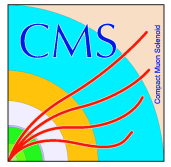


Dimuon resolution in Z'/graviton resonance searches

Jim Pivarski, Alexei Safonov

Texas A&M University

13 March, 2008

Dilepton resonances > 1 TeV

Generic signature and clean signal, especially for muons
$\Rightarrow$ potential for early discovery

Spin-1 Z' models (my list) (benchmarks)

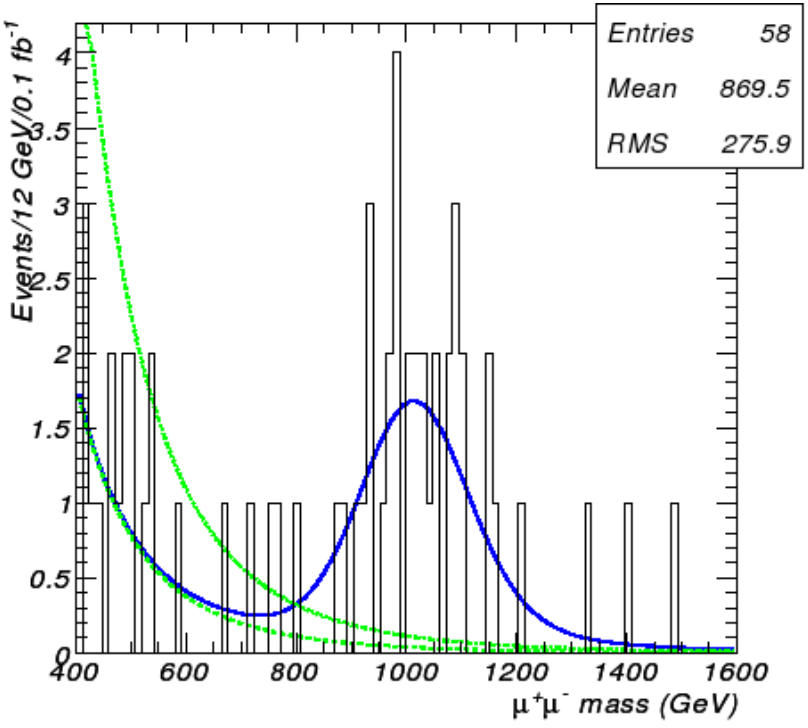
- Ad-hoc extension of the Standard Model Z'_{SSM}
- Extra dimensions: heavy photon
- $E(6)$ and $SO(10)$ GUTs *A. Leike, Phys. Rep. 317 (1999) 143.* Z'_{ψ}
- Left-right symmetric models
- String theory-inspired models *M. Cvetic and P.Langacker, Mod. Phys. Lett. A 11 (1996) 1247.*
- Technicolor *C.T. Hill and E.H. Simmons Phys. Rep. 381 (2003) 235.*
- The Little Higgs model *T. Han et al. Phys. Rev. D 67 (2003) 095004.*
- Related to dark matter *K. Hsieh, R.N. Mohapatra, S. Nasri Phys. Rev. D74 (2006)*
- Z'-mediated SUSY breaking *P. Langacker, G. Paz, L. Wang, I. Yavin Phys. Rev. Lett. 100, 041802 (2008)*

Spin-2 graviton

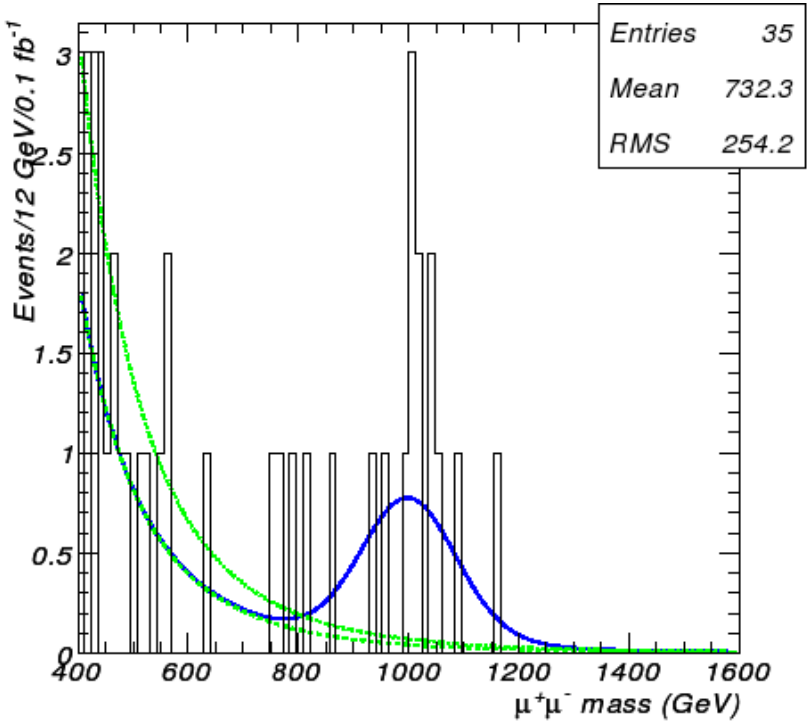
- Randall-Sundrum extra dimensions *H. Davoudiasl, J.L. Hewett, T.G. Rizzo, Phys.Rev.Lett. 84 (2000)* G^*

