Calorimeter Simulation for Gen-7

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Outline

- What are we tuning for Gen-7?
- Electron response
  - new phi profile (finalized)
  - phi crack check (finalized)
  - new tower 9 response (finalized)
- Hadronic response
  - single track analysis
  - new lateral profile in Central and Plug (finalized)
  - absolute response tuning for the Central (finalized) and for the Plug (almost finalized)
- Comments on Uncertainties
- Conclusion

Contributors:

Shawn K., Geumbong Y., Soon J., Yeon Sei C., Mel S., Ken H., Monica D'O., P.A.M.F., and others ...

What (and Why) Are We Tuning?

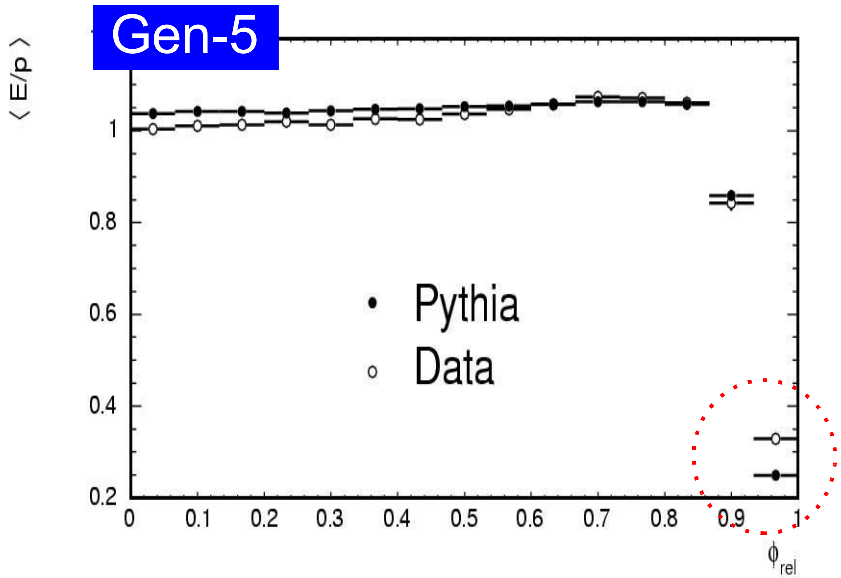
Calorimeter simulation tool: **GFLASH**

- single particle response
- fast shower parametrization
- very flexible, has lots of switches

What?	**Why?**
For recent tuning we played with... • lateral hadronic profile parametrization - shower core, shower spread	- reduce JES OOC–uncertainties (dominant at low jet p_T) - reduce bias of MC energy scale - improve shower shape
• absolute hadronic response parametrization - fraction of energy deposited (FEDP) - relative sampling fractions of EM/HAD compartments	- reduce absolute JES-uncertainties (dominant at high jet p_T)
• electron response correction functions - phi mapping function - tower 9 eta profile and energy scale	- reduce e.m. response uncertainties - improve pi-zero response inside jets - extend fiducial region for electron analyses (e.g. top mass)

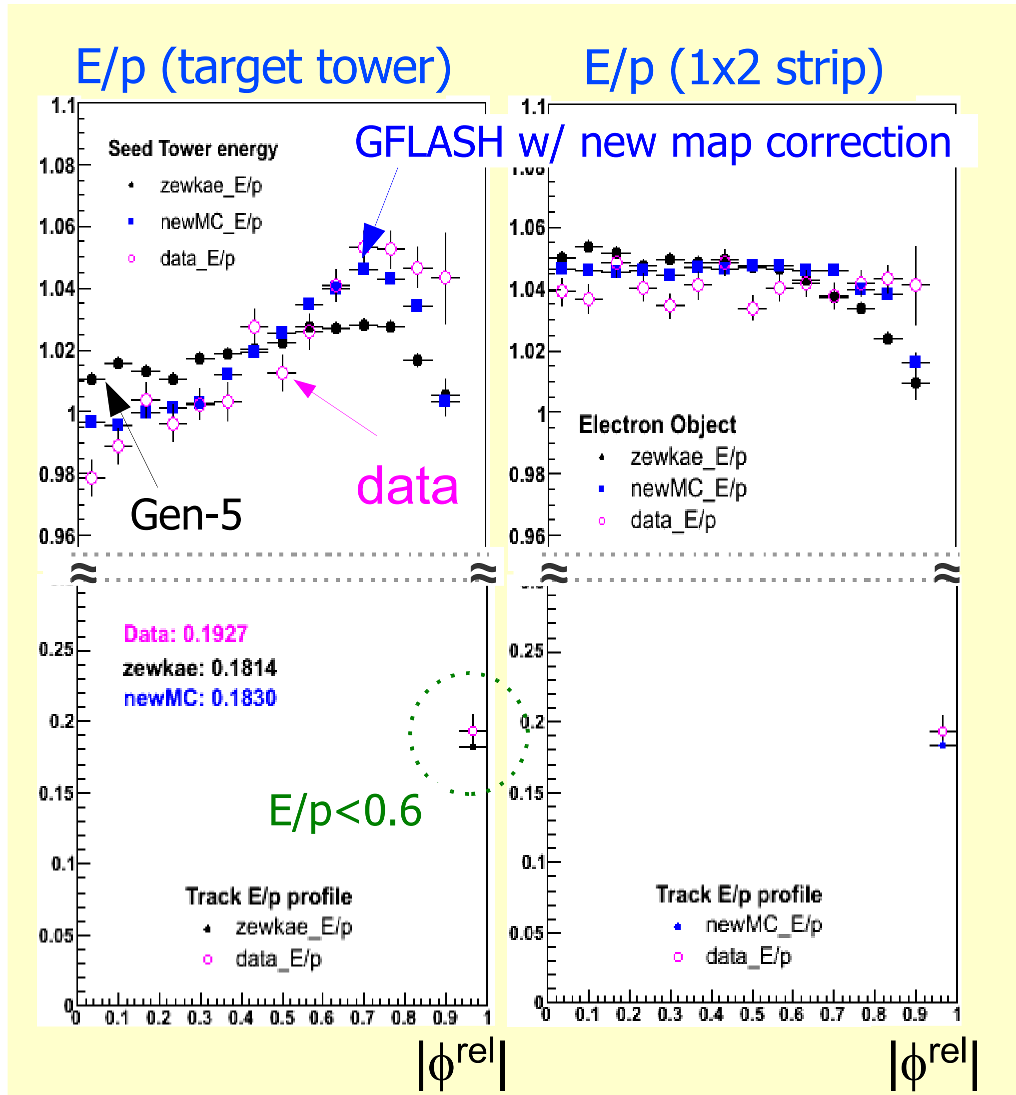
- Focus on lateral profile and average $\langle E/p \rangle$ response *in-situ.*
- Energy range considerably extended: 0-40GeV in the Central, 0-20 GeV in the Plug.
- Keep test beam parametrization at 57 GeV and above.

Electron Response

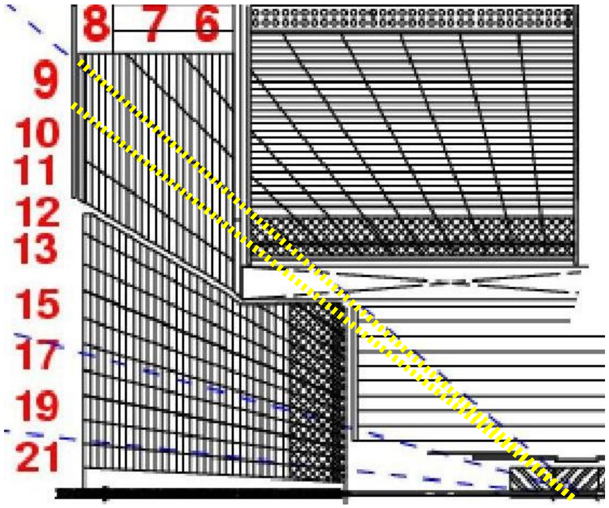


- Response along ϕ is monitored using electron pairs from Z decays in a window around Z mass
  - one leg in Central target tower, the other leg probes ϕ profile
- New map correction in phi, plus MC scaled down by 0.5%.
- ϕ profile has significantly improved.
- Gen-5 discrepancy in crack is most likely due to MC misalignment. Now much better agreement due to improved electron analysis cuts.

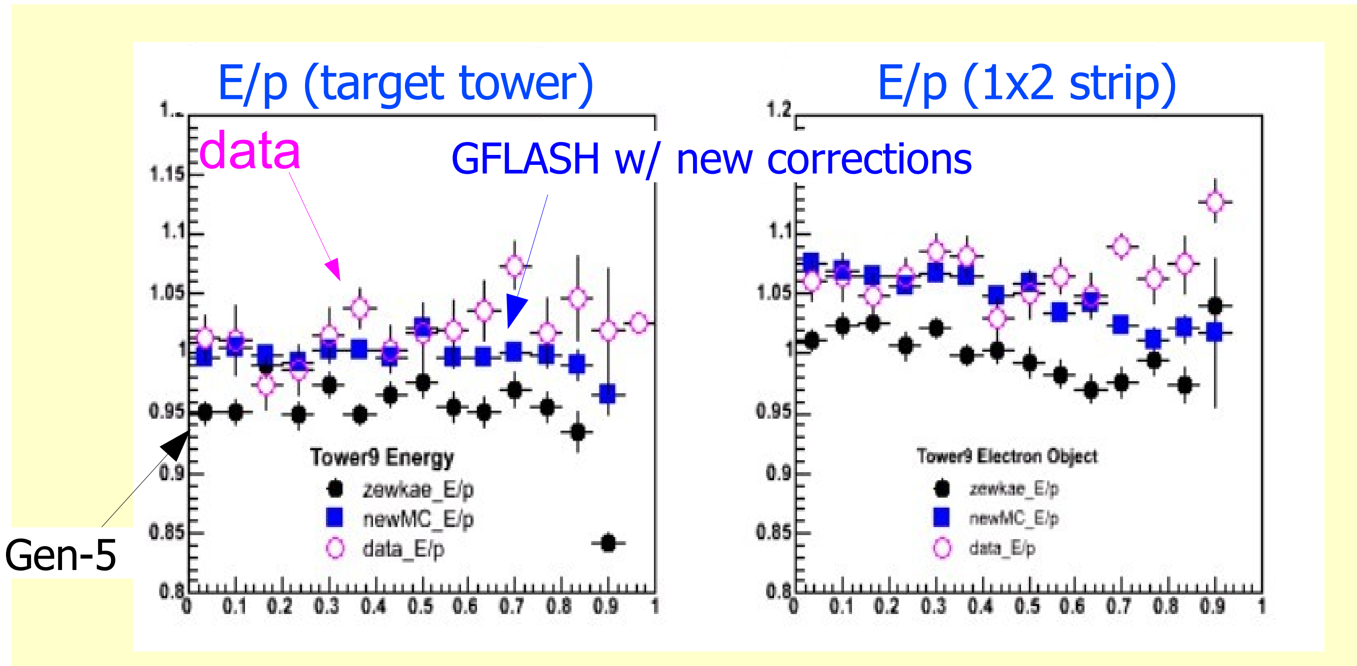
- In Gen-5 the electron response uncertainty is dominated by electrons pointing to ϕ cracks (WLS, steel bar).



