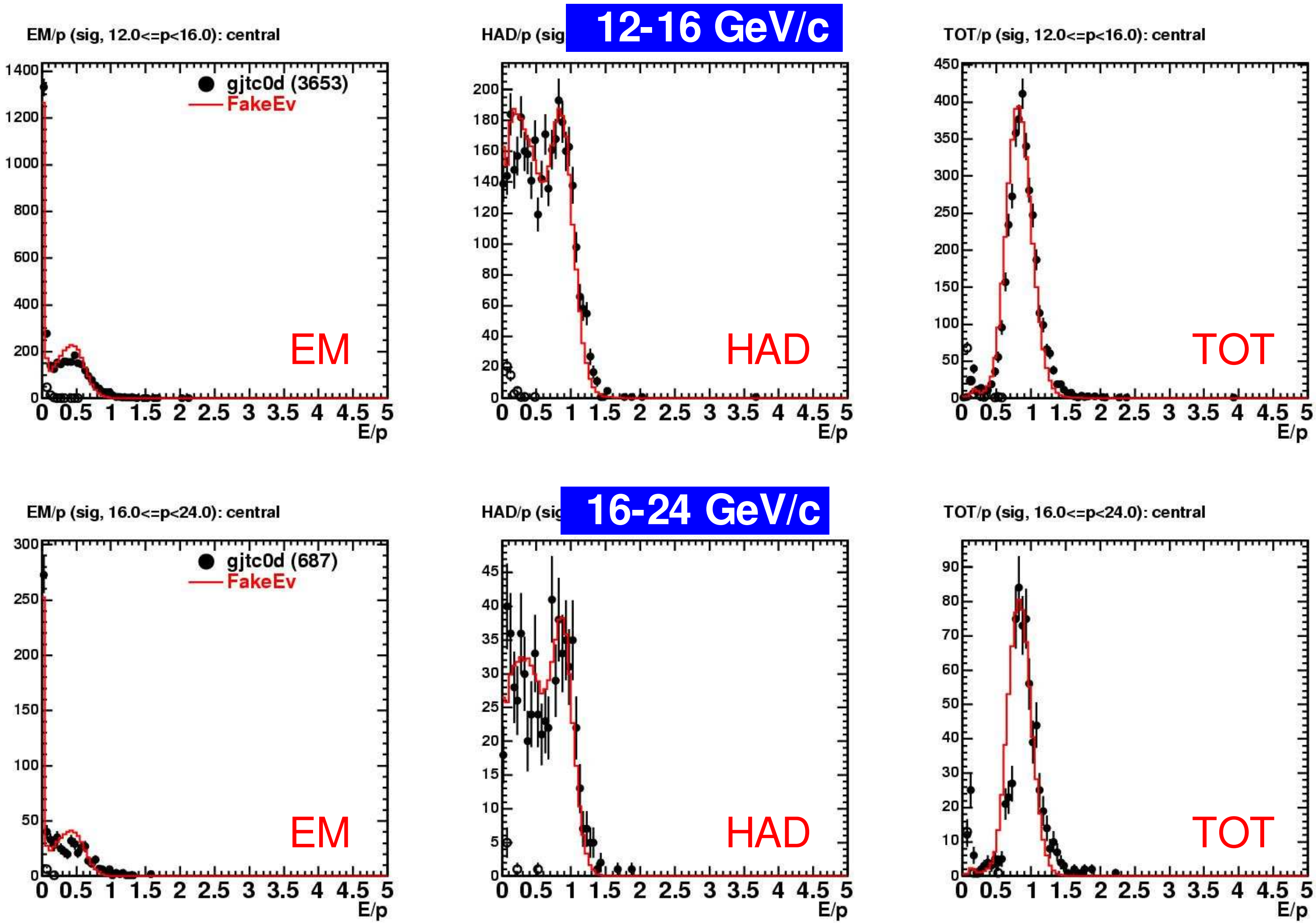
3-5 GeV/c



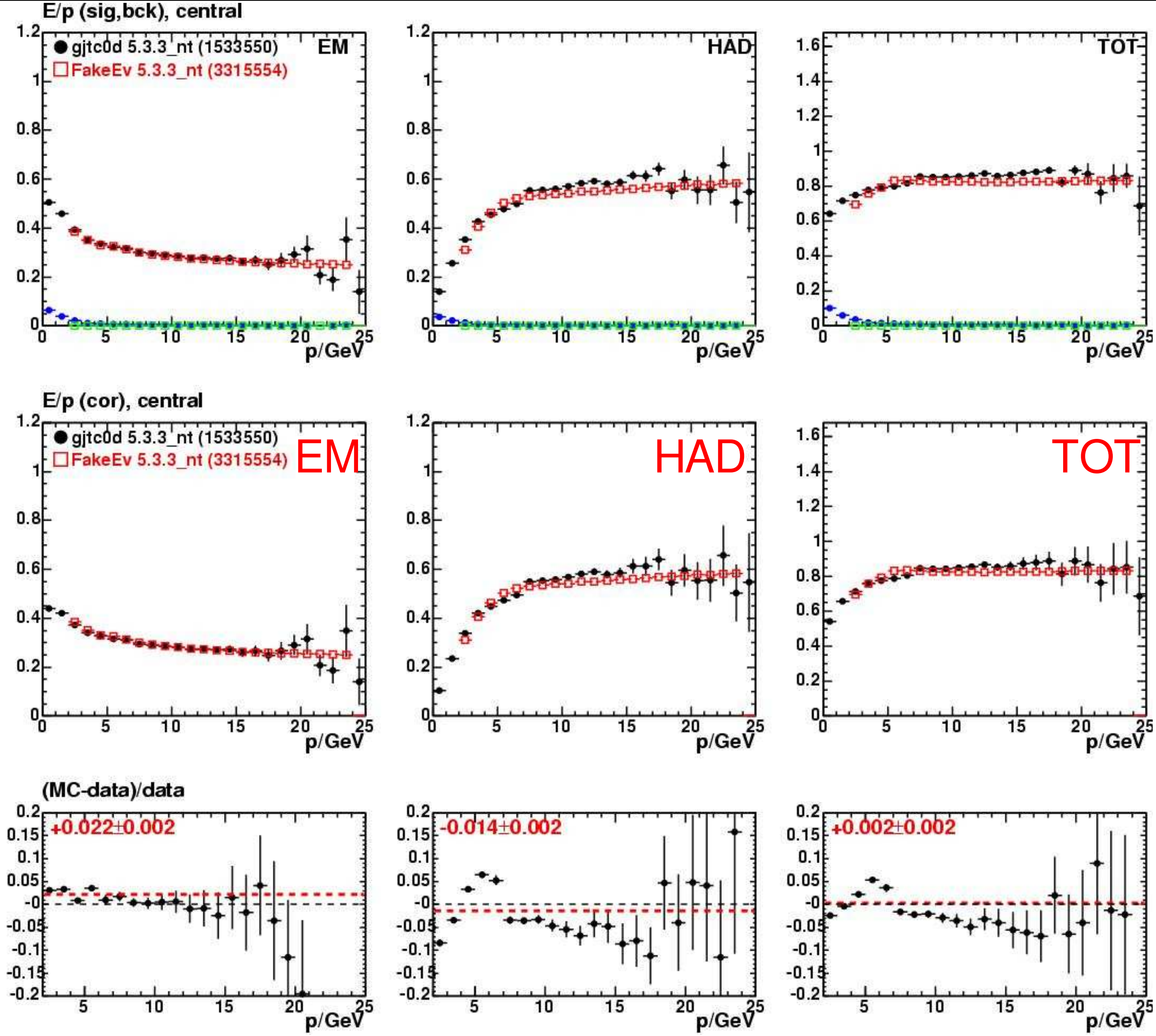
E/p Distributions (2)



E/p Distributions (3)



⟨E/p⟩ vs p (Central)