Benchmarks at 100 pb^{-1}

Z'_{SSM}

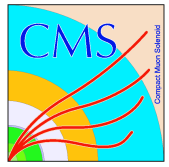


Z'_{ψ}



- Though the Z'_{SSM} is 5 times wider than the Z'_{ψ}, experimental widths are the same, primarily due to misalignment.
- 100 pb^{-1} misalignment scenario presented above

Steps toward discovery



- Understanding backgrounds:
  - relevant for discovery of a real TeV dimuon excess (broad/overlapping resonances, unparticles, PDFs at 14 TeV)

- Resolution, momentum scale:
  - discovery of a resonance (Z' or graviton)
  - measurement of its mass, upper limit on width

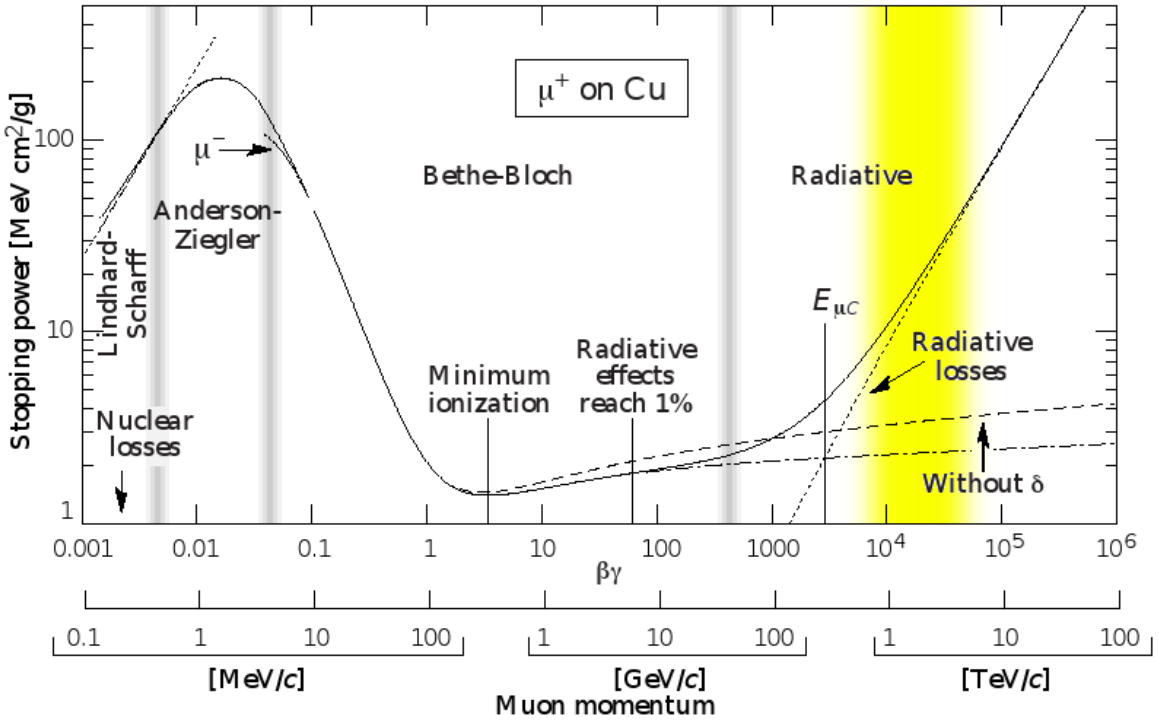
- Efficiency, PDF uncertainties:
  - measurement of its cross-section (weak discriminant between Z' models)

- Angular distributions:
  - measurement of its spin (determine Z' versus graviton)
  - forward-backward asymmetry (determine Z' model)

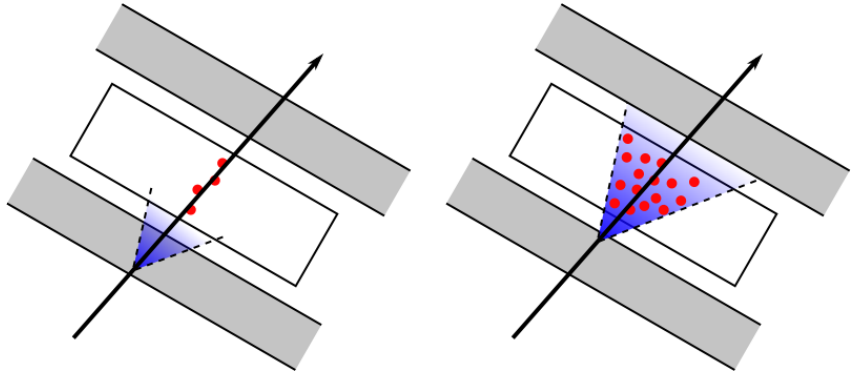
This talk will focus on dimuon resolution