Electron Response in Tower 9



- Tower 9 is not part of the fiducial region.
- Complicated geometry, CES appears “truncated”.
- Electron response versus eta was studied using electron pairs from Z^0.
- New map correction in eta, plus MC scaled up by 10%.
- Better agreement of shape and average responses.
- Extends geometrical acceptance of electron analyses.



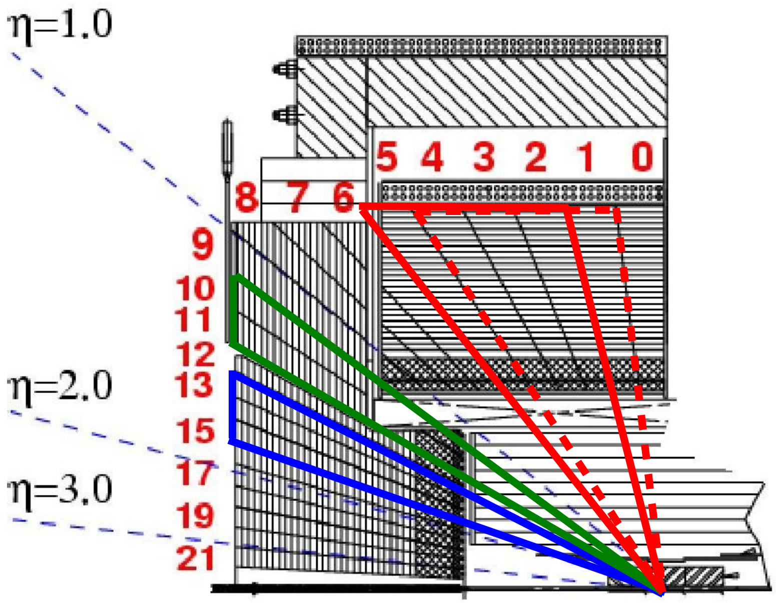
Thanks to Beate H. and Sam H. for their original input.

Single Track Analysis

- Tracks are extrapolated to CES/PES
- Track/CES isolation in 7x7 block around target tower
- Hits in

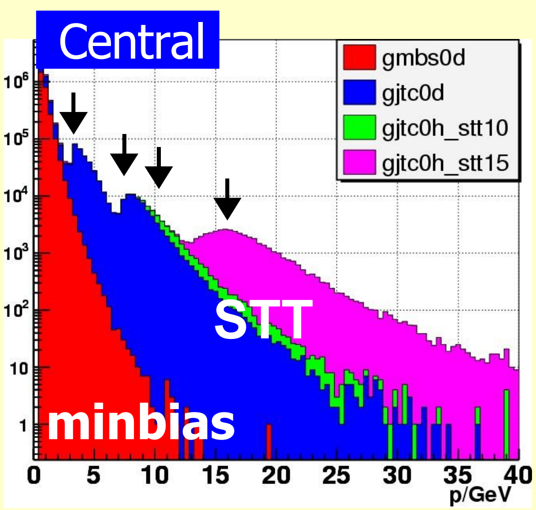
	COT		Silicon		
	axial	stereo	axial	stereo	z
Central (2-5)	≥30	≥30	–	–	–
Crack (10,11)	≥20	≥20	≥4	–	–
Plug (13-15)	≥7	≥7	≥4	≥2	≥2

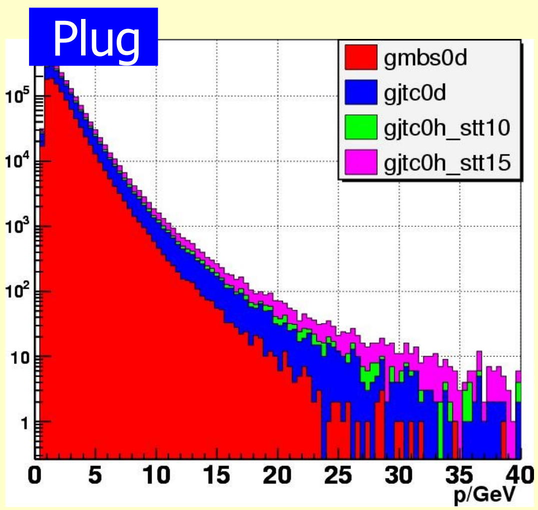
- Central: electron veto at 20GeV,
  muon veto at 25GeV added for some observables,
  p cuts to suppress trigger biases

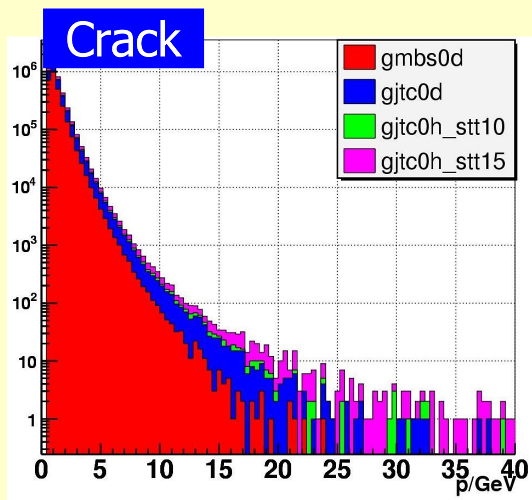


- Minimum bias (gmbs0d, ~21M events)
- JETCALIB sample (gjtc0d, ~16M events)
- Special high p_T single track SVT trigger: gjtc0h_stt15,gjtc0h_stt15 (~10M events)

Thanks to the TRWG!