signal

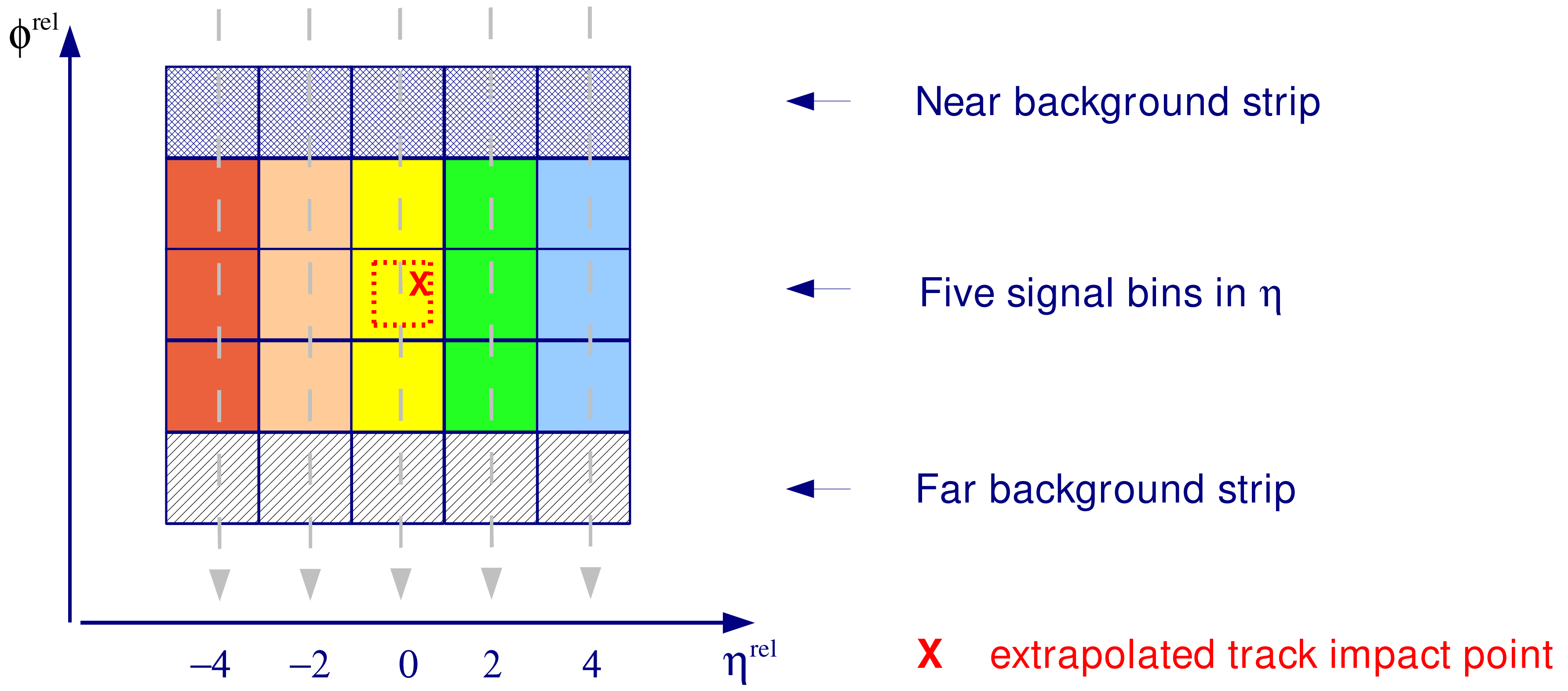
background

corrected

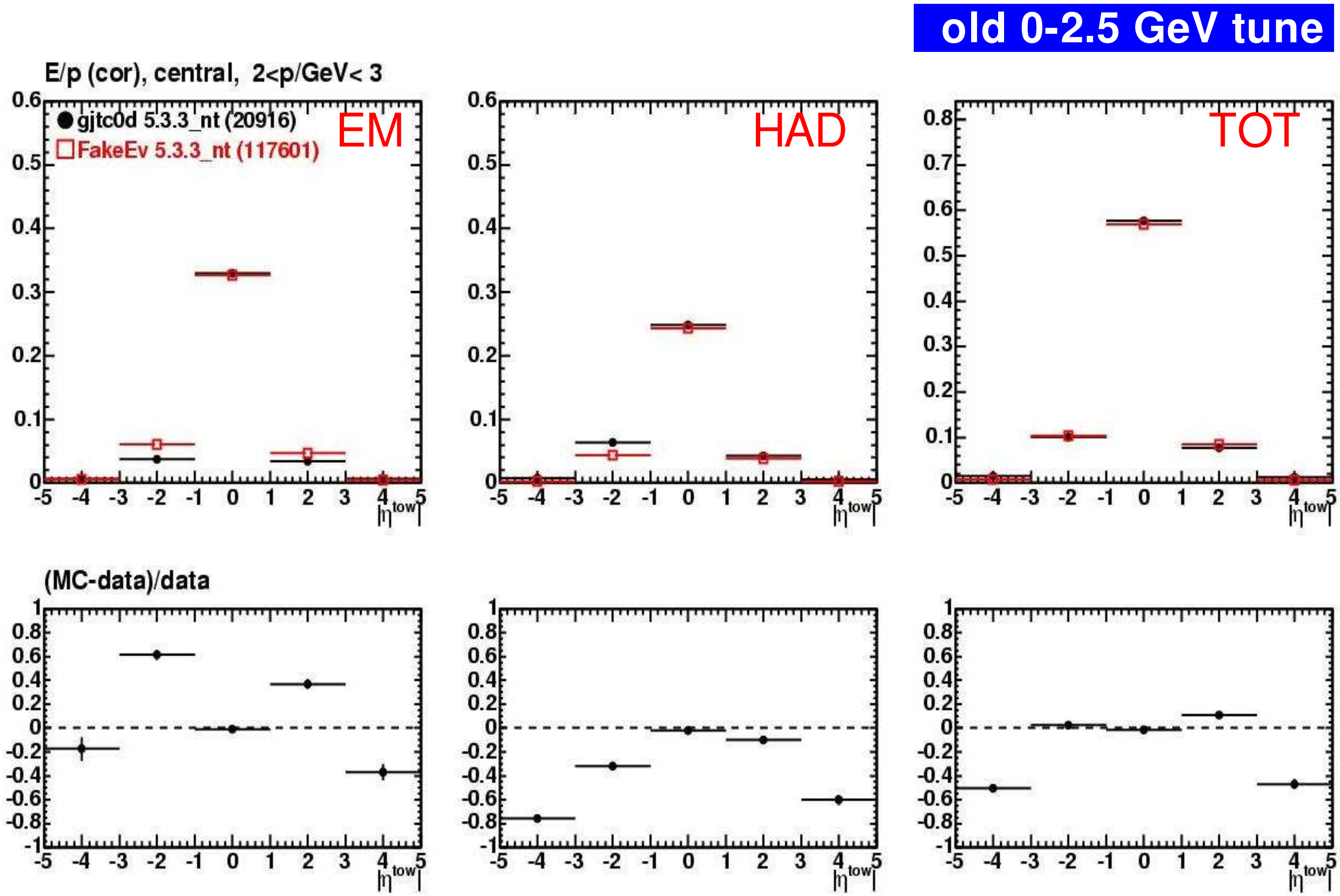
relative difference

Definition of Tune Distributions

- Tracks are extrapolated to CES/PES for both EM and HAD compartment
- η/ϕ coordinates of impact point are normalized to the η/ϕ of the tower boundaries
- Impact point must be in inner 60% of target
- A signal bin in η is the sum of E/p of target plus the two towers adjacent in ϕ
- Background estimate for each η bin = 1.5 x (far block + near block)

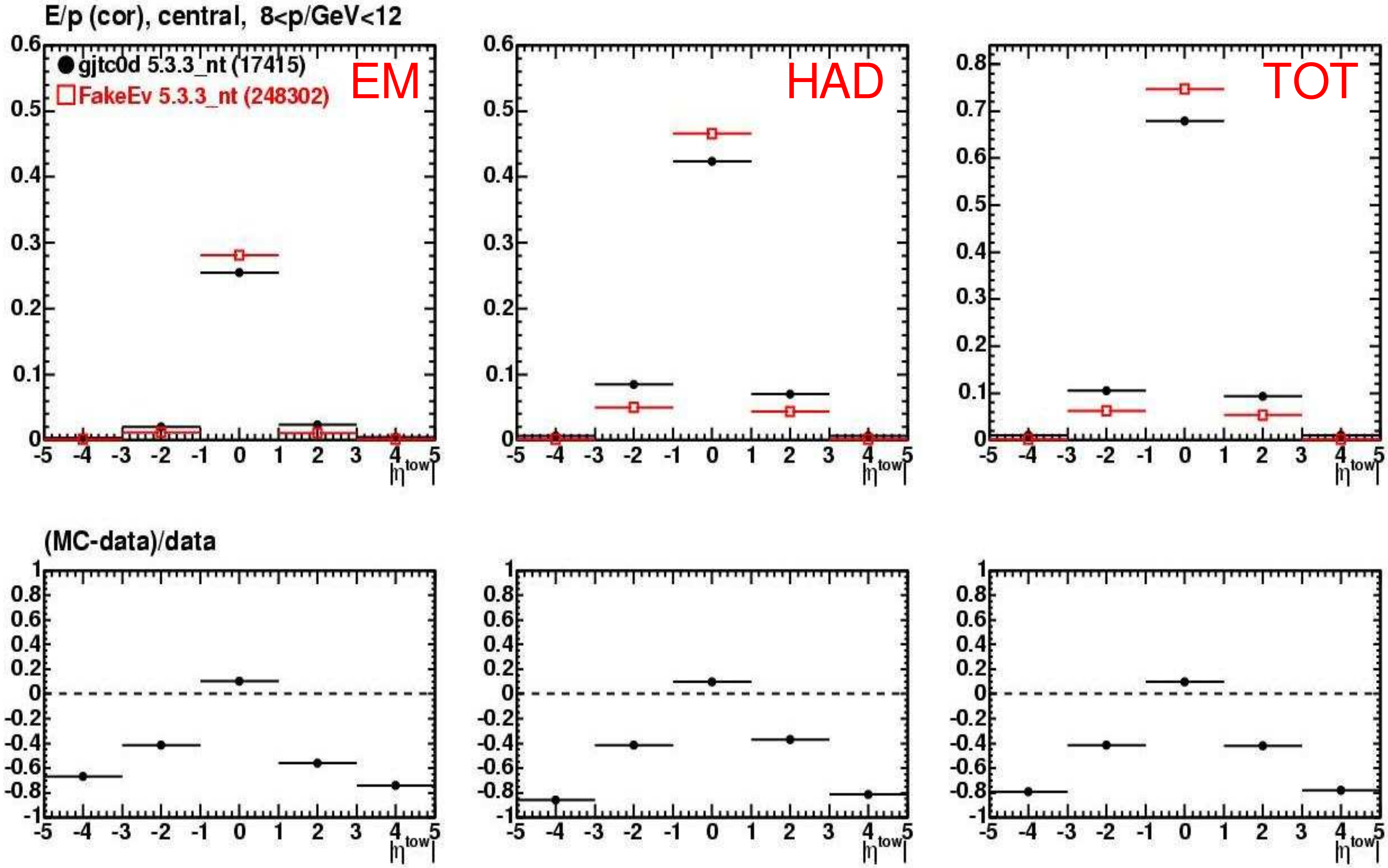


⟨E/p⟩ vs relative itow (2-3GeV/c)



⟨E/p⟩ vs relative itow (8-12GeV/c)

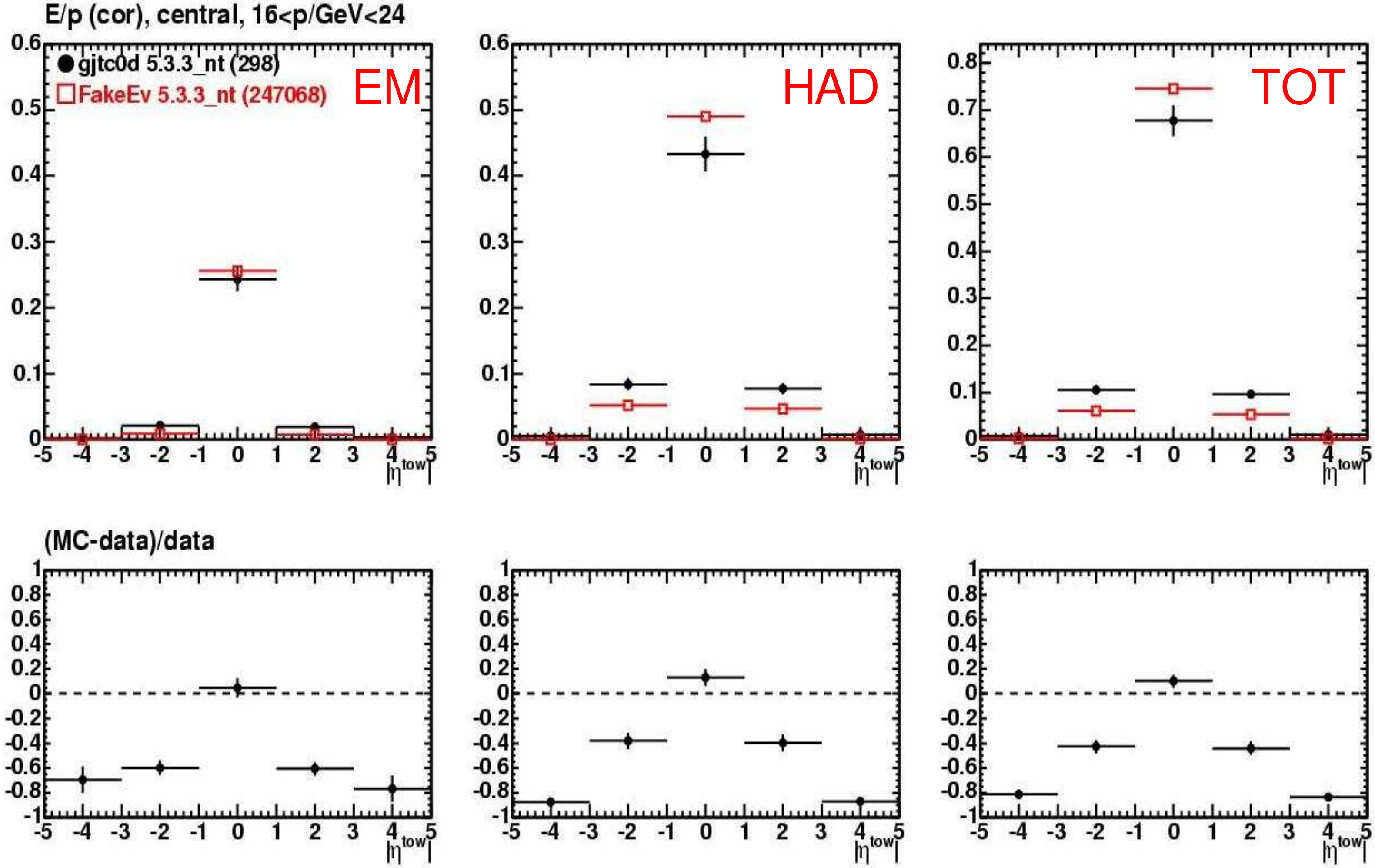
H1 default



- MC lateral shower profiles are too narrow for p>5GeV/c!

⟨E/p⟩ vs relative itow (16-24GeV/c)

H1 default



- MC lateral shower profiles are too narrow for p>5GeV/c!

Gflash Lateral Shower Profile

Parametrization:

E: energy of incident particle
x: shower depth
r: radial distance from shower center
$R_0(E,x)$: log-normal pdf
n=1(2) for HAD (EM) showers
Free: R_1, R_2, R_3, S_1, S_2, S_3, S_4

$$f(r) = \frac{2 r R_0^2}{r^2 + R_0^2}, \qquad \int_0^\infty f(r)\, dr = 1$$

$$\langle R_0(E,x)\rangle = \left[R_1 + (R_2 - R_3 \log E)\, x\right]^n$$

$$\sigma_{R_0} = \left[(S_1 - S_2 \log E)(S_3 + S_4 x)\right] \langle R_0(E,x)\rangle$$

Strategy:

- Tune distribution: <E/p> vs. relative tower η
- Focus on $\langle R_0\rangle$; calorimeter granularity prob. too coarse to be sensitive on σ_{R0}
- Optimize $R_1(p)$, $Q(p)=R_2(p)-R_3(p)\log p$ for each momentum bin p=E separately

$$\chi^2 = \sum_{i=-1}^{1} \frac{\left(\langle E/p\rangle^{data}(i) - \langle E/p\rangle^{MC}(i)\right)^2}{\left(\sigma(E/p)^{data}(i)\right)^2}$$