Intrinsic resolution

TeV muons shower in iron

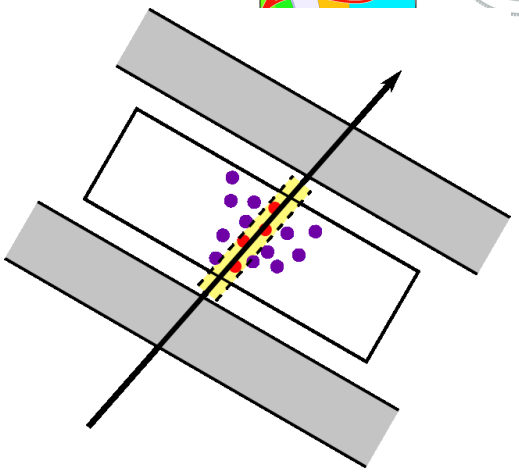


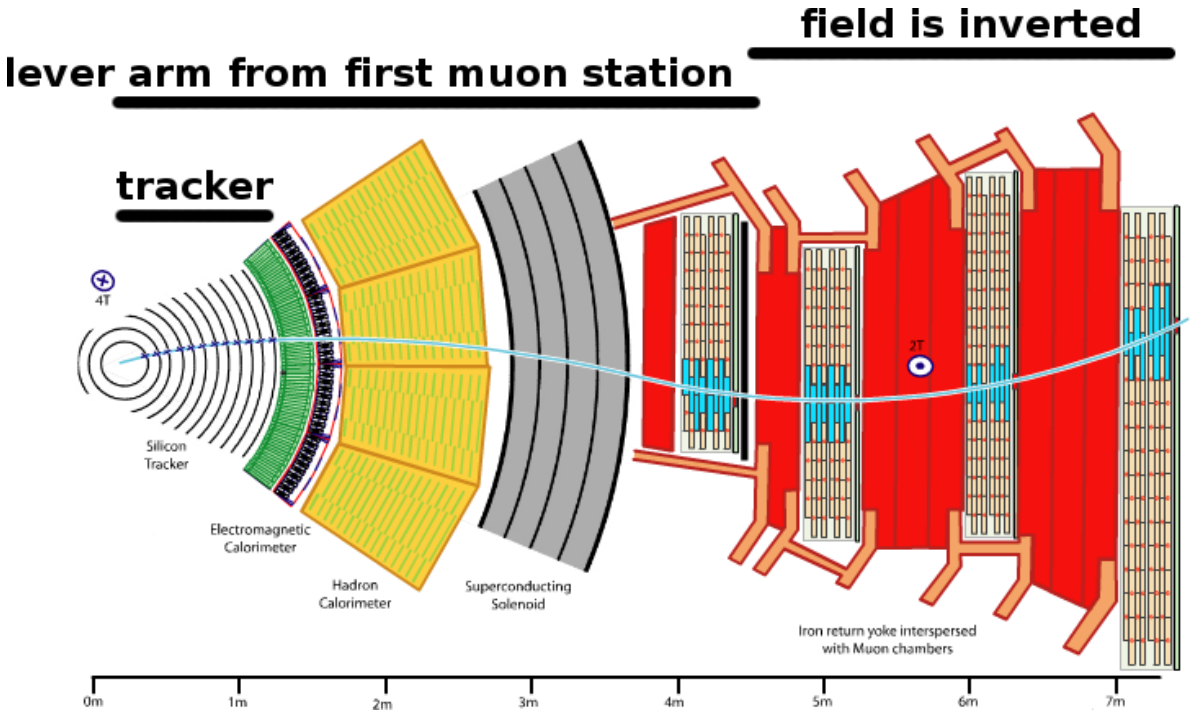
- Showers that start deep in the iron are suppressed
- Some chambers flooded with extra hits, others are fine



Optimizing track fits

1. Identify chambers with showers, apply tight cuts on hits ("Picky Muon Reconstruction")
2. First muon station is most important for momentum resolution, keep only first station ("Truncated Muon Reconstruction")
3. Run both and select best track χ^2 ("Tune N, P")