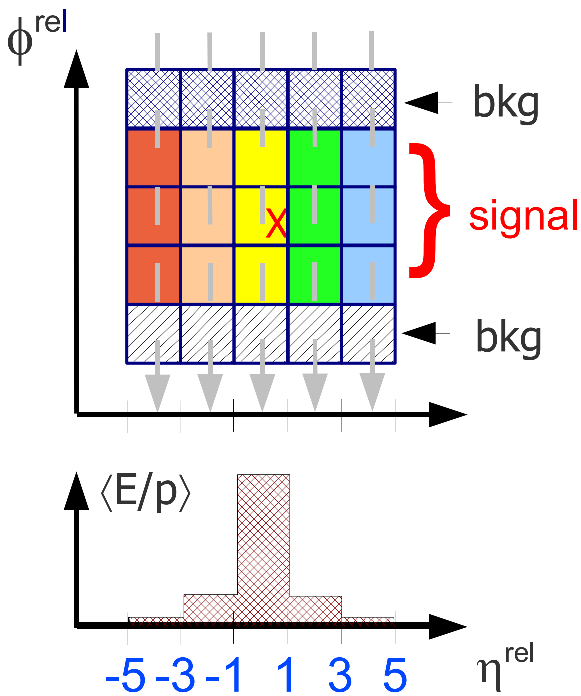


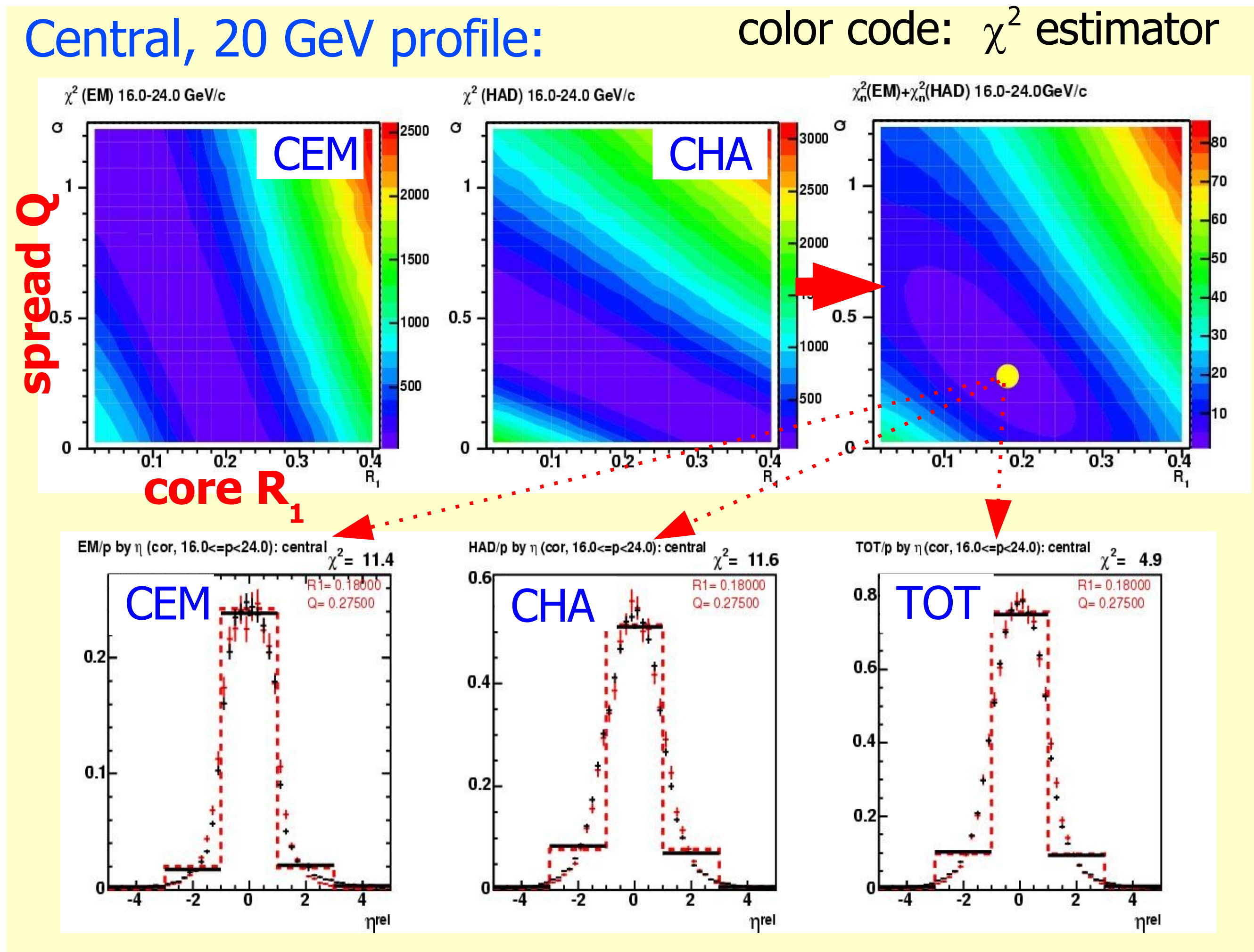


Lateral Profile Tuning

⟨E/p⟩ response <u>relative</u> to target tower:
- 5 tower strips (3x1) adjacent in η
- contour cuts: $|\eta^{rel}|<0.6$, $|\phi^{rel}|<0.6$
- background subtraction

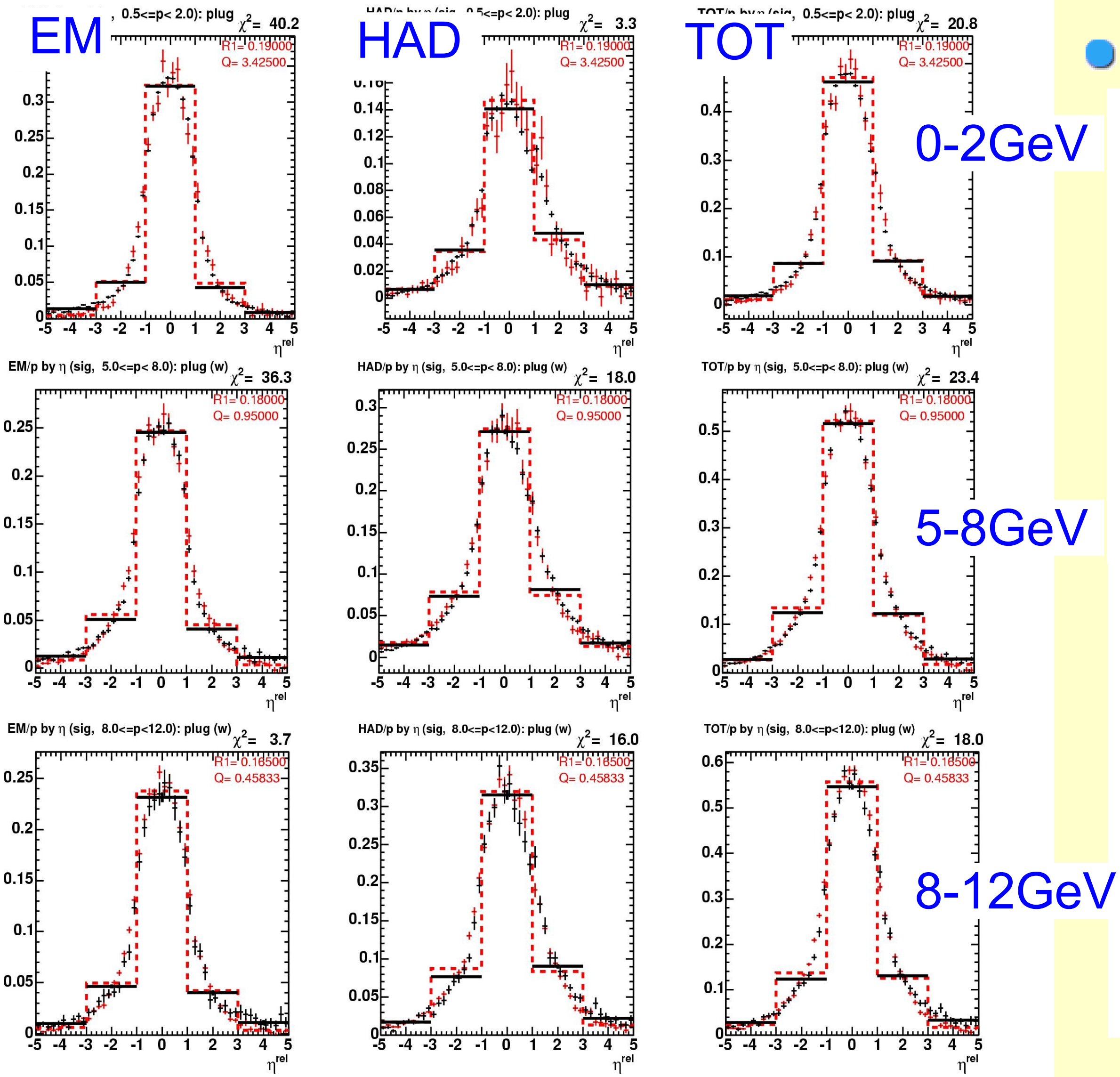
- Early Run-II: tuned only up to 5GeV due to lack of data.
- Now: systematic approach by scanning 2-d parameter space (GFLASH core vs. spread)



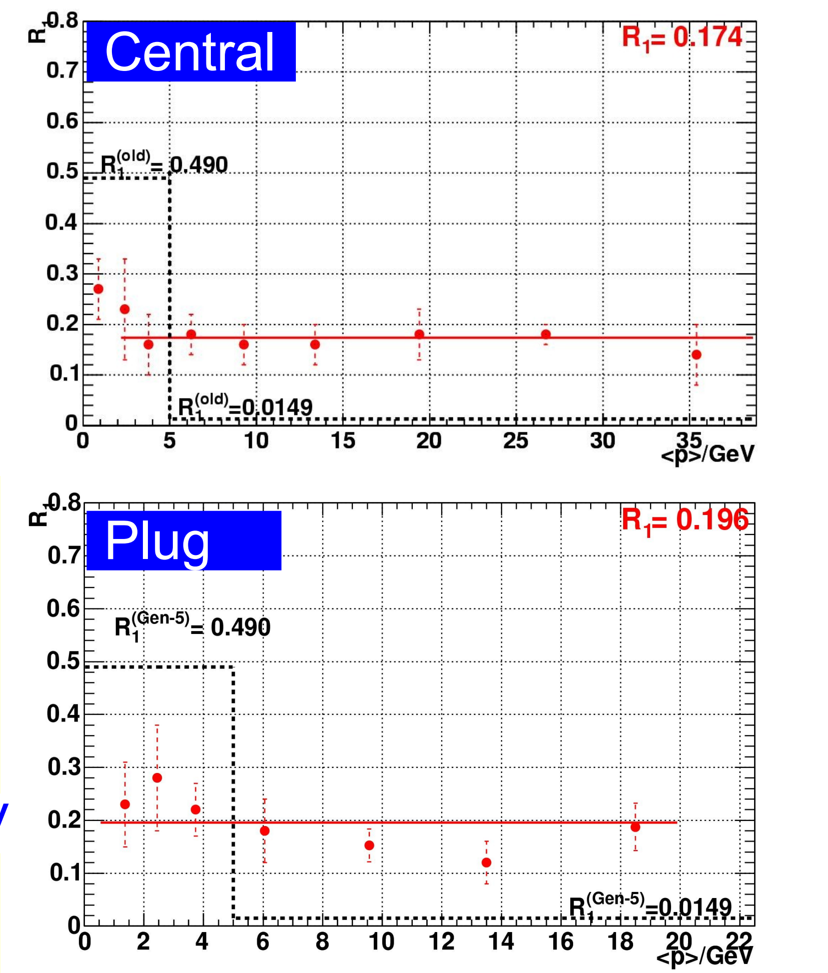


Hadronic ⟨E/p⟩ Profiles

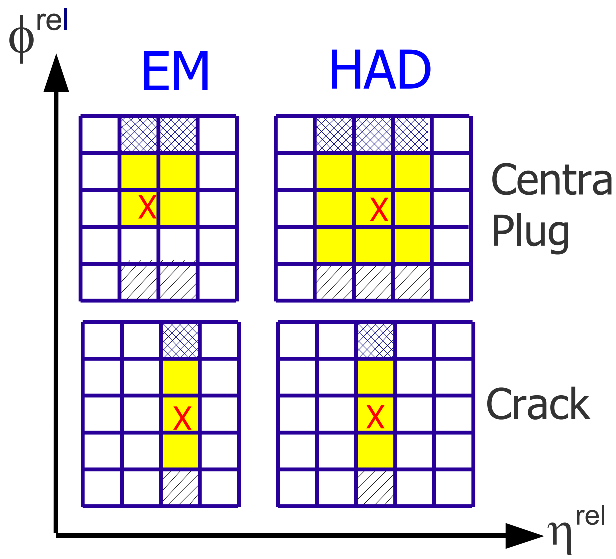
- Example: Plug profiles



- Consistent tuning up to 40(20)GeV in Central(Plug)
- Example: GFLASH shower core R_1