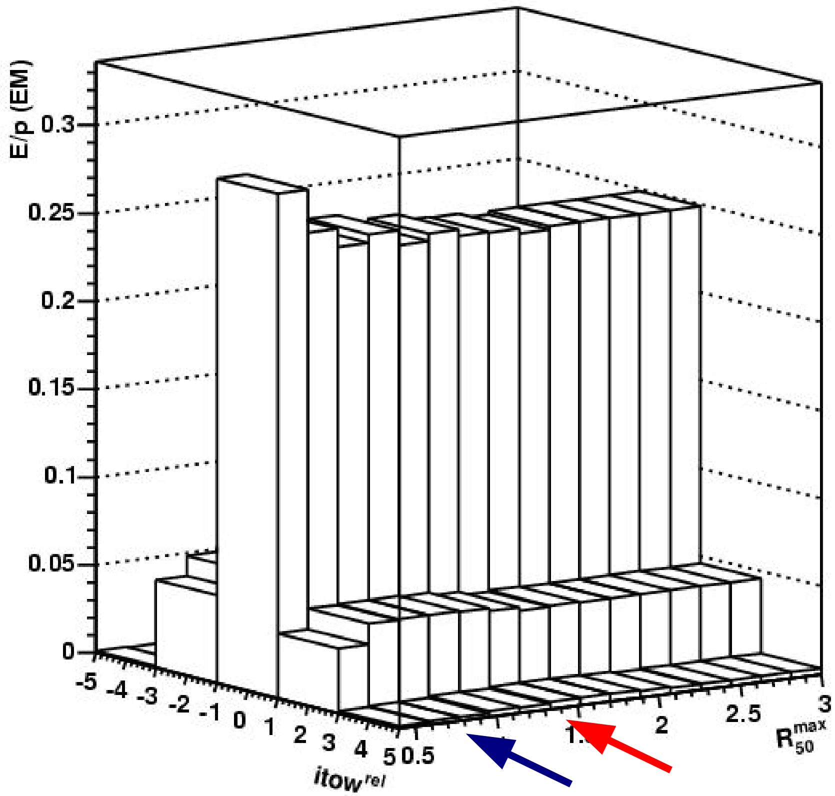
(i=-1,0,1: target tower + 2 adjacent towers)

- Absolute E/p (MC) is normalized to the E/p (data) in order to decouple from longitudinal shower profile details.
- Derive R_2 and R_3 from p dependence of Q

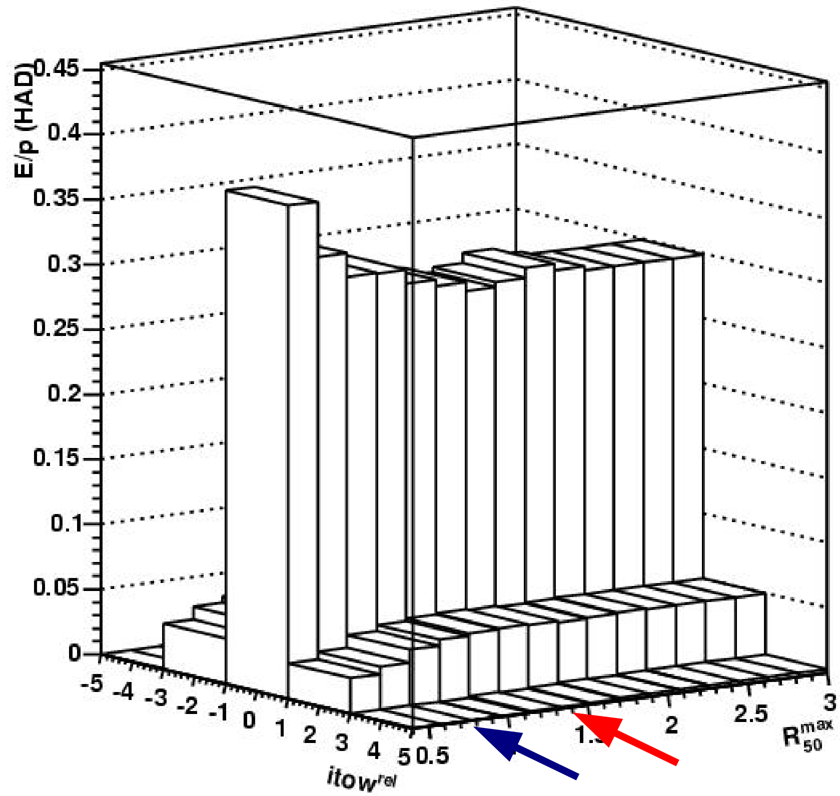
Dependence on Shower Cut-Off

2-3 GeV/c

EM

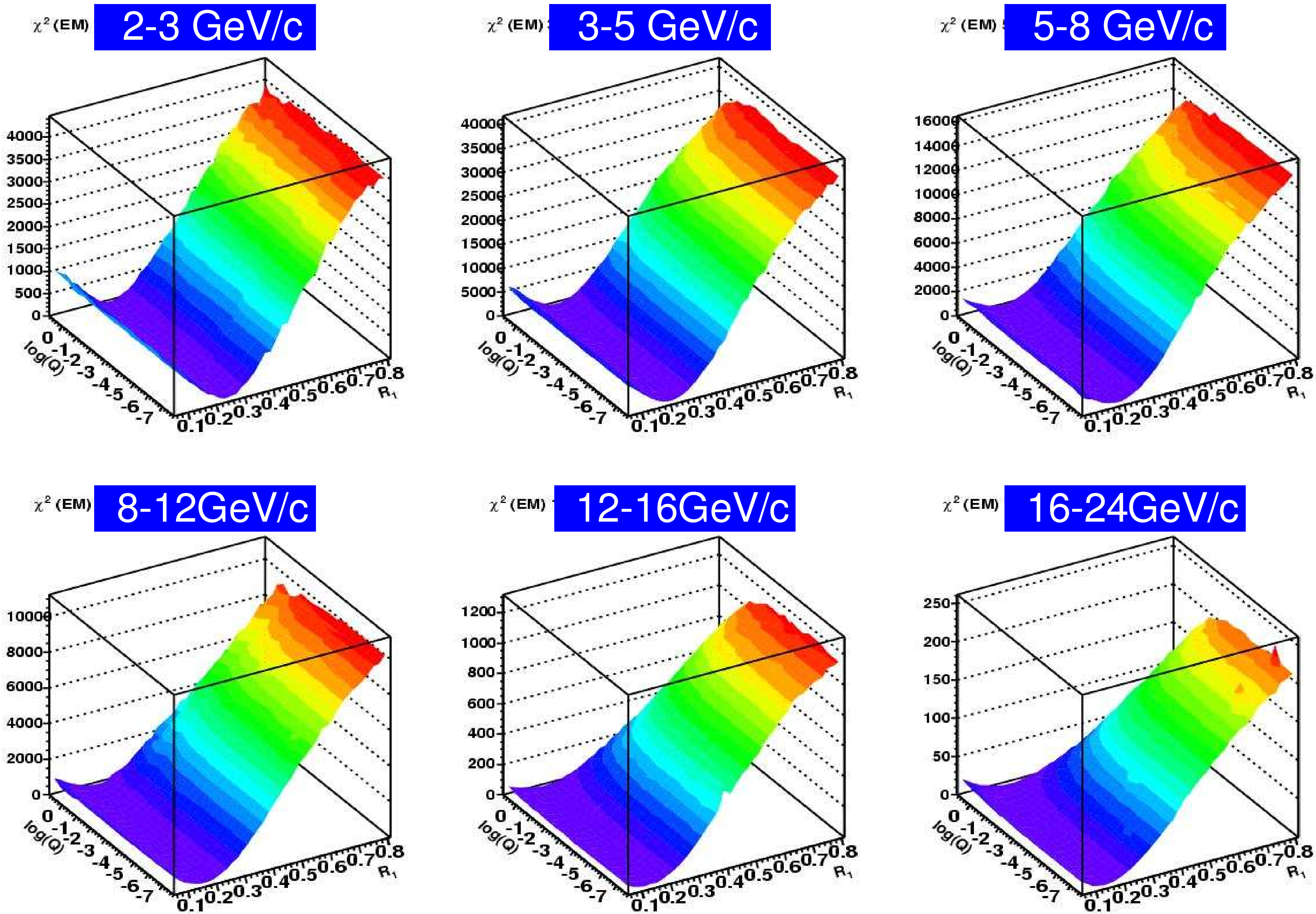


HAD

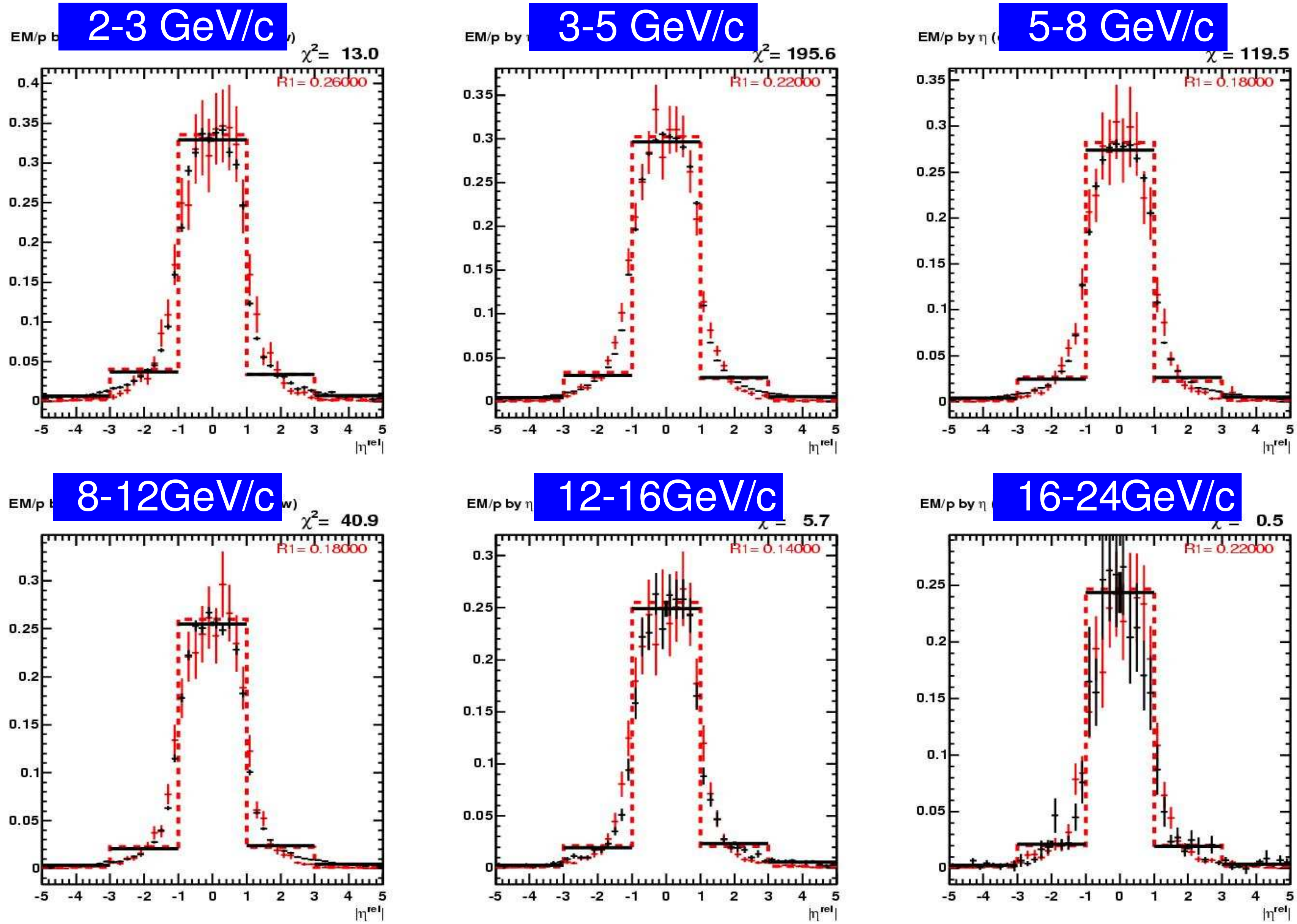


Current H1 default R_{50}^{max}=0.8, released value for tuning is 1.4.