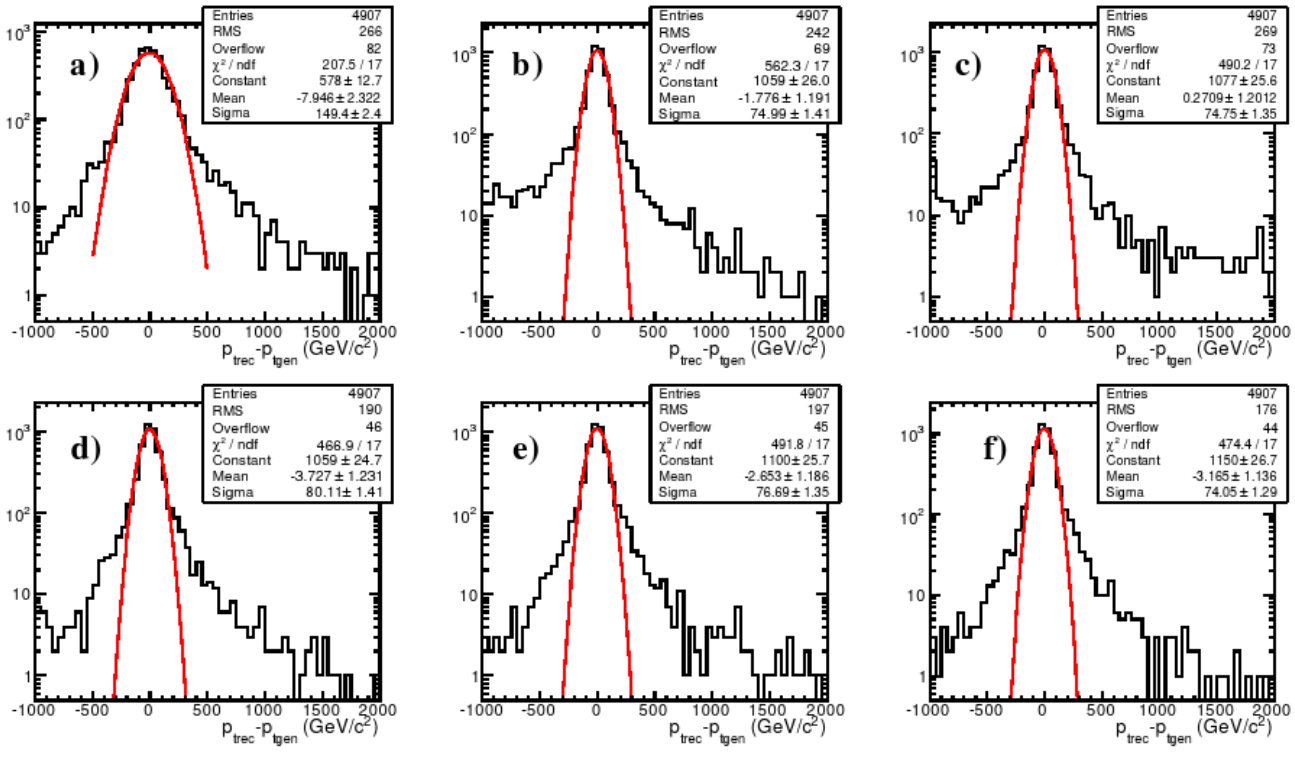




Comparison of 6 algorithms

- Optimize for statistical significance of peak over backgrounds
- All optimized variants are better than the default, but it's unclear which is best
  - Might depend on misalignment (untested)
  - Might prefer wider central Gaussian to long tails

Piotr Traczyk (Warsaw)



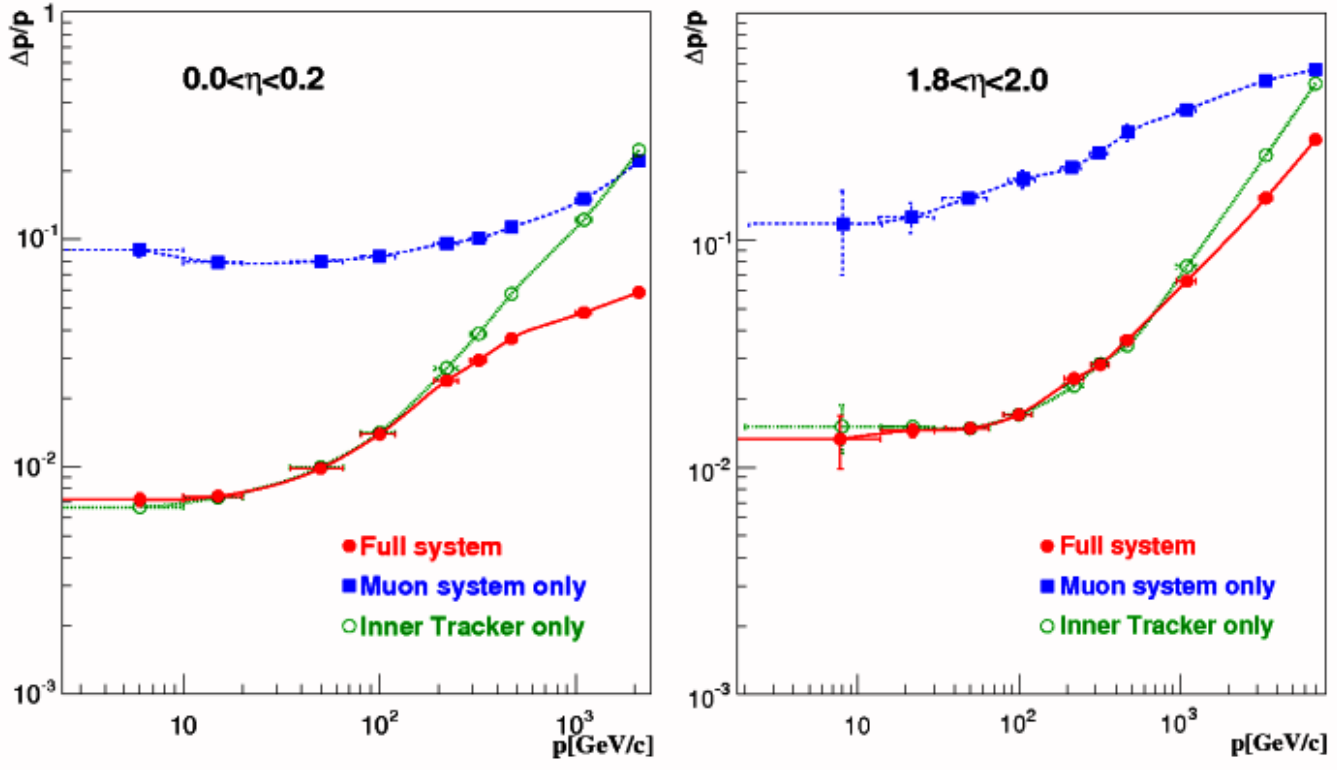
(a) default (keep all hits), (b) truncated, (c) picky, (d-f) tuned cocktails