Absolute Hadronic ⟨E/p⟩ Tuning

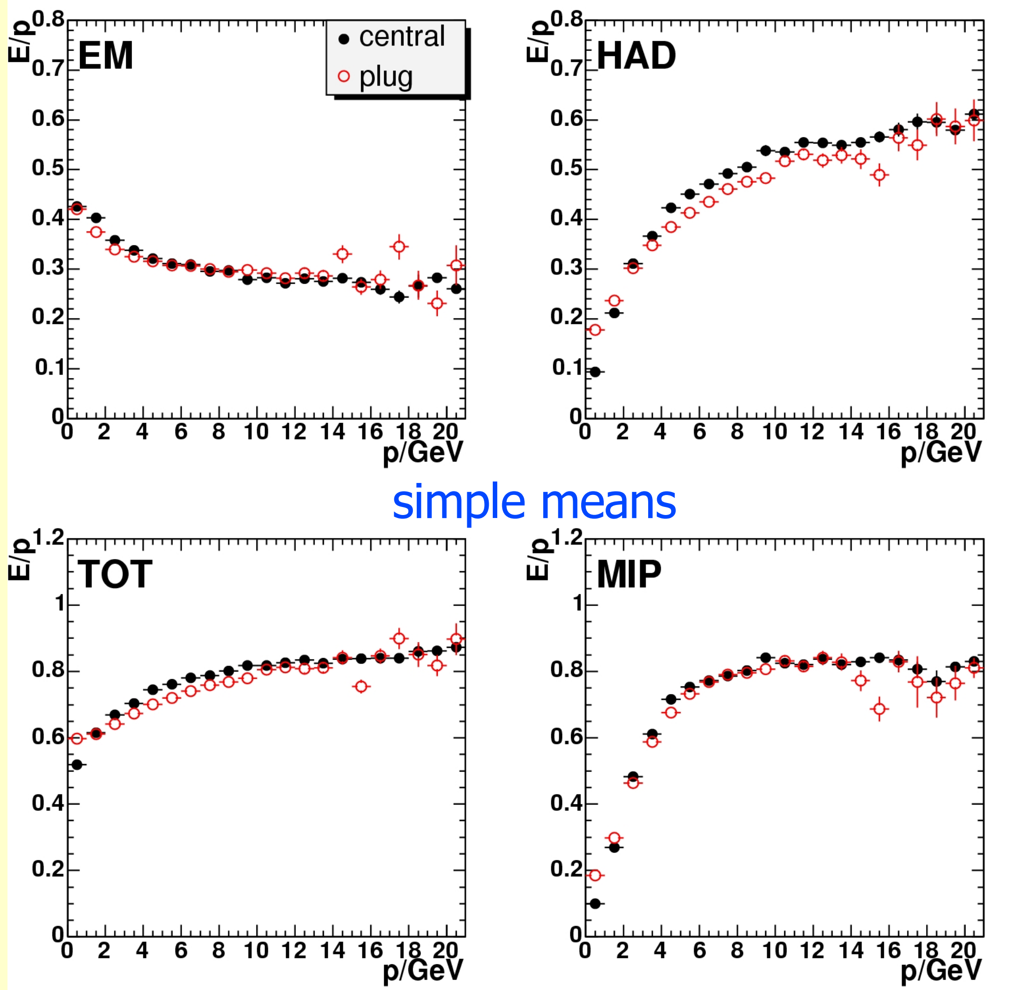


Central & Plug ⟨E/p⟩ response:
- 2x2(EM) and 3x3 (HAD) tower blocks
- contour cuts: $|\eta^{rel}|<0.9$, $|\phi^{rel}|<0.9$

Crack ⟨E/p⟩ response:
- 3x1 (EM,HAD) tower blocks
- contour cuts: $|\eta^{rel}|<0.6$, $|\phi^{rel}|<0.9$

Background correction

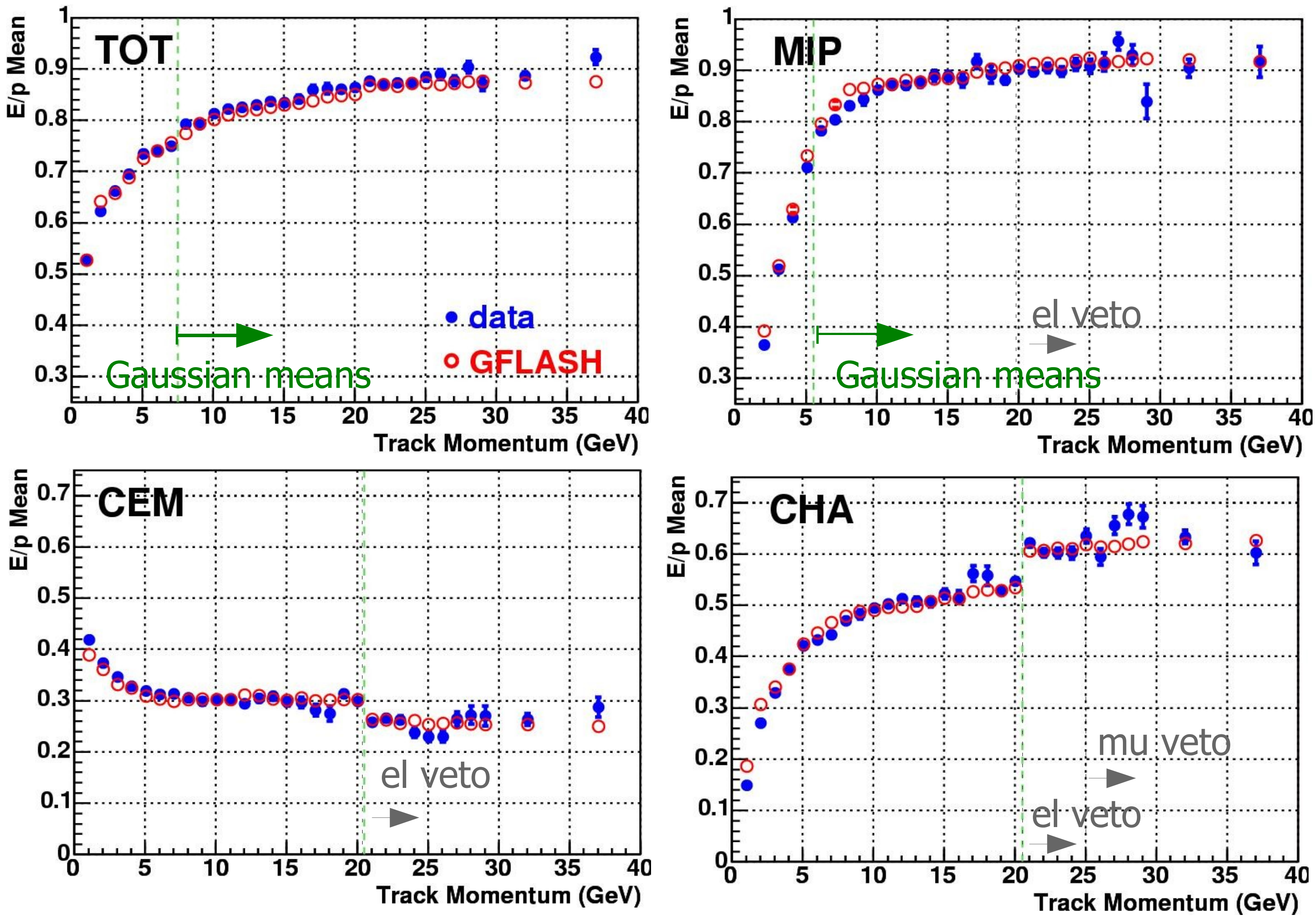
Data reference Central vs. Plug:



- Central: use all data sets
- Plug/Crack: focus on minbias+gjtc0d (see appendix)
- Plug vs. Central: Different track quality, data sample combination method, background conditions, no PES isolation...

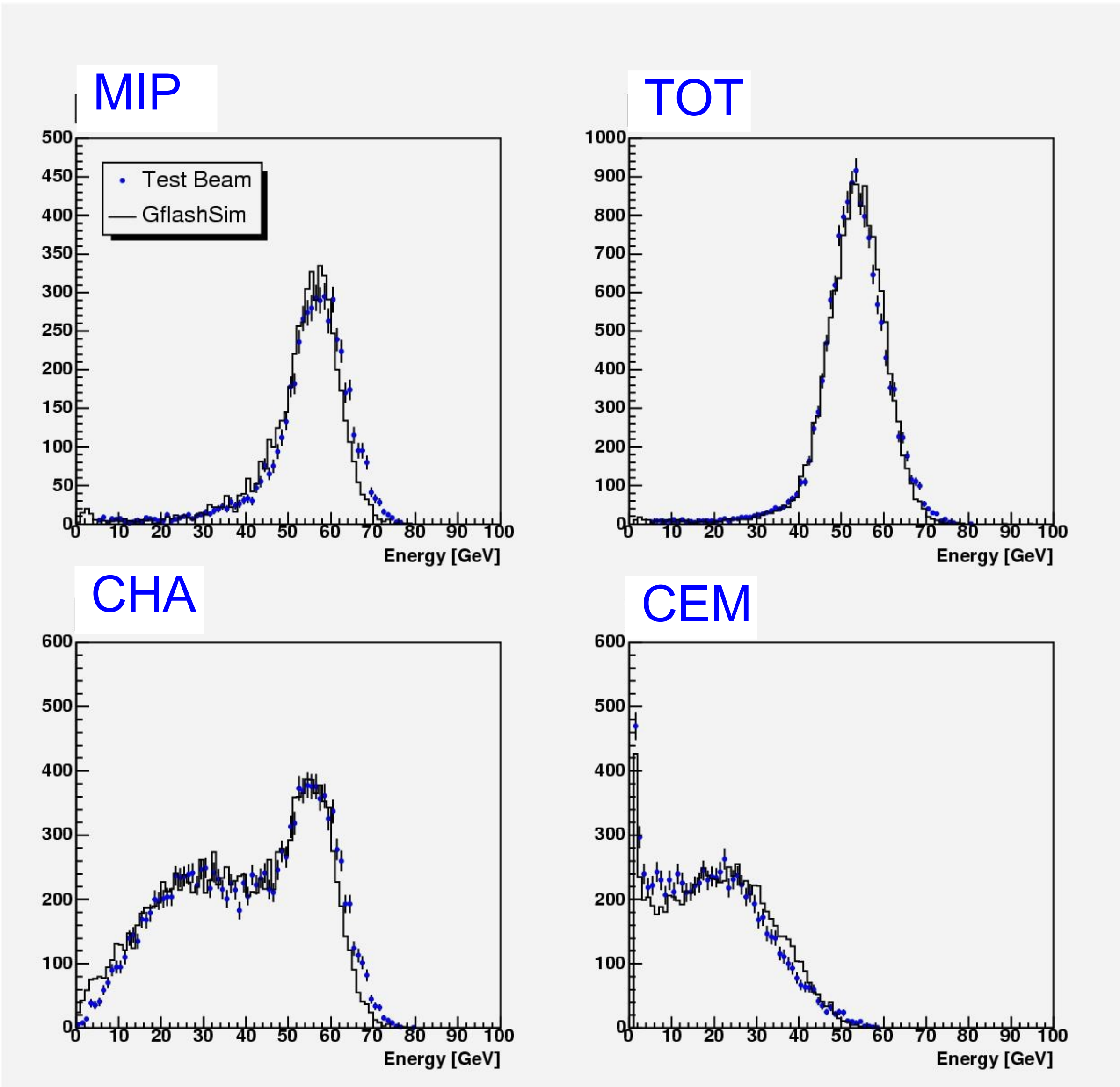
... nevertheless consistent picture of response measurement (as long as you use IO tracks in the Plug)