(R_1,Q) - Scan in EM

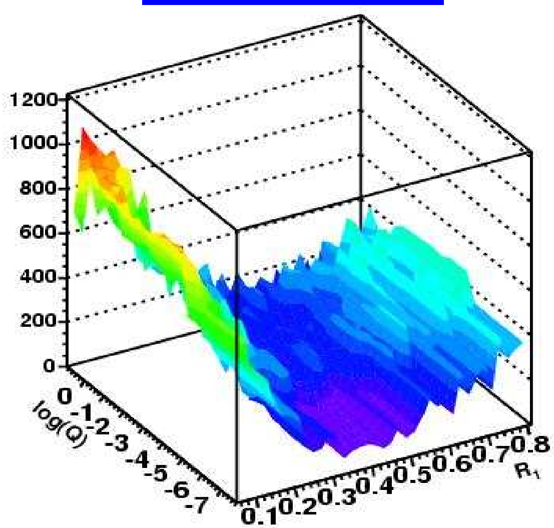


EM Tuned Profiles

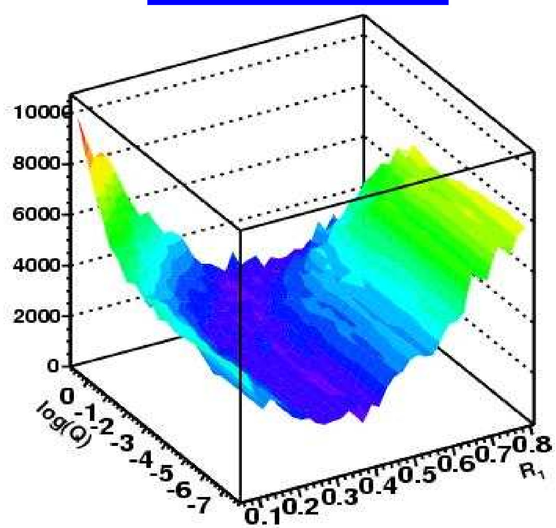


(R_1,Q) - Scan in HAD

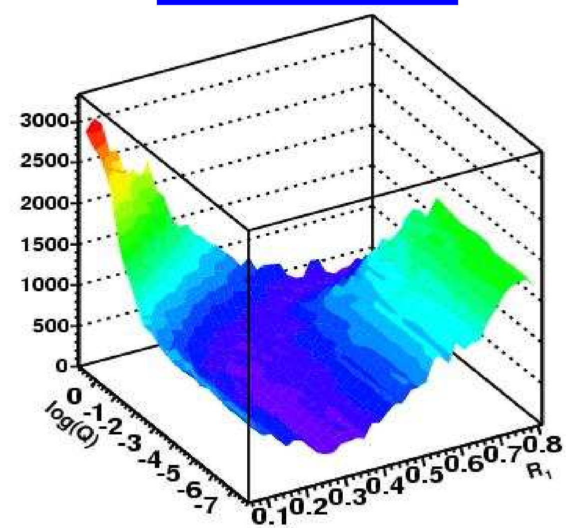
2-3 GeV/c



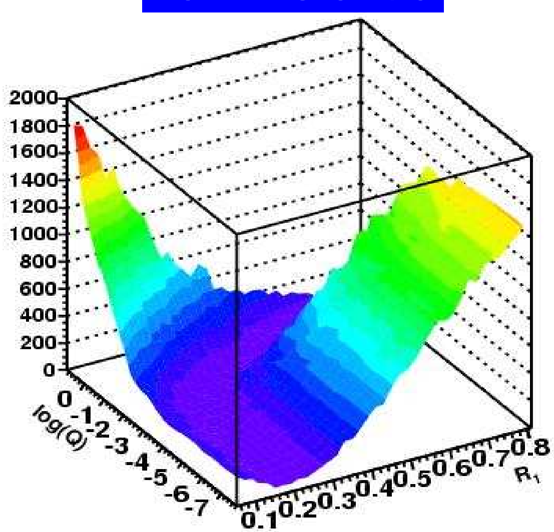
3-5 GeV/c



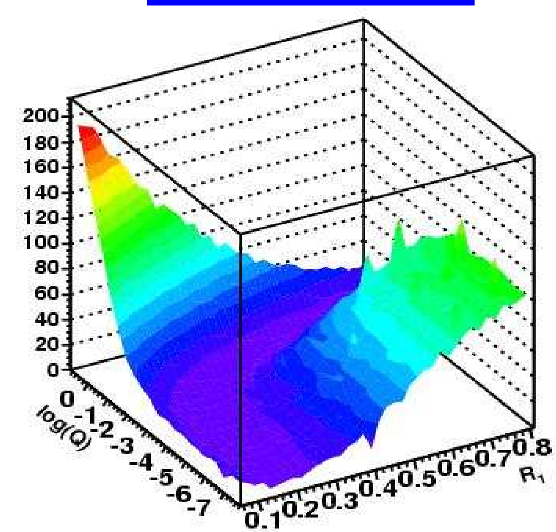
5-8 GeV/c



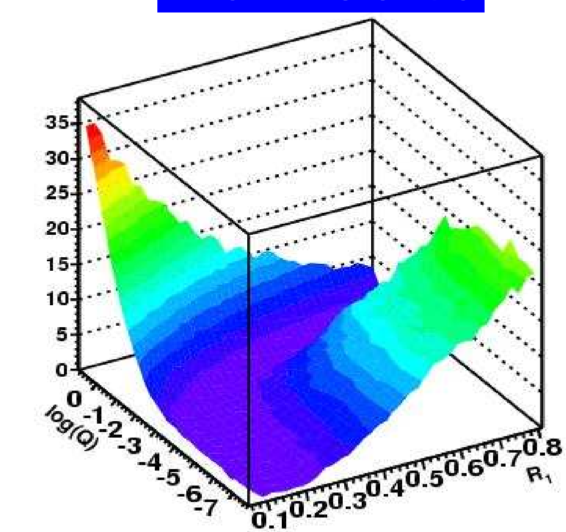
8-12GeV/c



12-16GeV/c



16-24GeV/c



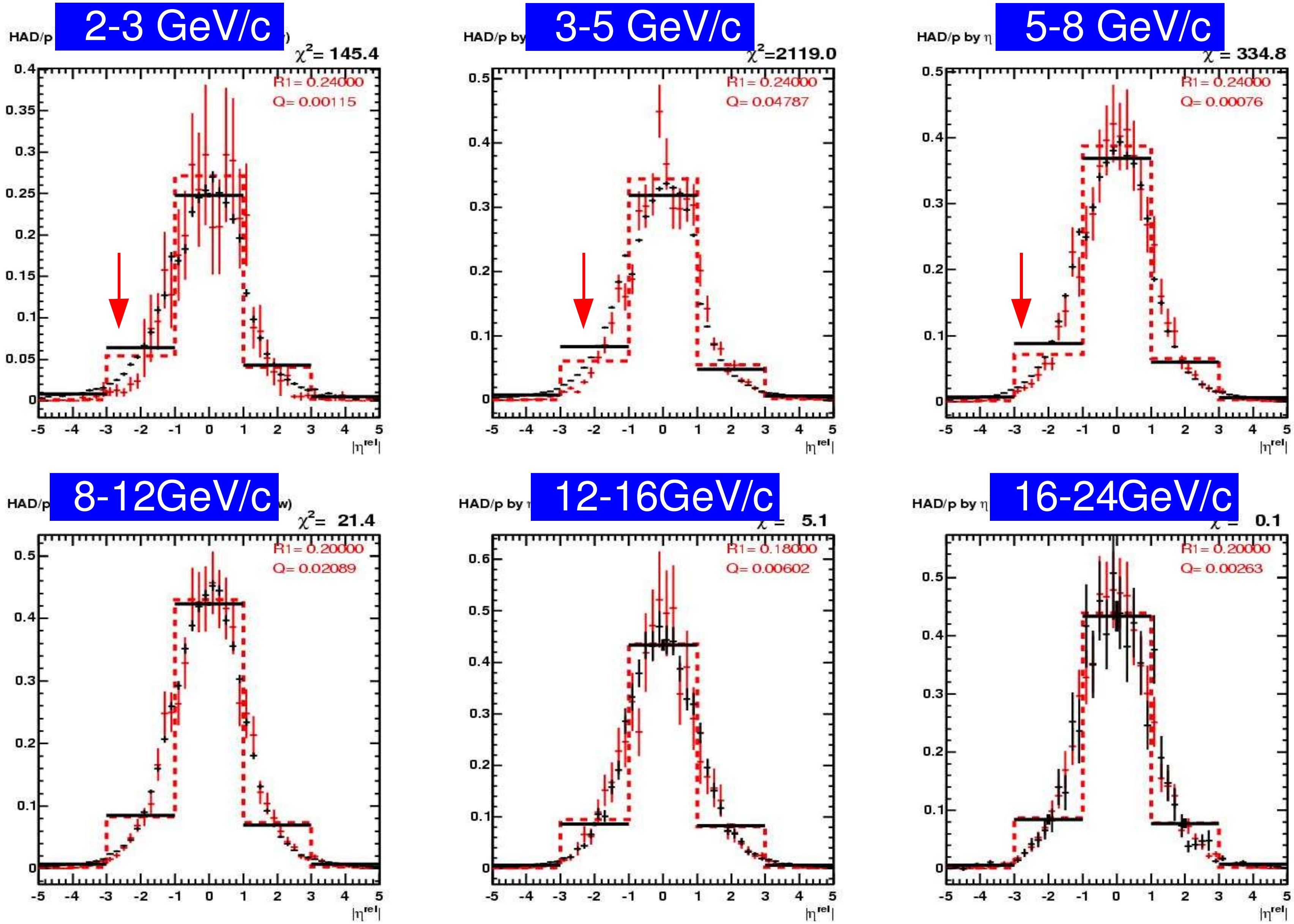
Observations

- EM compartment almost insensitive to Q; total interaction length ~ $1\lambda_0$ $\rightarrow$ useful to fix R_1.
- R_1^{opt} (EM) ~ const., according to expectation.
- R_1^{opt} (EM) ~ R_1^{opt} (HAD) only for p>8 GeV/c

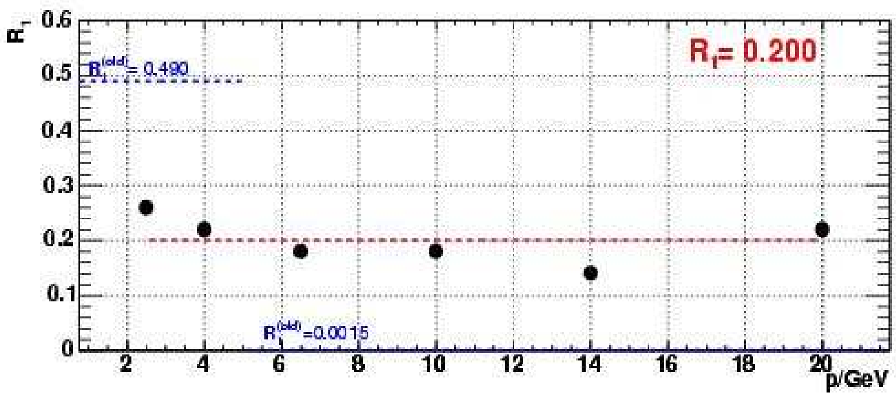
  ...probably related to kink structure in HAD profiles due to extrapolation effects from CES to HAD surface. This effect is different in MC and data and more pronounced at lower momenta where the shower cones are wider.
- Assume that quality of R_1^{opt} (EM) is better than in HAD;

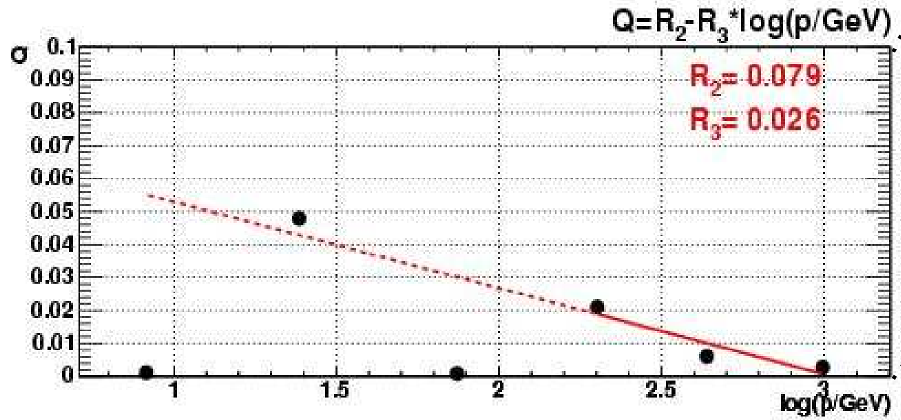
  $\rightarrow$ use a R_1^{opt} (EM) window as constraint for Q(p) from HAD
- Can use HAD profiles to fix Q(p), but there are regions with very flat minima along R_1 slices.
- For now determine Q(p) from data p>8 GeV/c.