Misalignment

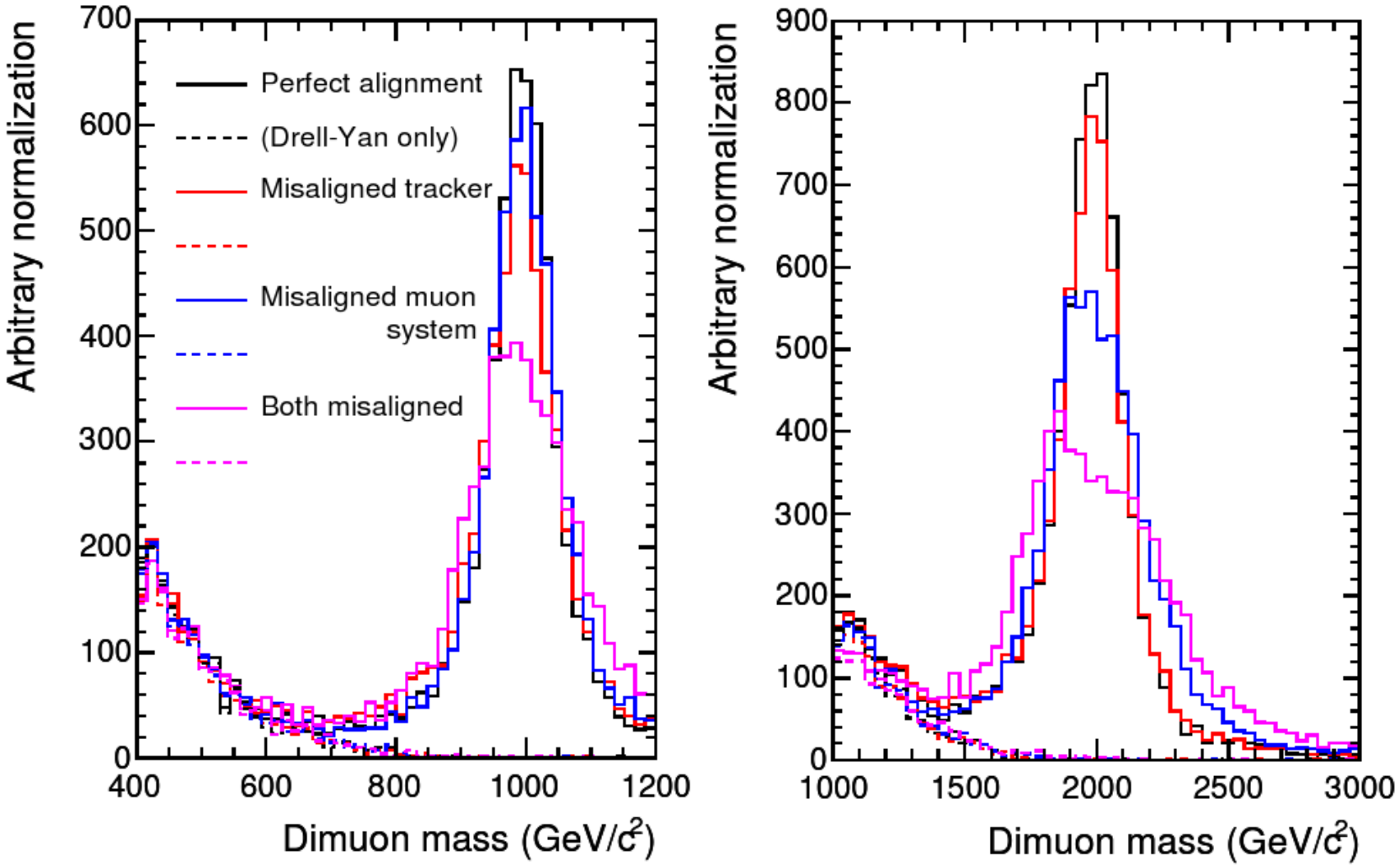
- Three sources:
  - Internal tracker misalignment
  - Internal muon system misalignment
  - Relative misalignment of tracker and muon system