Central: Status of ⟨E/p⟩



- CEM, CHA, TOT=CEM+CHA, MIP =CHA (CEM<670MeV)
- Tuning of FEDP, CHA and CEM sampling.
- Picture improved significantly, direct control in-situ up to 40GeV (was 5GeV in Gen-5)

Comparison with 57 GeV Test Beam Data



Gaussian Fits of the MIP and Total

MIP

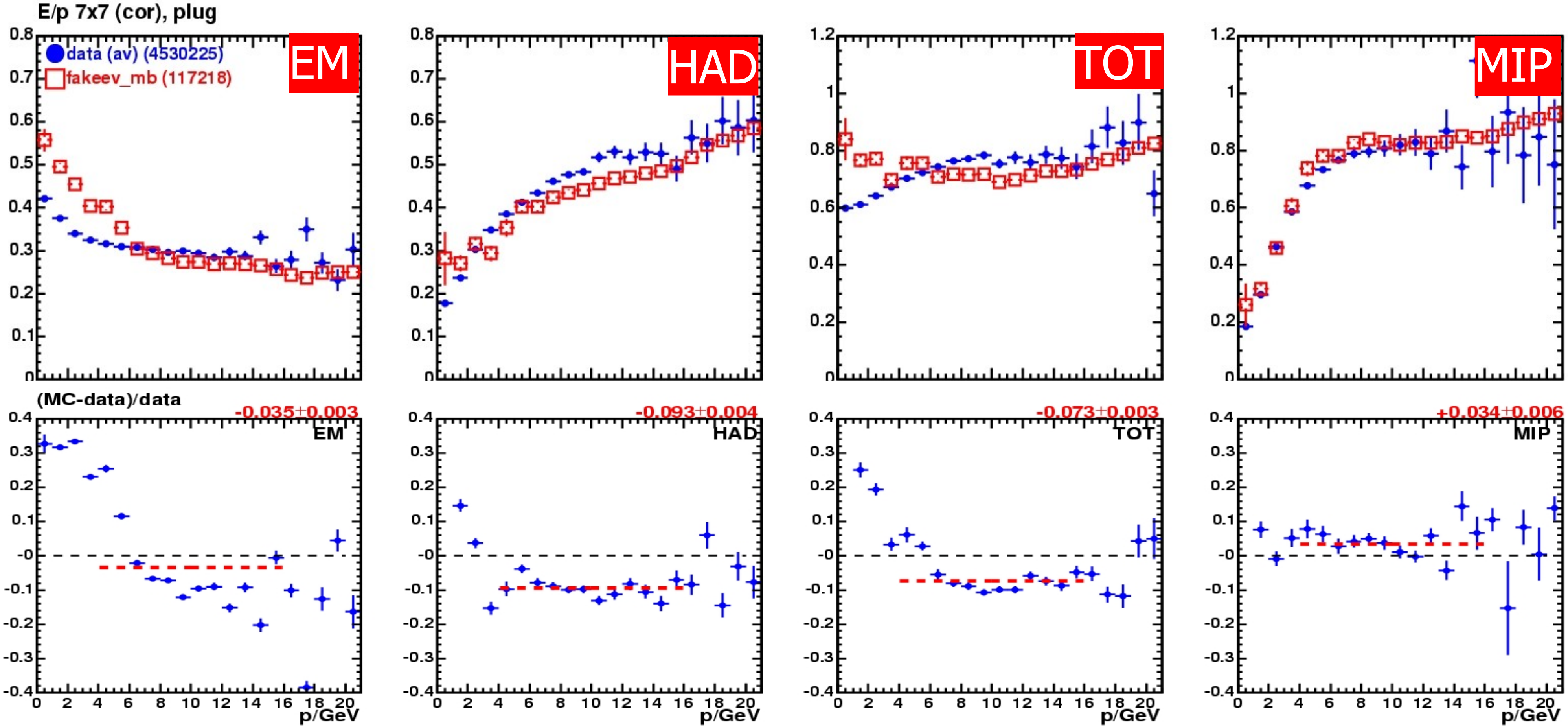
57 GeV testbeam	57.2668 ± 6.3638
f4 tune MC	56.1179 ± 5.6968
percent difference	-2.0%

TOT

57 GeV testbeam	53.4797 ± 6.2428
f4 tune MC	53.6959 ± 6.3393
percent difference	+0.4%

- Reassure latest tuning using pure pion response from 57 GeV test beam.
- Test beam is still reference for many longitudinal details.
- Reasonable agreement of E/p shapes between MC and data.

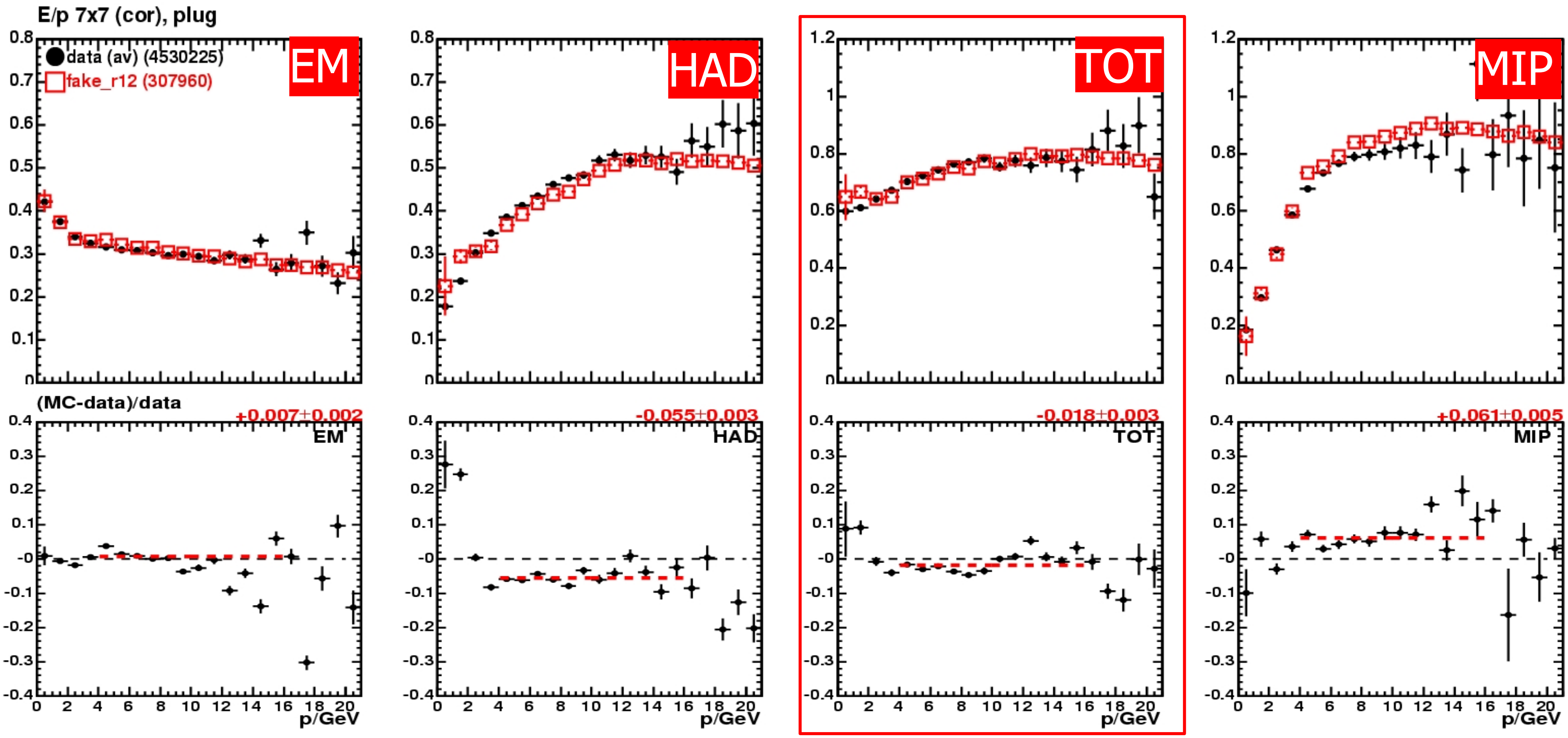
Plug: Old Gen-5/6 Picture but with New Profiles




```
PBYMIP(1)= 2.30 - 0.48 * TANH( 7.45 * ( LOG(p) - 1.74 ) )
PBYMIP(2)= 3.01 + 0.19 * TANH( 5.04 * ( LOG(p) - 1.32 ) )
FEDP = 0.7366 + 0.1699 * TANH( 0.6569 * ( LOG(P) - 2.0826 ) )
```

- Above plots: Gen-5 FEDP & sampling with new Plug lateral profile parameters.
  → shift of absolute responses due to modified leakage out of the signal region
- Re-adjustment of GFLASH parameters necessary.