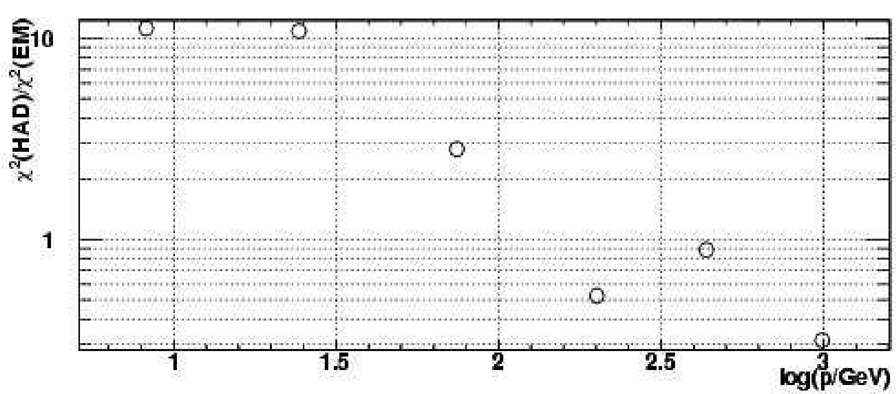
HAD Tuned Profiles (w/ EM constraint)

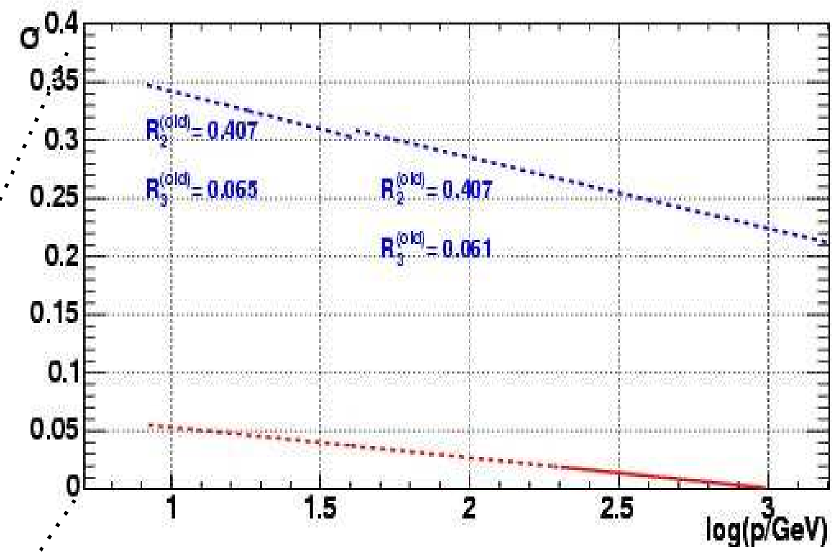


Numerical Results









Quality of tune in EM and HAD similar only for p> 8GeV/c.

(R_1, R_2, R_3) = (0.20, 0.079, 0.026)

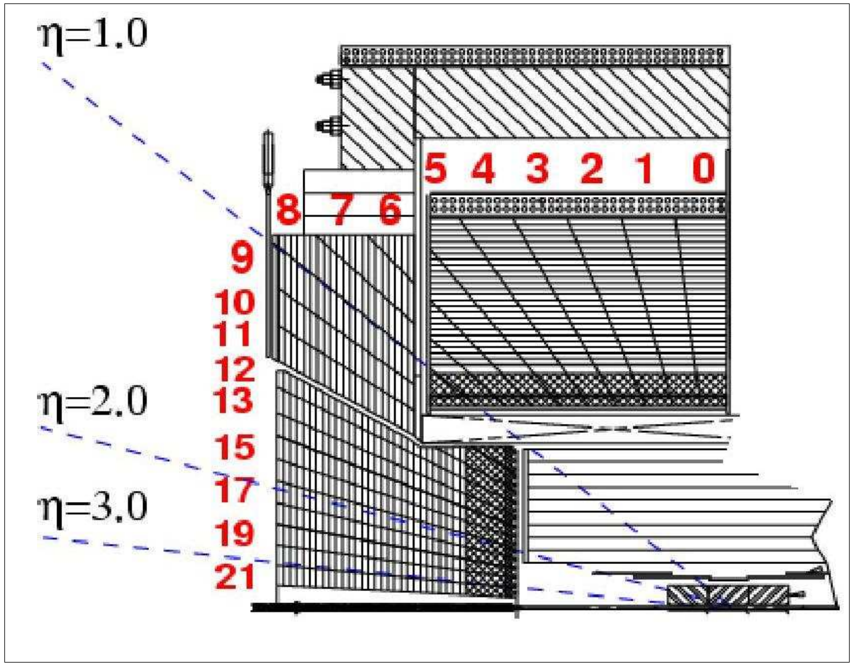
Old values:

p<5GeV/c: (R_1, R_2, R_3) = (0.49, 0.407, 0.065)

p>5GeV/c: (R_1, R_2, R_3) = (0.0149, 0.407, 0.061)

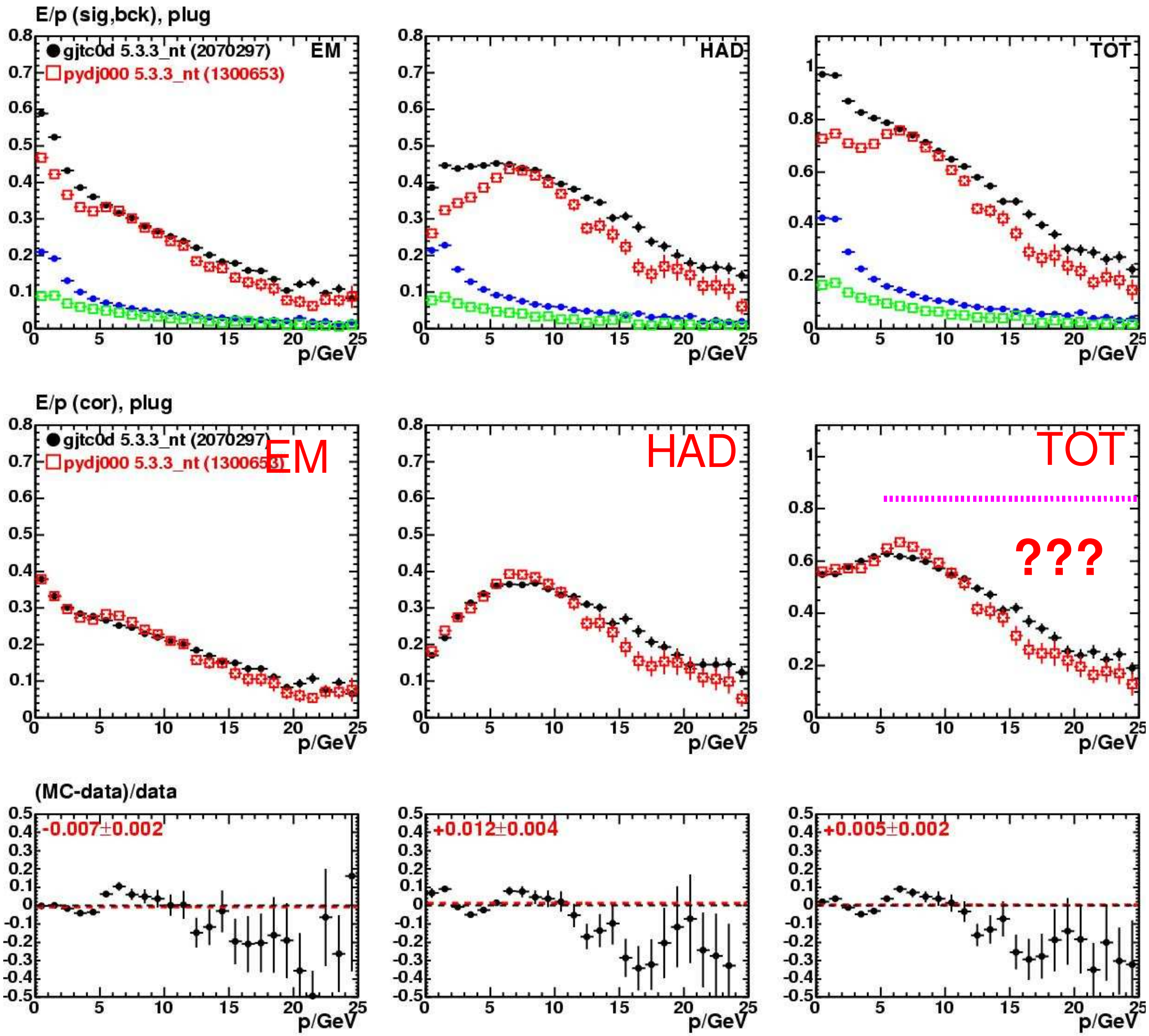
⟨E/p⟩ Measurement in the Plug

- Plug vs. central:
  - Finer granularity in polar angle
  - Radiation length in EM = 21 X_0 (central 19X_0)
  - Absorption length in HAD = 7 λ (central 4.5λ)
- Problems in the plug:
  - Less/no COT hits
  - Lower track reconstruction efficiency
  - Poor momentum resolution
  - Higher background contribution
- Standard analysis so far:
  - Adjacent 7.5 deg ϕ wedges are paired to 15.0 deg wedges
  - Relies mostly on SISA tracks
  - No PES isolation cut
  - "Plug": tower 13-16
- Plots shown in the following:
  - Data: JETCALIB (gjtc0d)
  - MC: Pythia Minbias MC (pydj000)



tower	COT		Silicon		
	axial	stereo	axial	stereo	z
12-21	—	—	4	2	2

⟨E/p⟩ vs p (Plug)



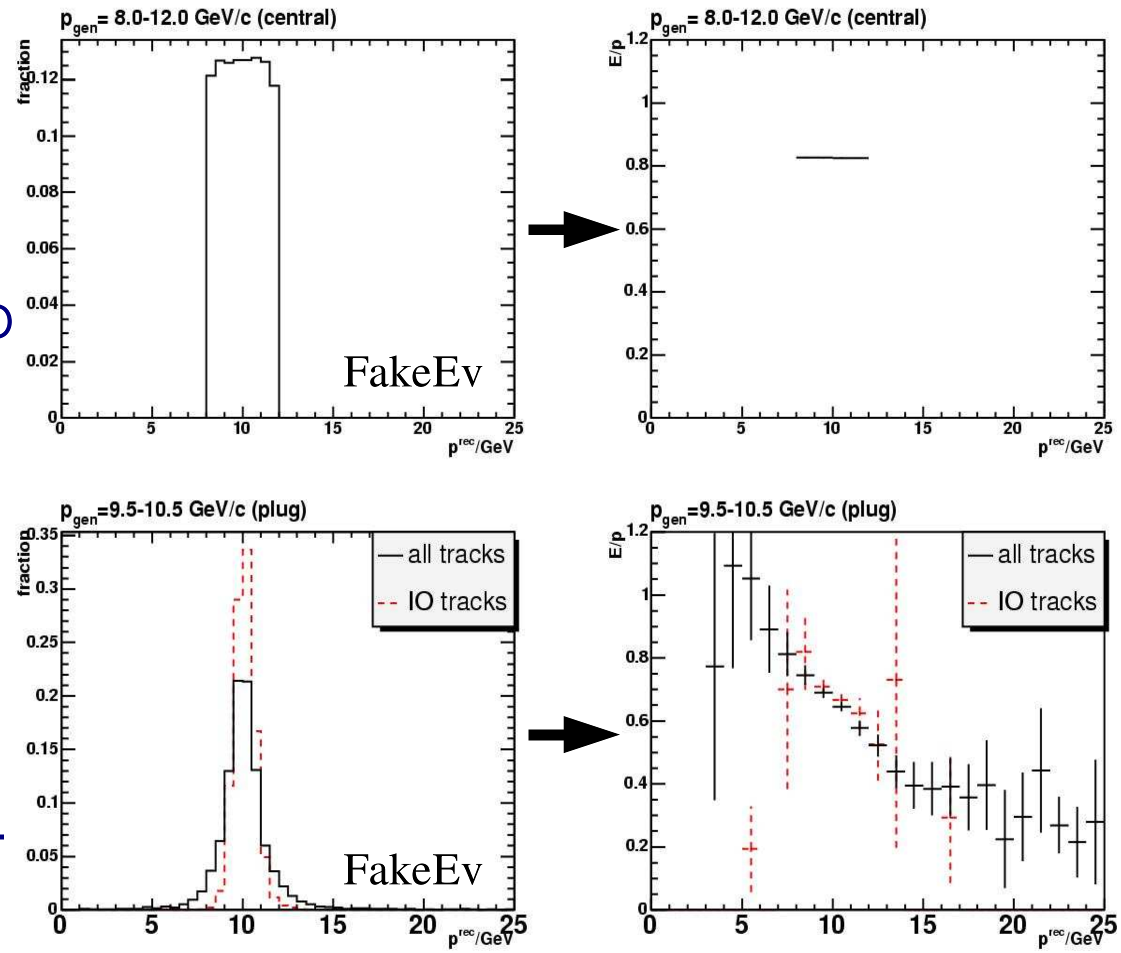
expectation from central part and test beam data

What's wrong in the high momentum region ?

What's Wrong in the Plug?