Momentum resolution with and without tracker, muon system

- Tracker dominates below 1–2 TeV, but not above



100 pb^{-1} misalignment scenario



- Muon misalignment matters a lot more at 2 TeV
- Expected misalignment is not sufficient to smear a lot of Drell-Yan up in mass

Alignment systems

Tracker

- Laser alignment system (LAS) provides first alignment
- Track-based alignment: vary presumed sensor positions until track χ^2 are minimized
  - HIP algorithm: iteratively fit tracks and update sensor positions
  - MillePede and Kalman-based algorithms: fit tracks and sensor positions simultaneously
- Non-IP tracks (cosmic rays, beam-halo) are crucial for breaking degeneracies along "weak modes"

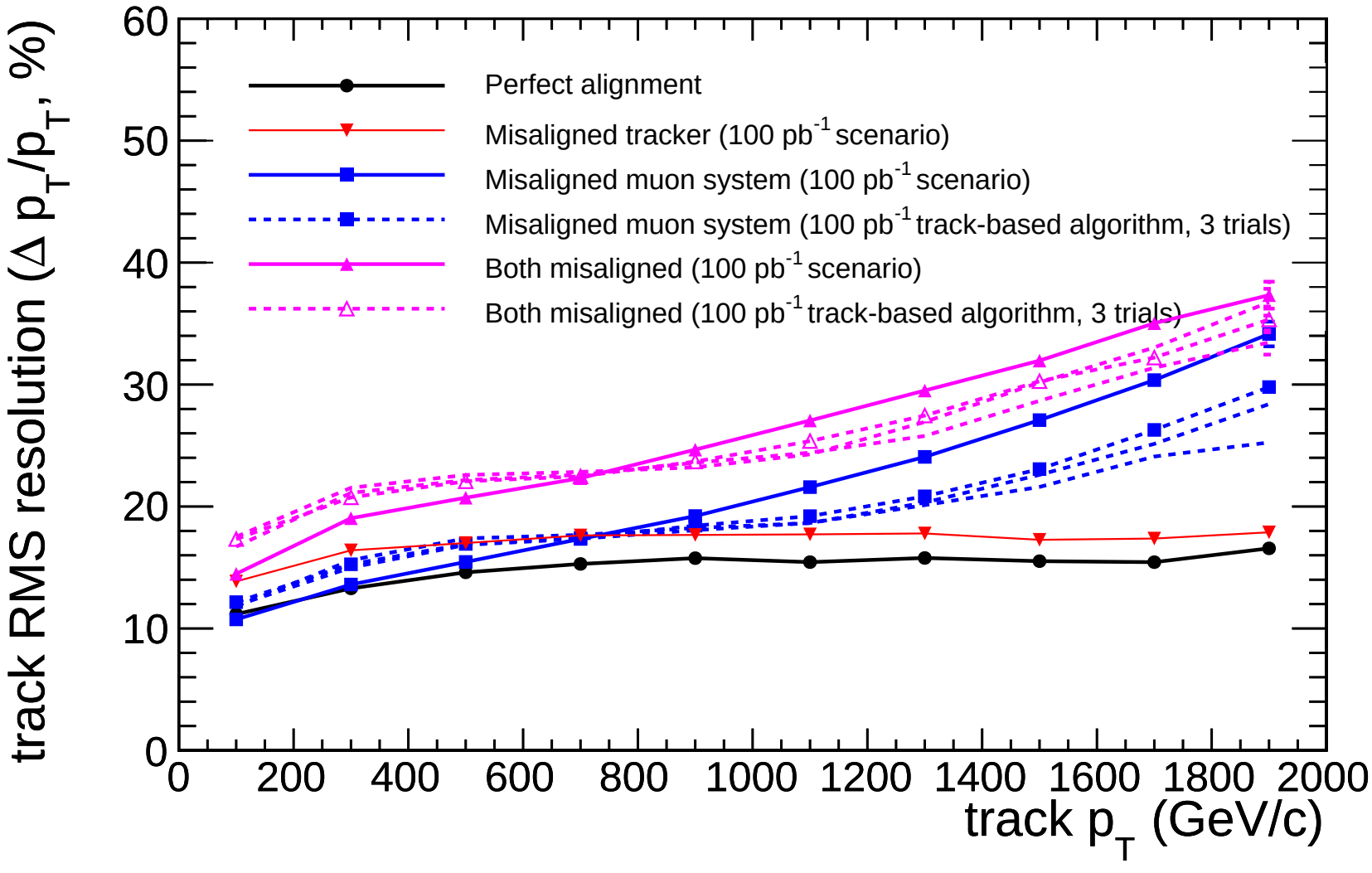
Muon system

- Hardware alignment system: laser position monitors and analog calipers
- Track-based alignment
  - weight tracker hits more heavily to align muon chambers relative to the tracker
  - HIP and MillePede algorithms