Plug: Status of ⟨E/p⟩ (near final)

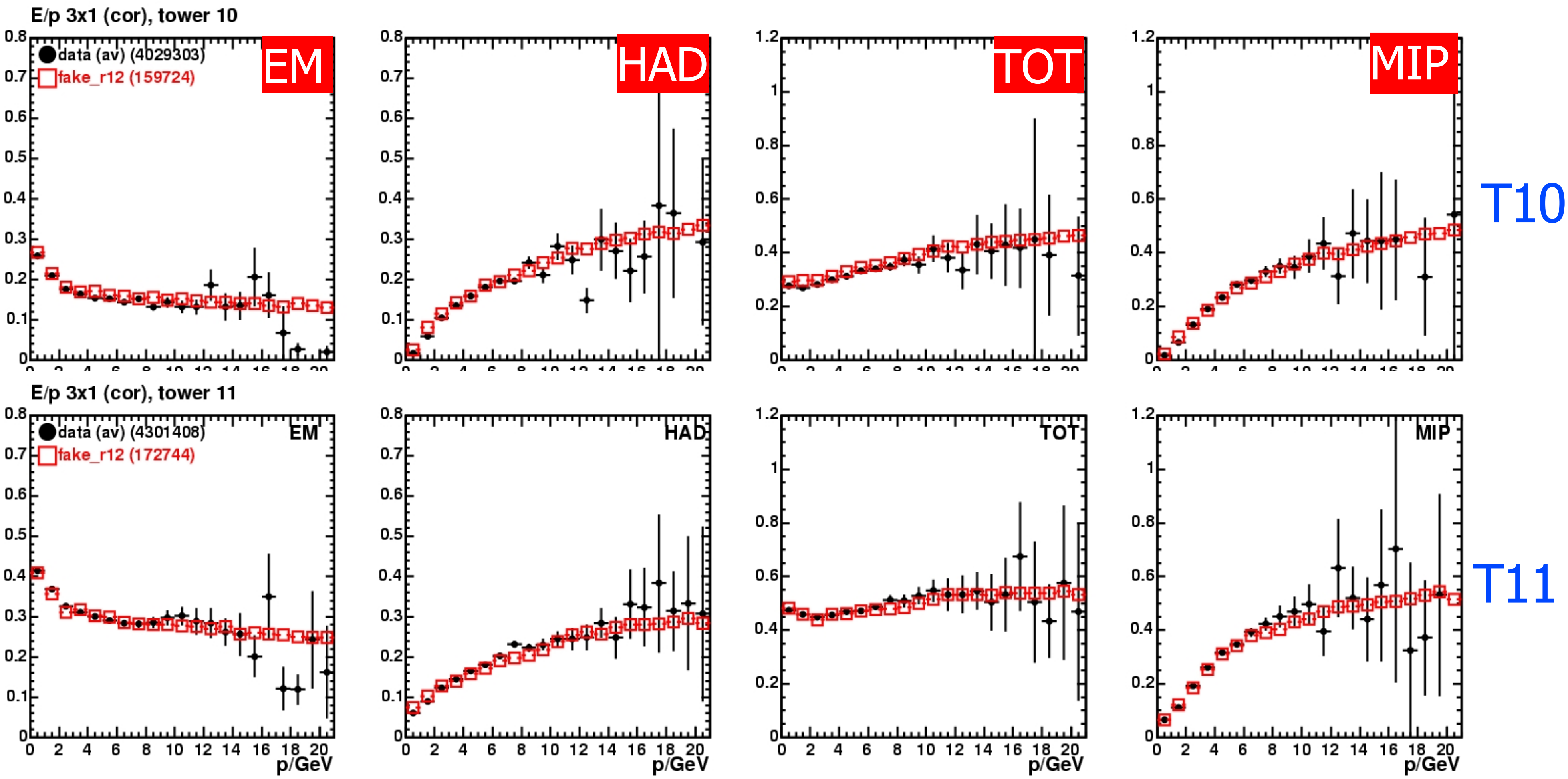


PBYMIP(1)= 1.83 – 0.13 * TANH(8.50 * (LOG(P) - 1.35))
PBYMIP(2)= 2.70 – 0.625 * TANH(8.50 * (LOG(P) - 1.35))
FEDP = 0.7071 + 0.1362 * TANH(2.2600 * (LOG(P) - 1.2692))

R12

- Currently, control of MIP response requires variation of PHA sampling by ± 25% (see appendix for parametrization changes).
- Picture is improvable, goal is precision at **2-5%** level for all four distributions (ongoing work).

Crack: Status of ⟨E/p⟩ (near final)



- For crack towers individual tower-by-tower scaling factors are applied to default relative sampling fractions (PEM, PHA, WHA).
- Picture is further improvable (ongoing work).

Comments on Uncertainties

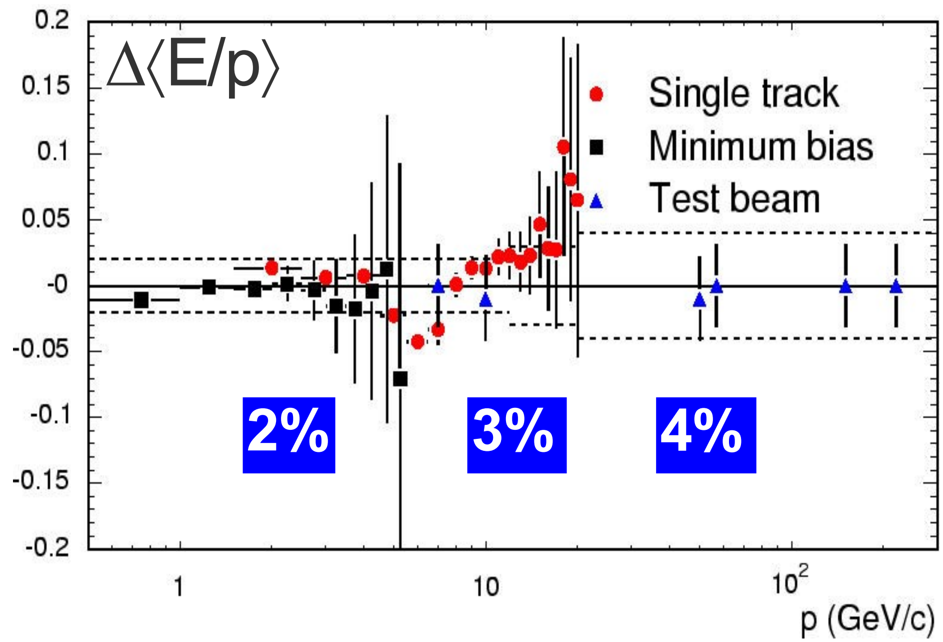
- E/p analysis
  - For TOT and MIP we consider Gaussians so we are insensitive to background contamination (e.g.: high p muons or electrons).
  - Treatment of uncorrelated background ensures that we can compare E/p from different event activity.
  - CES partially suppresses correlated background in Central.
  - Not sure about correlated background sources in the Plug (we don't use PES) – at least we are using a reasonable MC tool (Pythia) to model background.
  - Differences due to momentum spectrum have proven to be negligible.

- Lateral profile dependence
  - Profile mismatch can cause leakage effects (see appendix).
  - After tuning these effects should be minimized.

- Flavor dependence
  - MC mixture used at low p: minimum bias composition
at high p: pions/kaons/protons = .6/.3/.1
  - GFLASH treats pion/kaons/protons equally, but shower start (GEANT) depends on flavor
  - very weak flavor dependence for primary variable TOT because of complete coverage of longitudinal shower shapes (see appendix)
  - moderate effect for MIP response (CHA, PHA sampling fractions)
  - larger effect for EM response (CEM, PEM sampling fractions)
  - negligible effect for lateral E/p profiles due to normalization

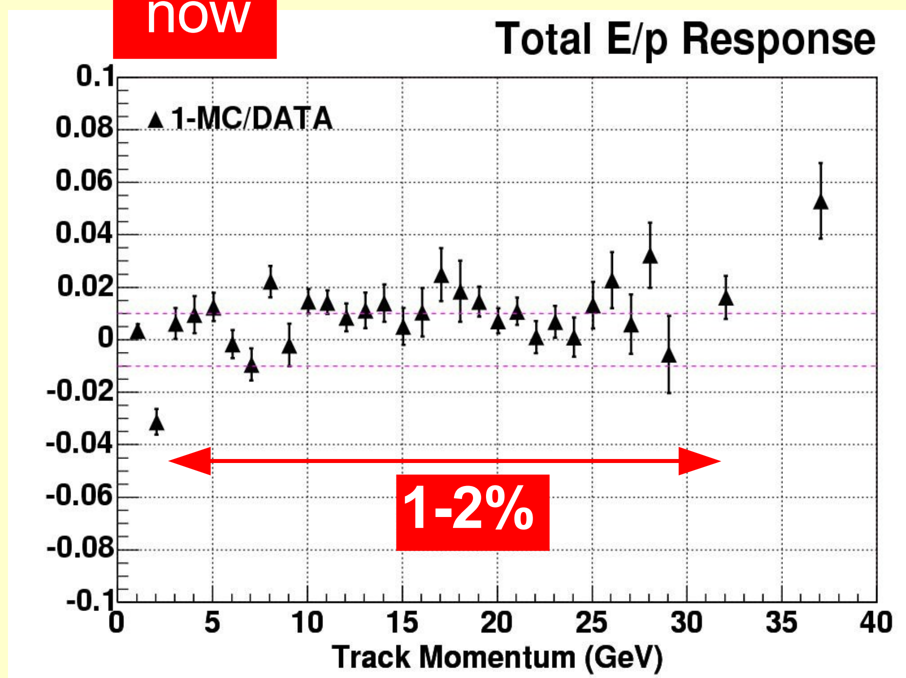
Central Simulation Performance

Gen-5



- Early Run-II picture (above) currently imprinted into ongoing CDF publications.
  - in-situ tuning only up to 2.5 GeV/c
  - validation at higher p (red points) limited by statistics
  - conservative test beam uncertainties
- Percentages directly translate into JES uncertainties.
  ...see Monica's JER talk...

now



- Much higher statistics, in-situ control of the hadronic calorimeter response up to 40 GeV/c.
- We are now using the right lateral profile for p>5 GeV/c
- Better and more consistent tuning at a level of 1-2% over a wide momentum range.