<u>Check:</u>

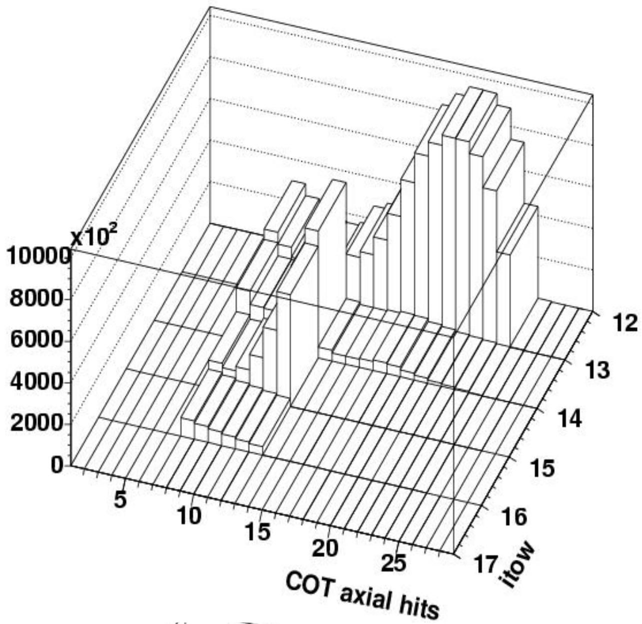
- Consider tracks generated in a precise momentum bin
- Momentum resolution of SISA tracks (plug) much worse than of IO tracks (central).
- This example: $p_{gen}=10 \pm 0.5$ GeV/c large tails down to 3 GeV/c and up to 20 GeV/c !
- Since measured EM/HAD is related to the real track momentum, resolution effects cause a fake E/p evolution with decreasing values at increasing reconstructed momenta.

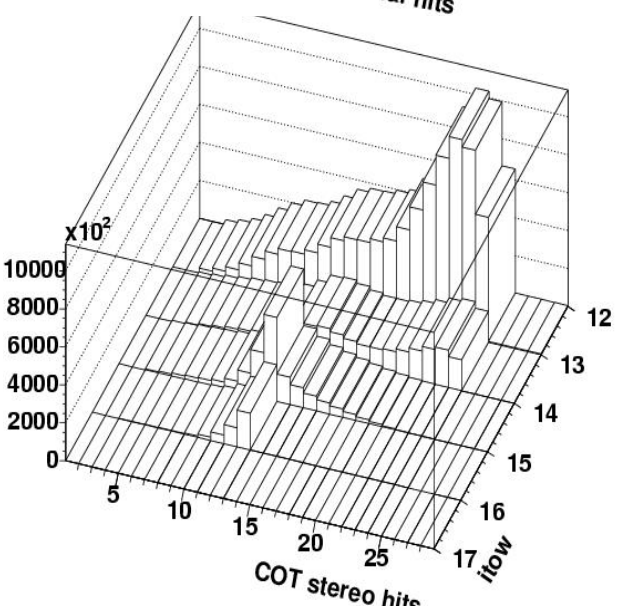


- In samples with e.g. $1/p^2_{gen}$ spectrum, the fractional population of fake (i.e. too small) E/p_{rec} values is much larger in higher p_{rec} bins than in lower p_{rec} bins.
- Effect can be significantly reduced by requiring IO tracks in the plug.
- Have to handle remaining resolution effects by choosing appropriate bin widths.

Using Plug IO Tracks

COT hits (gjtc0d):





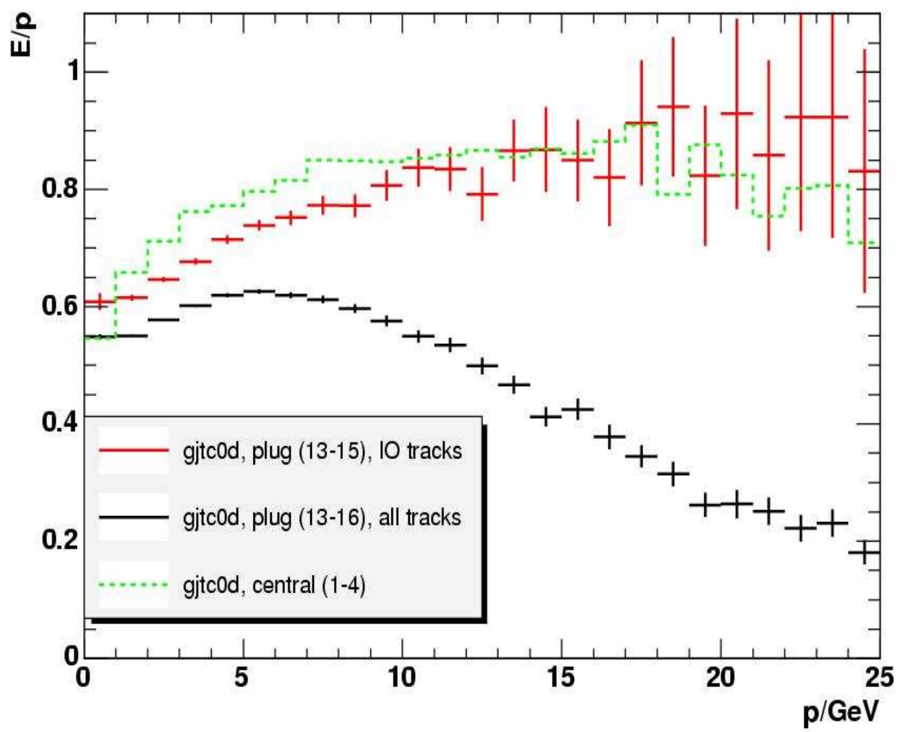
New tentative cuts:

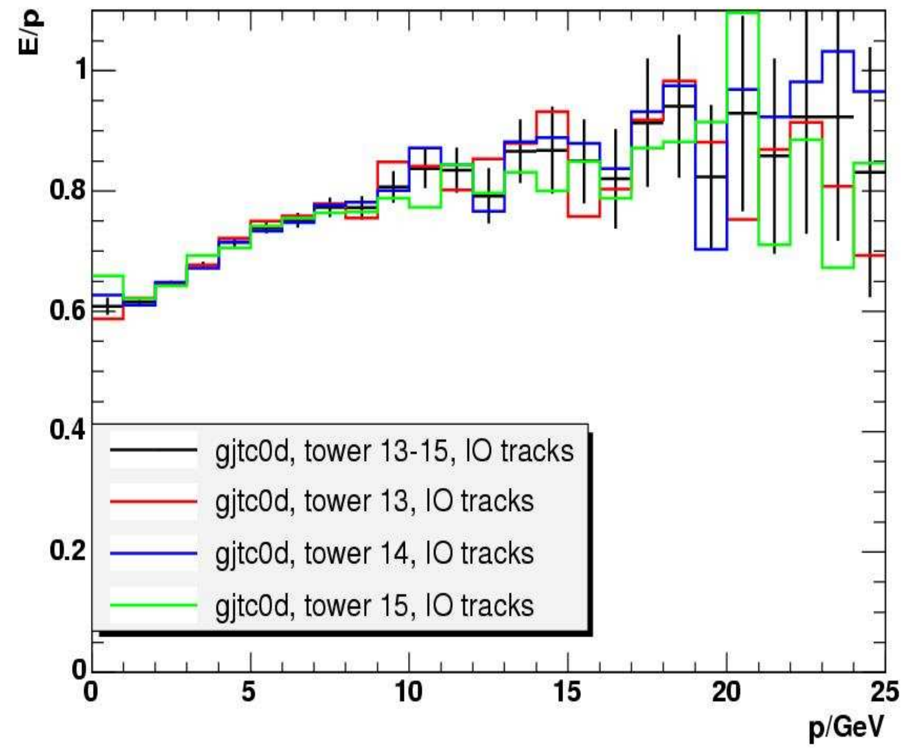
tower	COT		Silicon		
	axial	stereo	axial	stereo	z
12	18	20	4	2	2
13	7	20	4	2	2
14-15	7	7	4	2	2
16-21	—	—	4	2	2

Number of tracks (9M events):

tower number	momentum range (GeV/c)								
	≥ 2	0.5-2	2-3	3-5	5-8	8-12	12-16	16-24	>24
12	34534	99453	21374	10433	2241	394	65	24	3
13	36572	43371	18221	13245	3982	867	168	71	18
14	88968	72298	41846	33366	10781	2320	441	161	52
15	33543	16694	13730	13058	5139	1245	243	106	19
16	436835	346051	207135	150747	53504	15269	4186	2617	2644
17	402262	167825	169639	140429	59386	19377	5600	3626	3379
18	328043	42903	118674	114158	56327	21955	7226	4718	4004
19	154502	230	32760	55907	34789	16166	5969	4341	3764
20	6985	0	19	2362	2064	1150	497	426	384
21	92	0	0	7	24	19	12	12	11

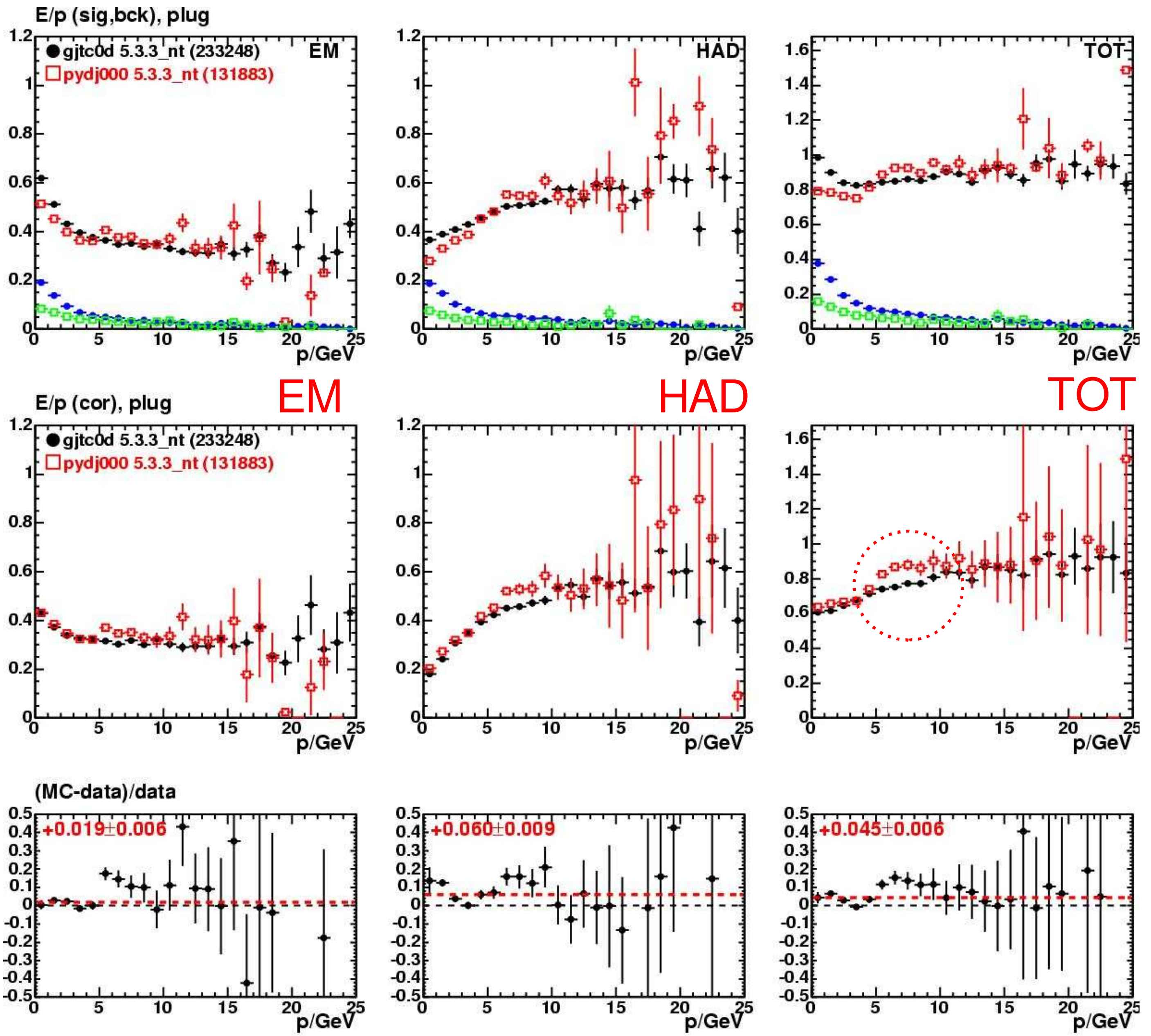
⟨E/p⟩ in the Plug with IO Tracks





- E/p based on IO tracks look sane for towers 13-15
- Systematically smaller values than in central.
  - Wider profiles (shower coverage)?