Muon misalignment scenarios

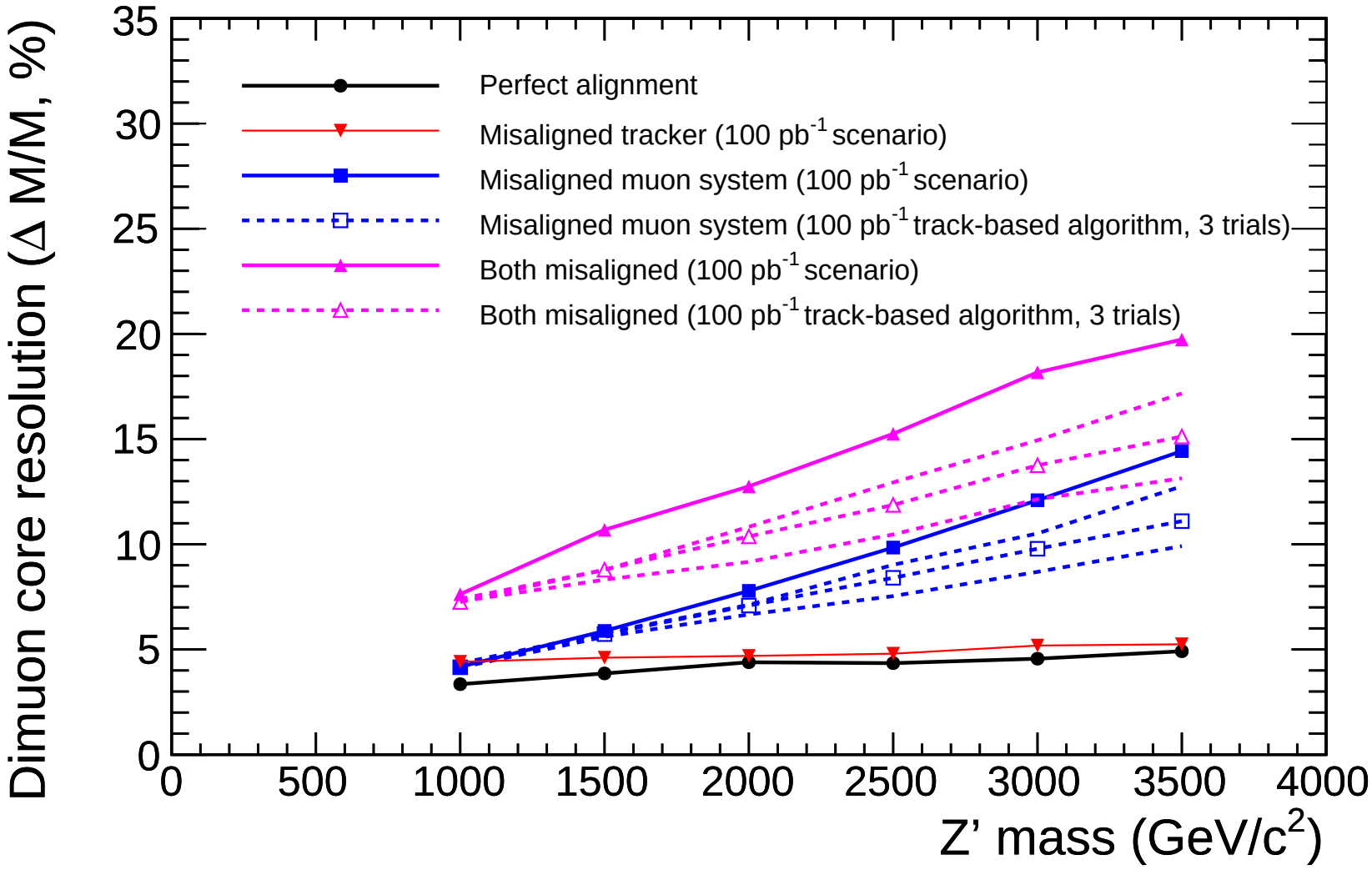
- CSA07
  - 10 pb^{-1} scenario: represents state with no track-based input
  - 100 pb^{-1} scenario: some track-based input
  - Due to a mistake, the 100 pb^{-1} scenario is *worse* than the 10 pb^{-1} at high mass
- Output of track-based alignment algorithm (HIP)
  - 10 pb^{-1} with and without 10 pb^{-1} tracker misalignment
  - 100 pb^{-1} with and without 100 pb^{-1} tracker misalignment
  - 3 trials each: to quantify dependence on initial condition
  - Doesn't incorporate improvements discovered since Nov. 2007
  - Tuned for 10 pb^{-1}; makes poor use of extra tracks in 100 pb^{-1}
- CSA08
  - 0 pb^{-1} scenario: represents state with no track-based input
  - 10 pb^{-1} scenario: combination of hardware and track-based
  - 100 pb^{-1} scenario: more heavily track-based, still doesn't scale as $\sqrt{10}$ relative to 10 pb^{-1} scenario
  - Mistake fixed (and new scenarios are more detailed, precise)