Conclusions

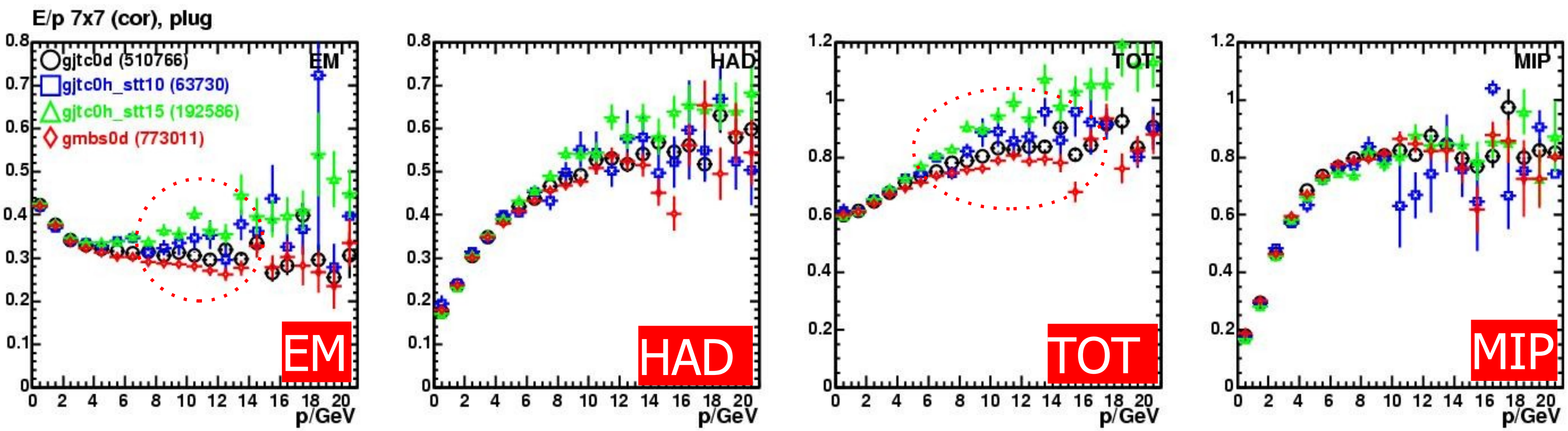
- The simulation group has established/finalized various improvements for the calorimeter simulation to be implemented into Gen-7 soon.
- Much better control of the simulated electron response near phi cracks → is expected to reduce dominant contribution to CDF e.m. scale uncertainty.
- Gained considerable in-situ control of the hadronic scale up to 40 GeV
  - systematic tuning of the lateral profile
  - absolute response tuning to a precision of 1-2% in Central
  → is expected to reduce dominant contribution to JES uncertainties
  - precision in Plug: ~5% for TOT (expect to further improve soon)
- Impact on physics analysis performance still under evaluation, validation work in progress (see Monica's talk)
  - photon-jet balance, di-jet balance, out-of-cone energy flow...

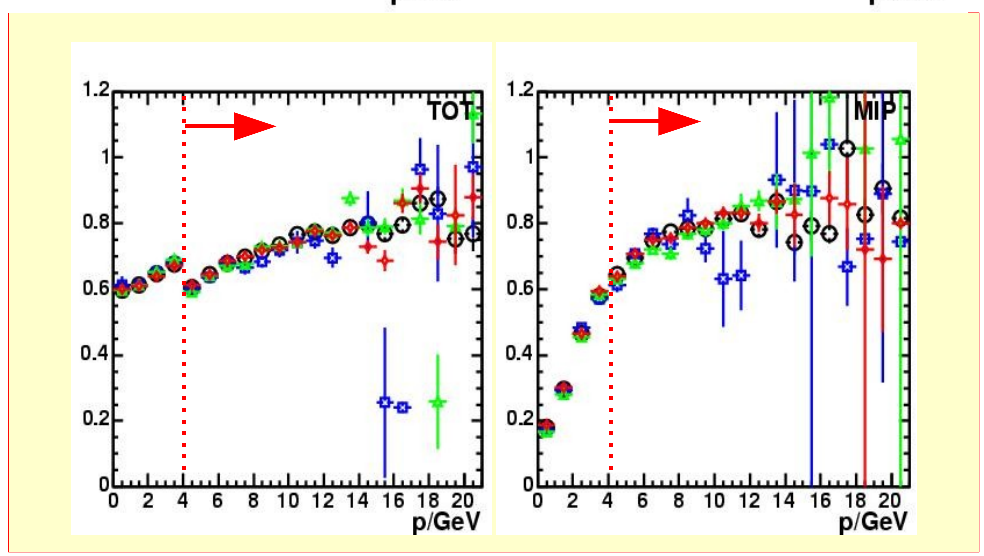
...stay tuned!

Appendix

Data Samples for Plug Tuning

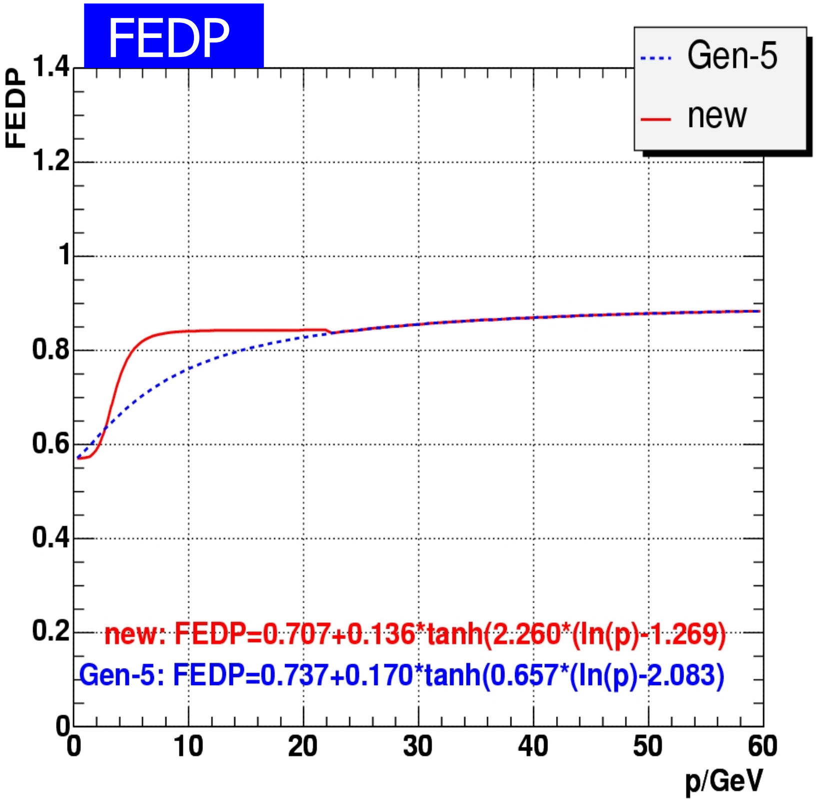
- Focus on 0d datasets: gmbs0d (21M events) & gjtc0d (16M events)
- ⟨E/p⟩ background correction is performed individually for each data set.
- Corrected distributions are combined using weighted means.
- For p>10 GeV/c, Gaussian means instead of simple means are used.
- Ignore 0h STT data sets because of possible electron contamination (didn't optimize el veto).

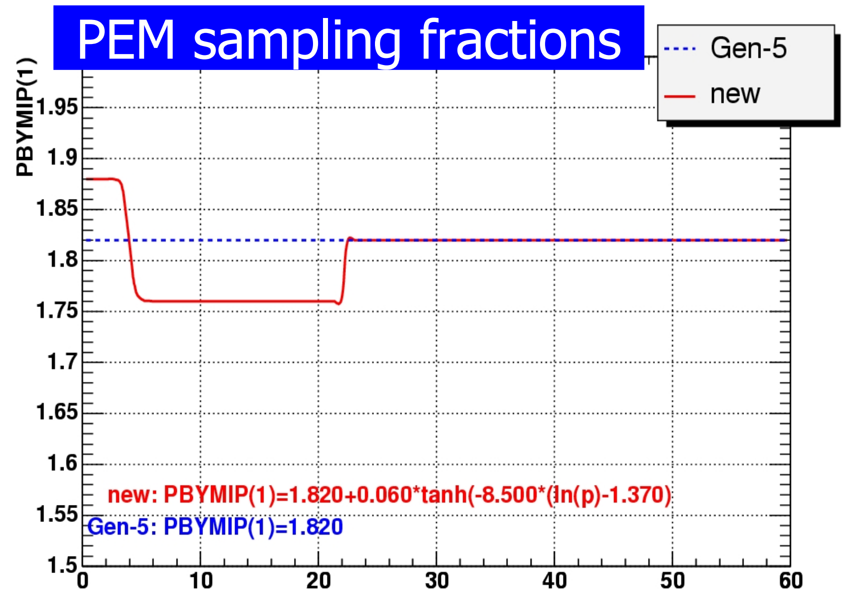


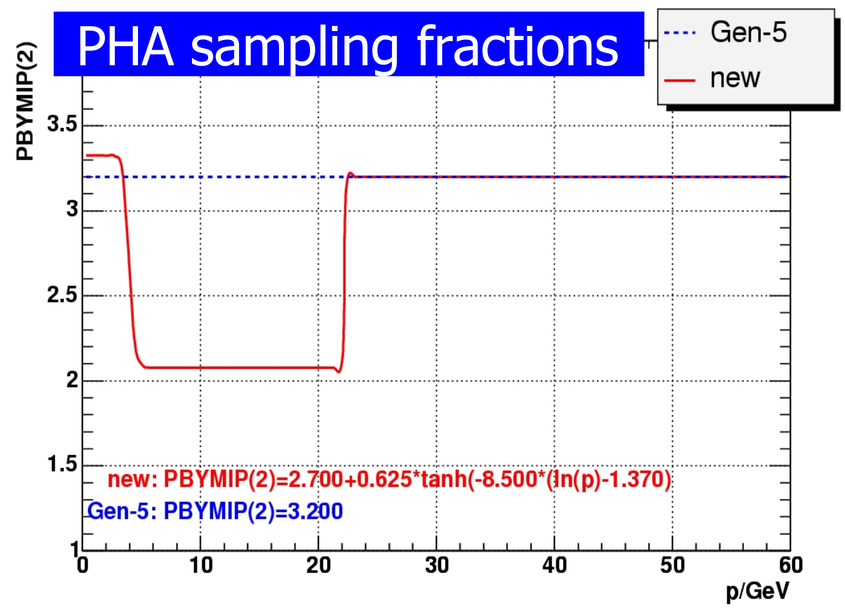


Gaussian means:
(NB: threshold is different
in actual analysis)