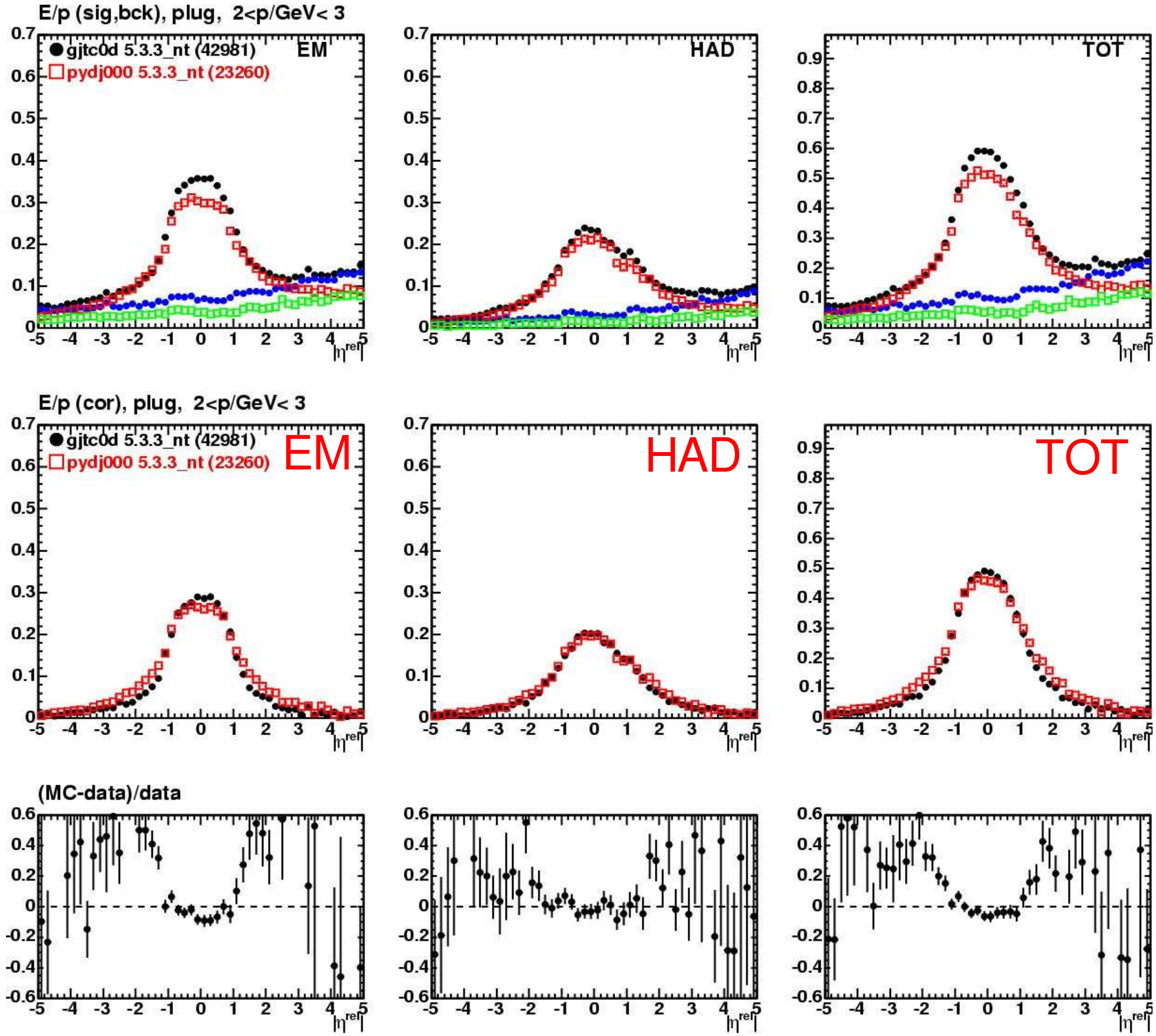
⟨E/p⟩ vs p (Plug, IO Tracks)



- Corrected E/p shape now according to expectation.
- Jump in MC at 5 GeV/c might be related to discontinuity of current tuning / shower coverage

⟨E/p⟩ vs relative η (Plug, IO Tracks, 2-3GeV/c)

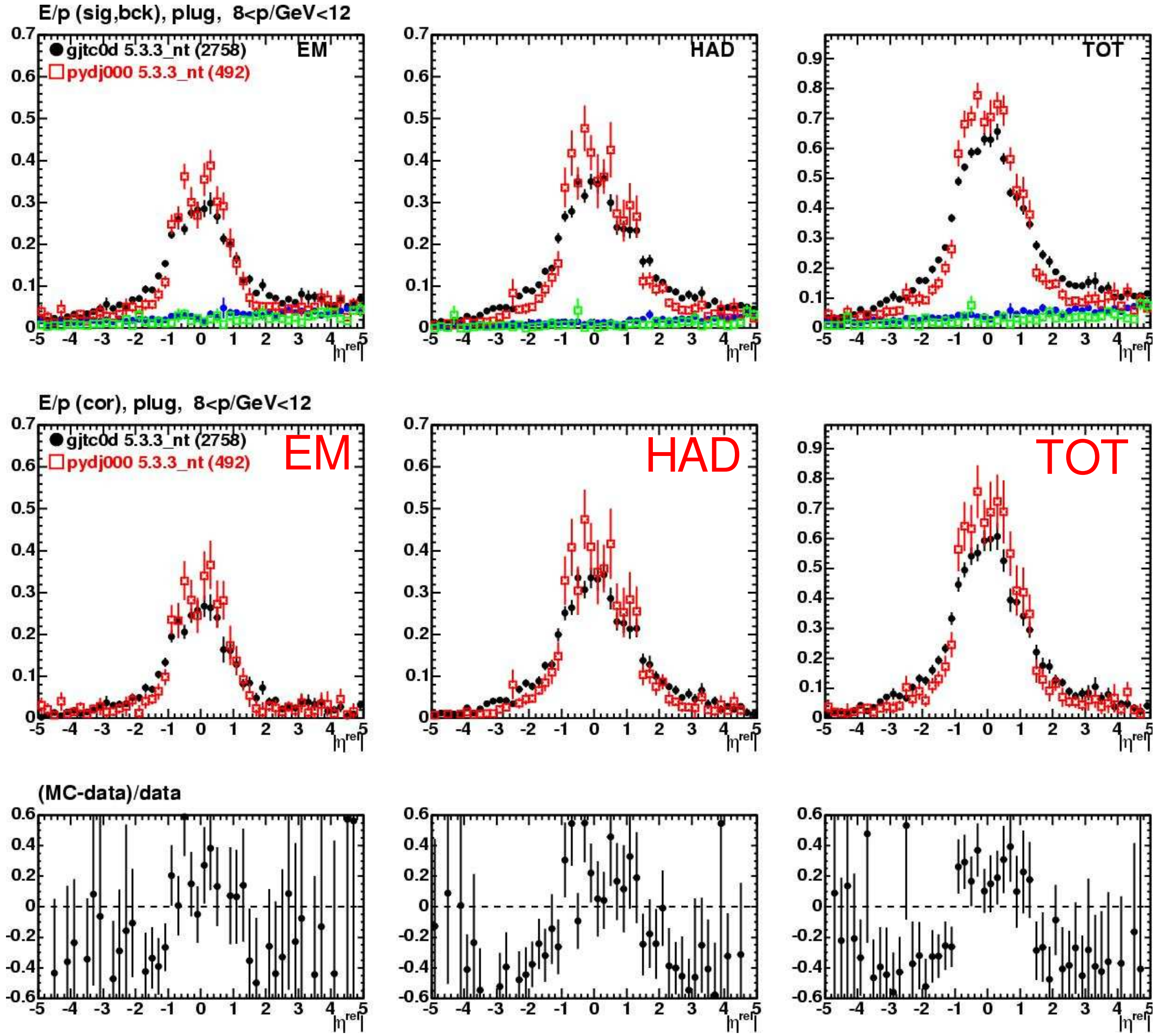
old 0-2.5 GeV tune



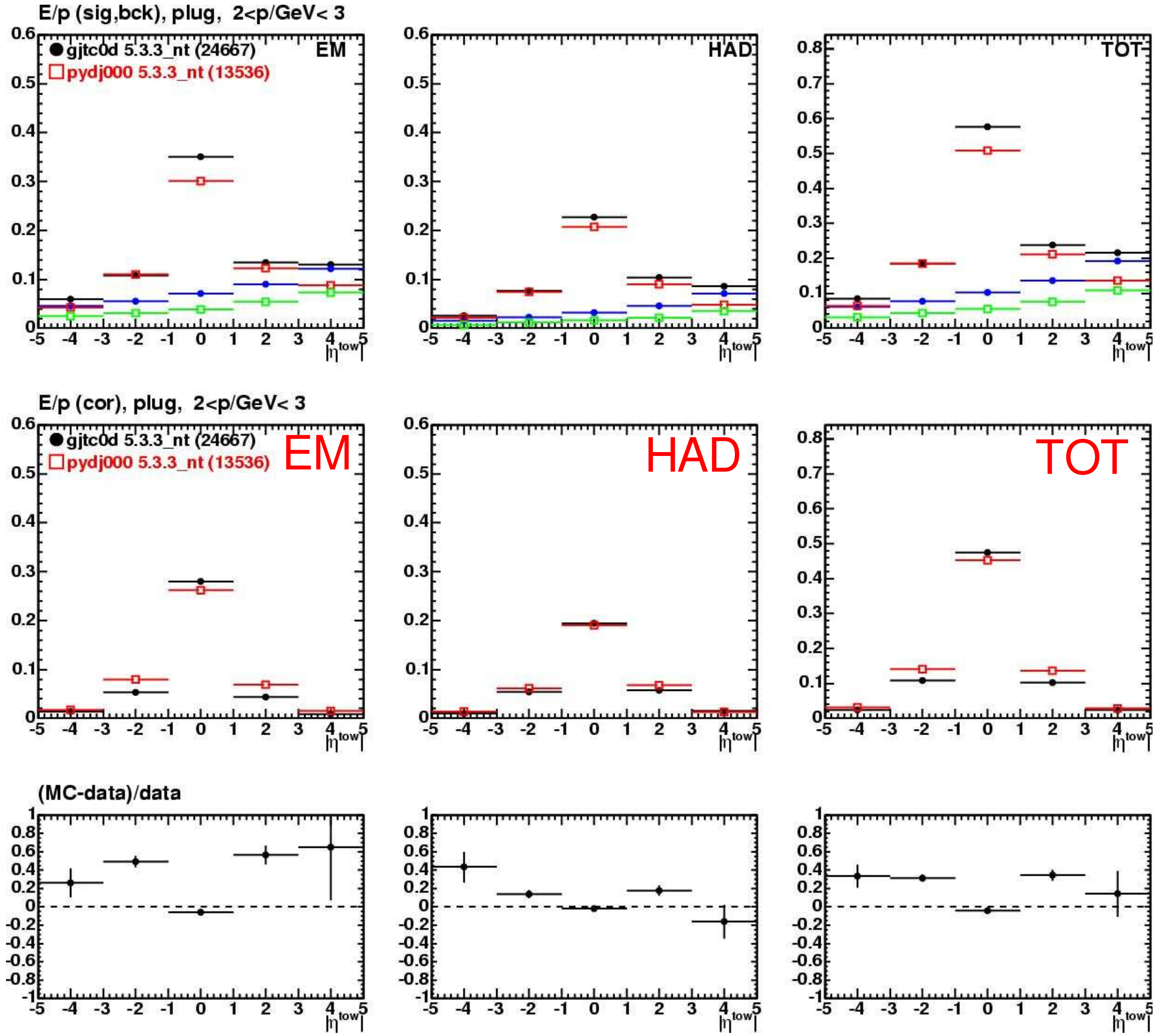
- Sign convention:
  - – = tower points to central crack
  - + = tower points to beam line
- Background:
  - non-negligible
  - asymmetric
  - not linear in η

⟨E/p⟩ vs relative η (Plug, IO Tracks, 8-12GeV/c)