Plug: GFLASH Parameters

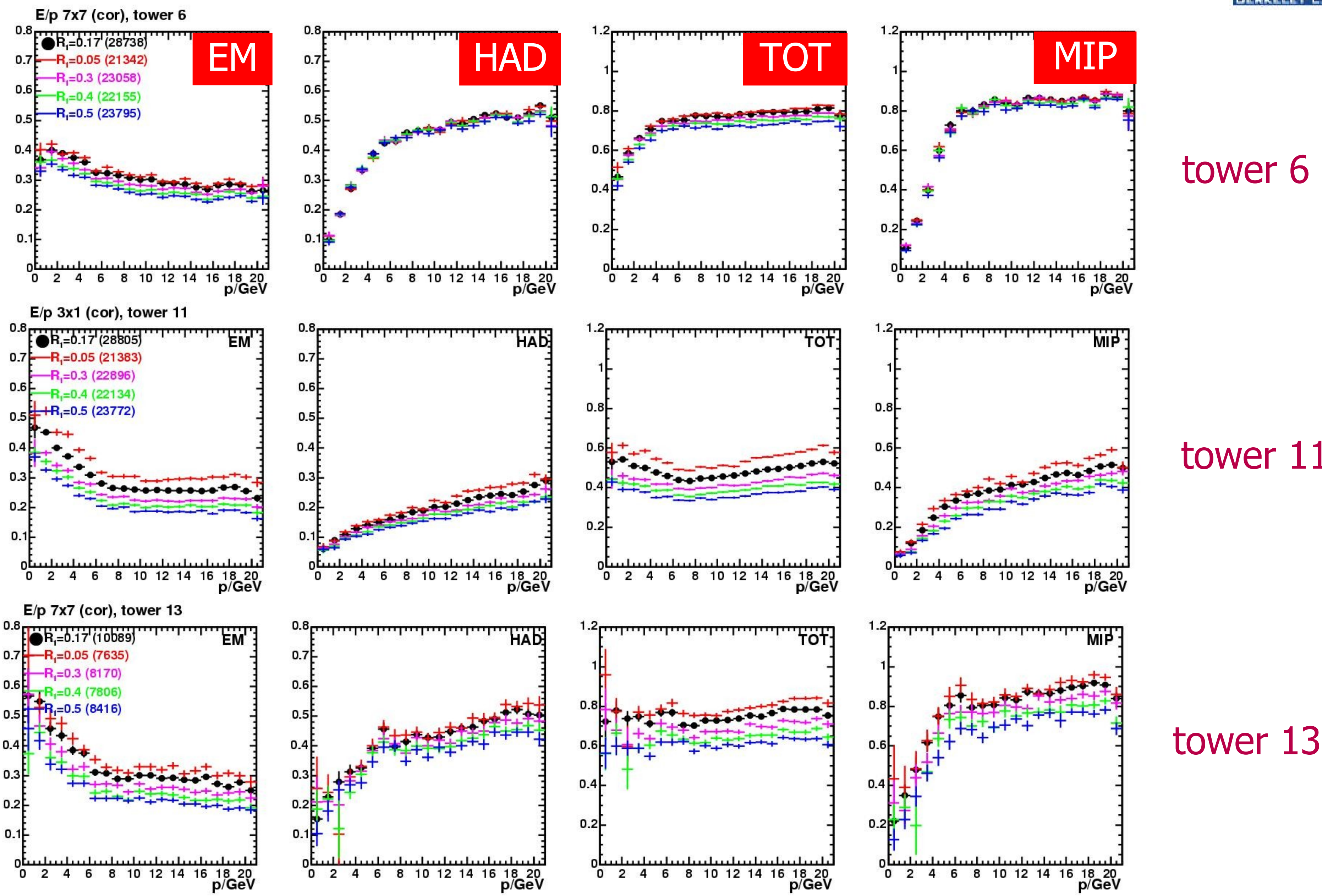






- Getting the MIP response right requires stretching of FEDP plateau to low energies.
- Smooth transition of FEDP from in-situ to test beam parametrization at ~20-25 GeV. (transition also smooth in simulated E/p response!)
- Can achieve constant sampling within in-situ tuning range (work in progress) .

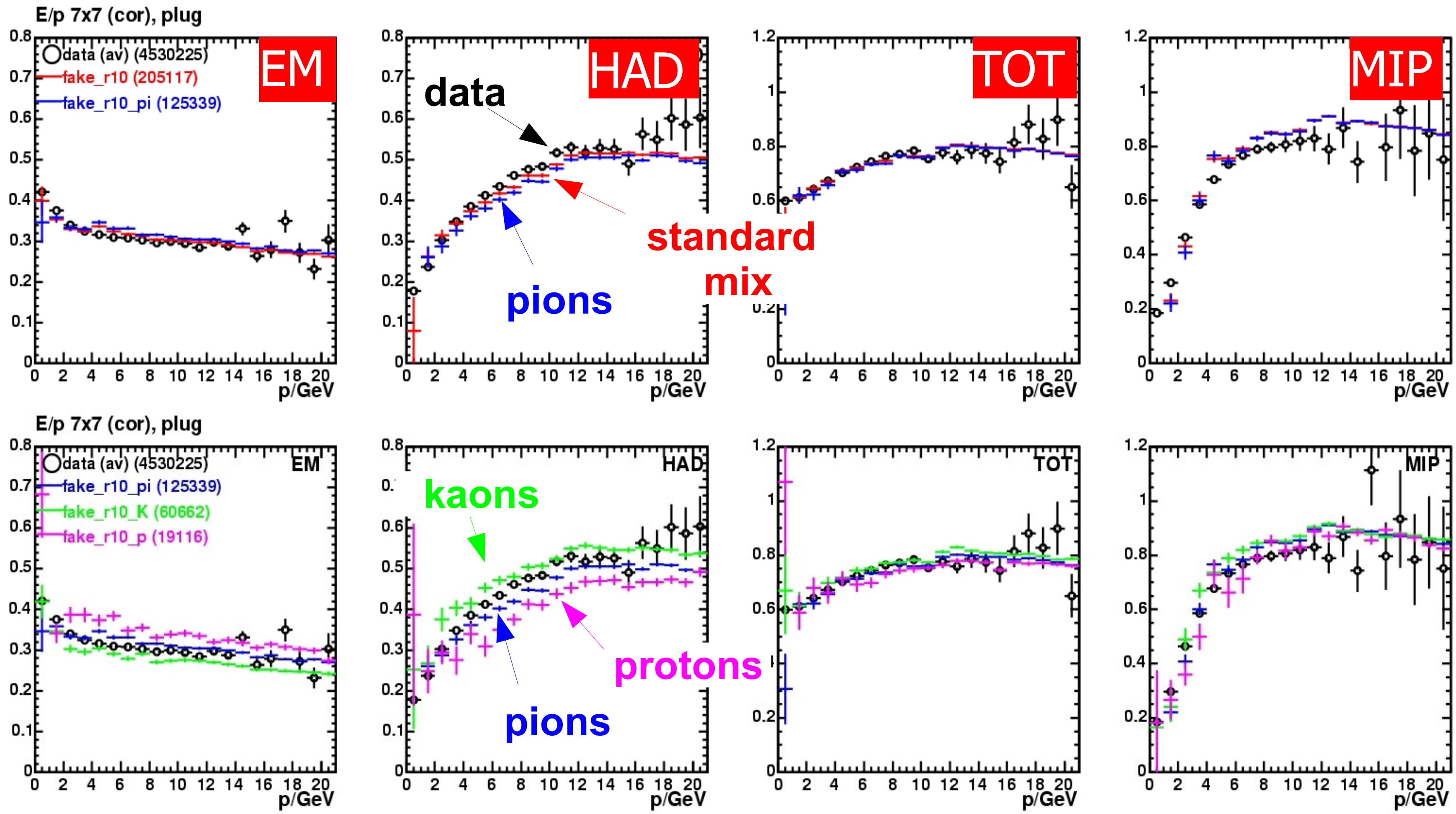
Lateral Profile Dependence



- Effect of varying the lateral profile core parameter R_1 from 0.05 to 0.50.
  R_1 values used in Gen-5: 0.490 (p<5GeV), 0.015 (p>5GeV)

Flavor Dependence

- Extreme scenario: consider individual flavors (FAKEEV flavor/anti-flavor = 50%/50%)
  NB: Minbias spectrum dominates low p.



- GFLASH treats pion/kaon/proton showers equally! Flavor dependence is pure effect of different typical shower starts given by GEANT cross sections!
- Larger effect in EM and HAD, but <u>little effect in TOT</u> and moderate effect in MIP due to almost complete coverage of shower shapes.