H1 default



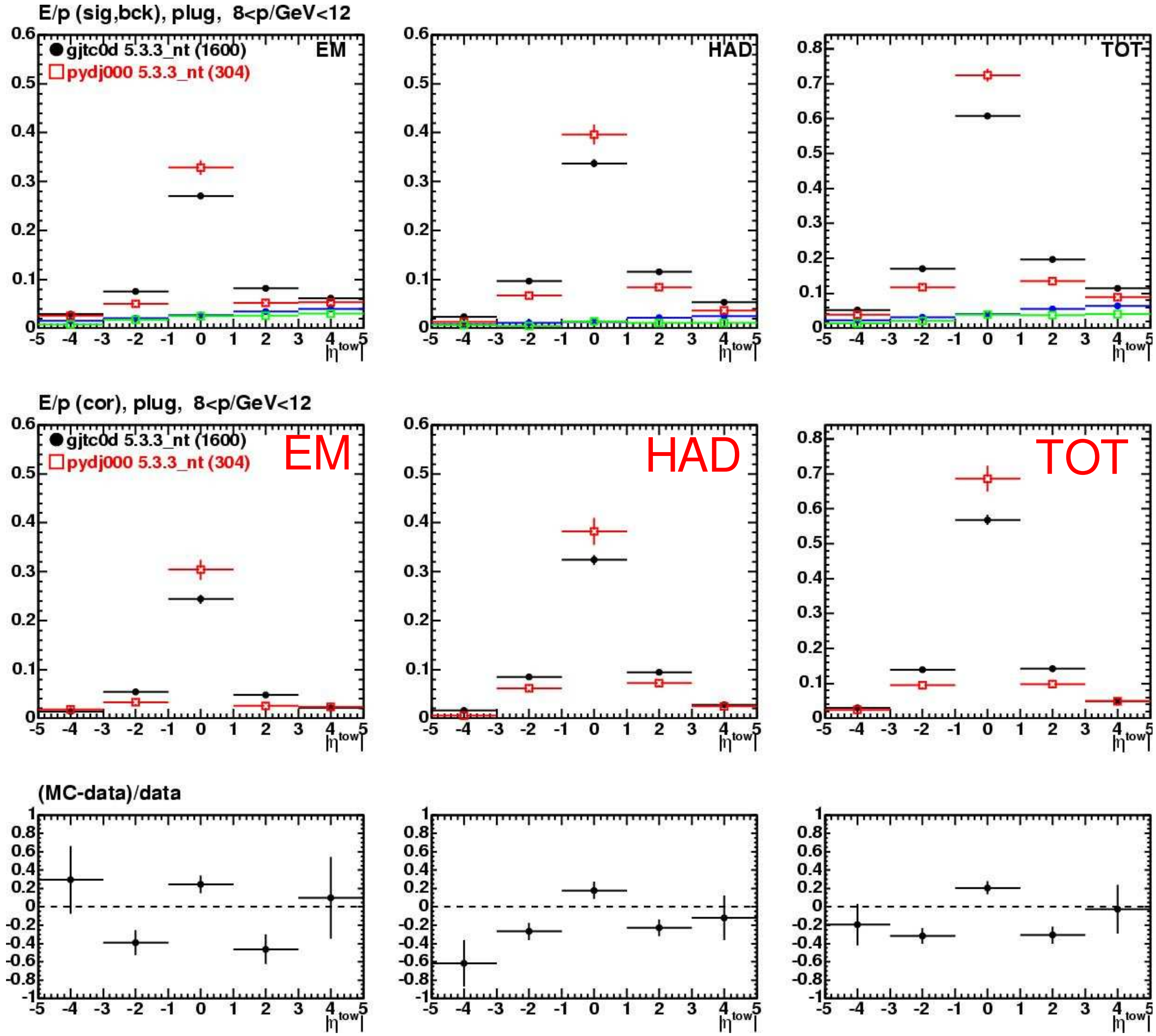
Tune Distributions (Plug, IO Tracks, 2-3GeV/c)



old 0-2.5 GeV tune

Again too wide MC profiles for p<5GeV/c!

Tune Distributions (Plug, IO Tracks, 8-12GeV/c)

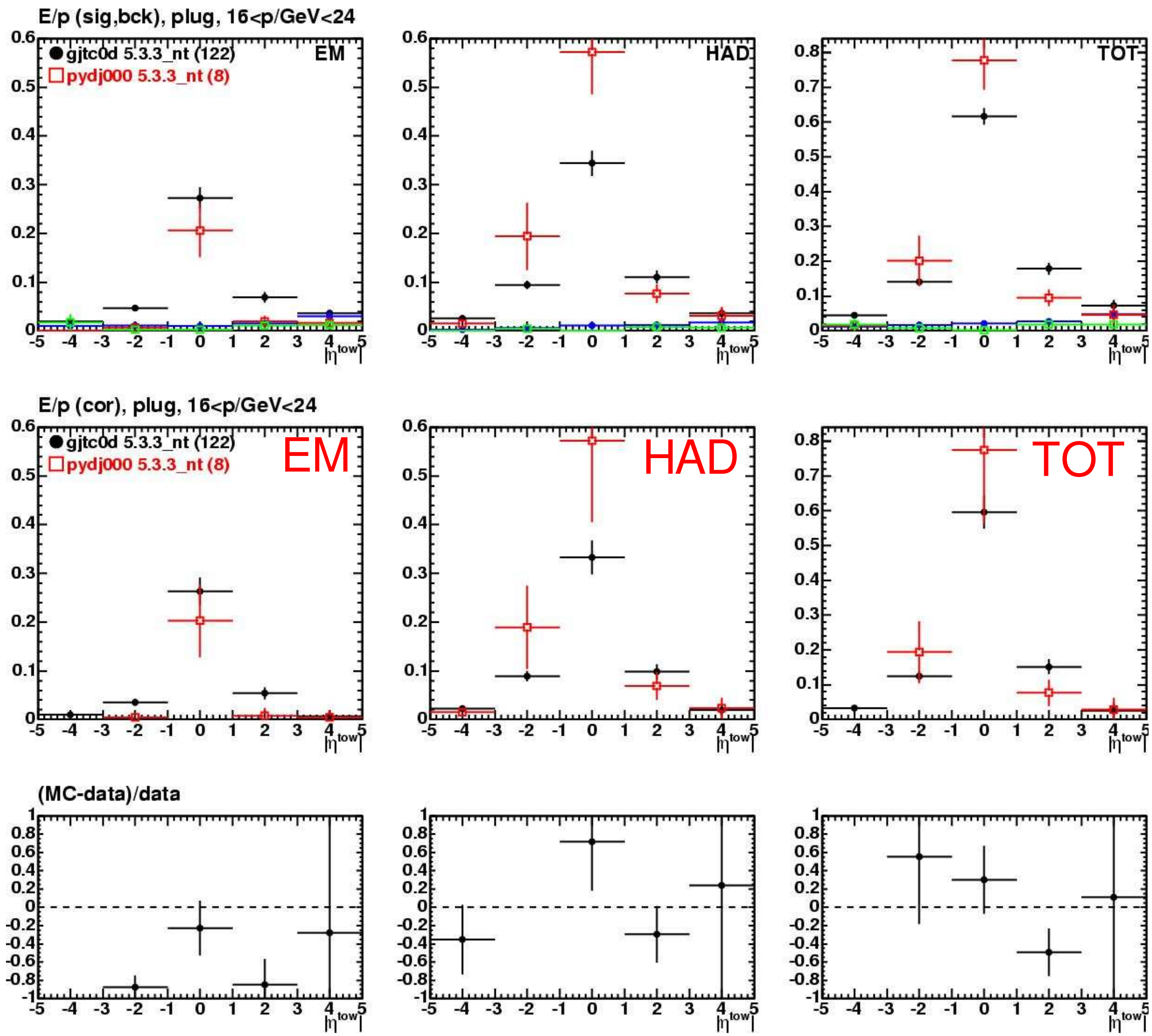


H1 default

Again too narrow MC profiles for p>5GeV/c

Tune Distributions (Plug, IO Tracks, 16-24GeV/c)

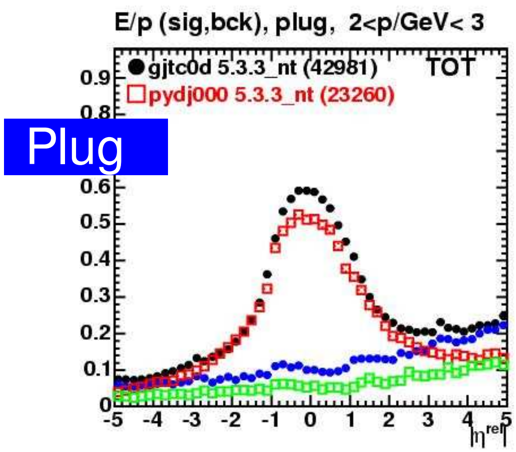
H1 default

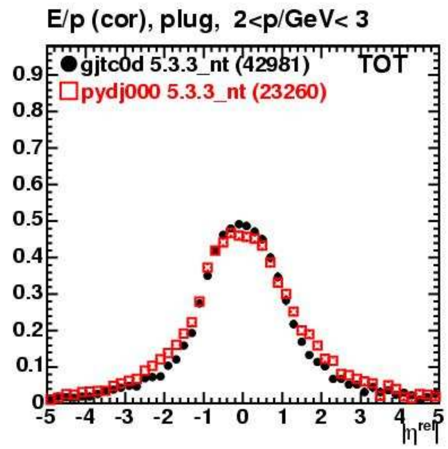


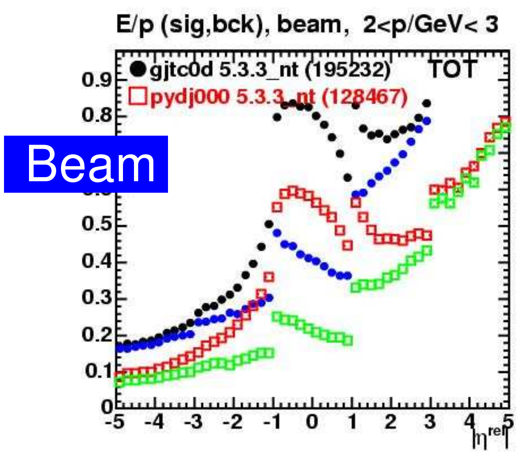
- We have enough data tracks for tuning the plug up to 20GeV/c
- Will switch to FakeEv with flat p spectrum to improve MC statistics

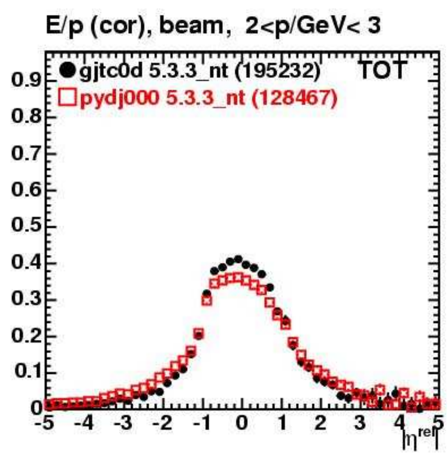
Background Issues

For η profiles we are using background strips in ϕ:

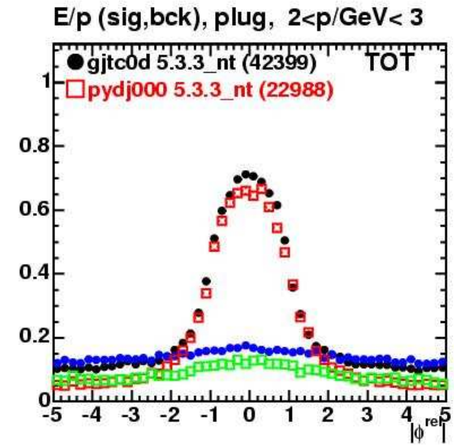


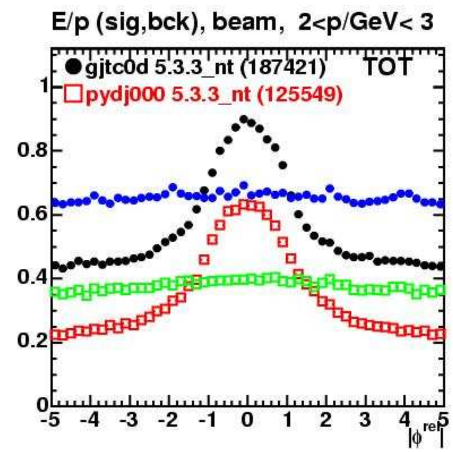






For ϕ profiles we are using background strips in η:





- Background symmetric in $\phi \rightarrow$ no problem for η profiles
- Non-linearity in $\eta \rightarrow$ "1.5 x (near+far)" overestimates background in ϕ profiles

Conclusions

- First uniform tuning of hadronic lateral shower profile in central region of calorimeter at p = 2 – 24 GeV/c
- Next tuning iteration:
  - Improvement in HAD due to tighter z-vertex cut expected.
  - Impact of tighter shower cut-offs
  - Finer steps
- E/p measurement in the plug needs better track resolution
  - Use IO tracks in tower 13-15
  - SISA tracks with better quality?
- We have sufficient IO tracks for tuning in the plug up to 24 GeV
  Will have first results soon!

For a map of the calorimeter with detailed tower-by-tower plots showing quality of shower simulation:

http://www-cdf.lbl.gov/~pmf/Calorimeter