Muon track resolution



- p_T resolution is curvature resolution: $\left(\frac{\Delta p_T}{p_T}\right) = \left(\frac{\Delta \kappa}{\kappa}\right)$

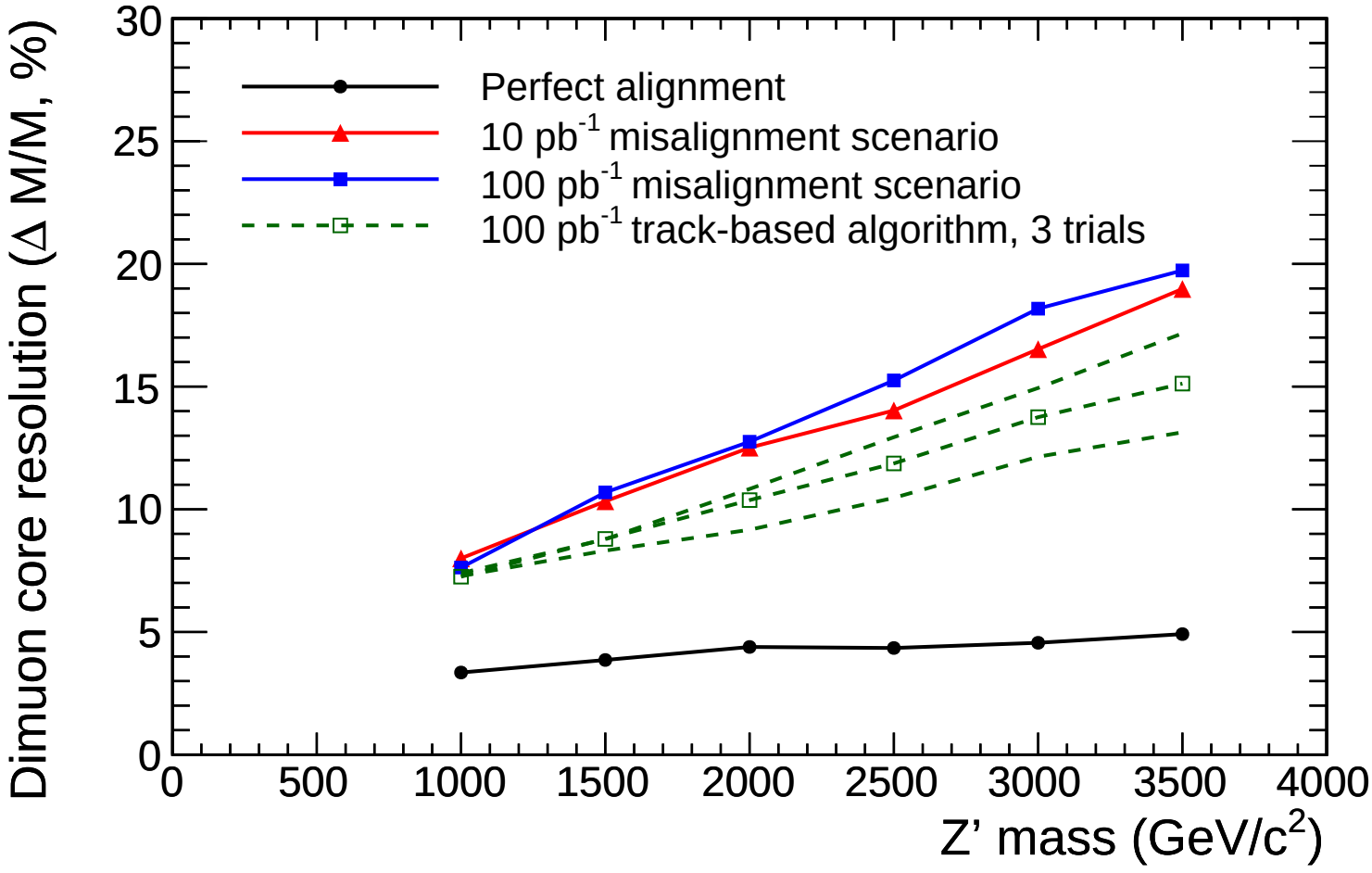
Dimuon mass resolution



- "Core resolution" is σ of the Gaussian fit, with the fit range restricted to -1.5σ through 1.5σ

Dimuon mass resolution

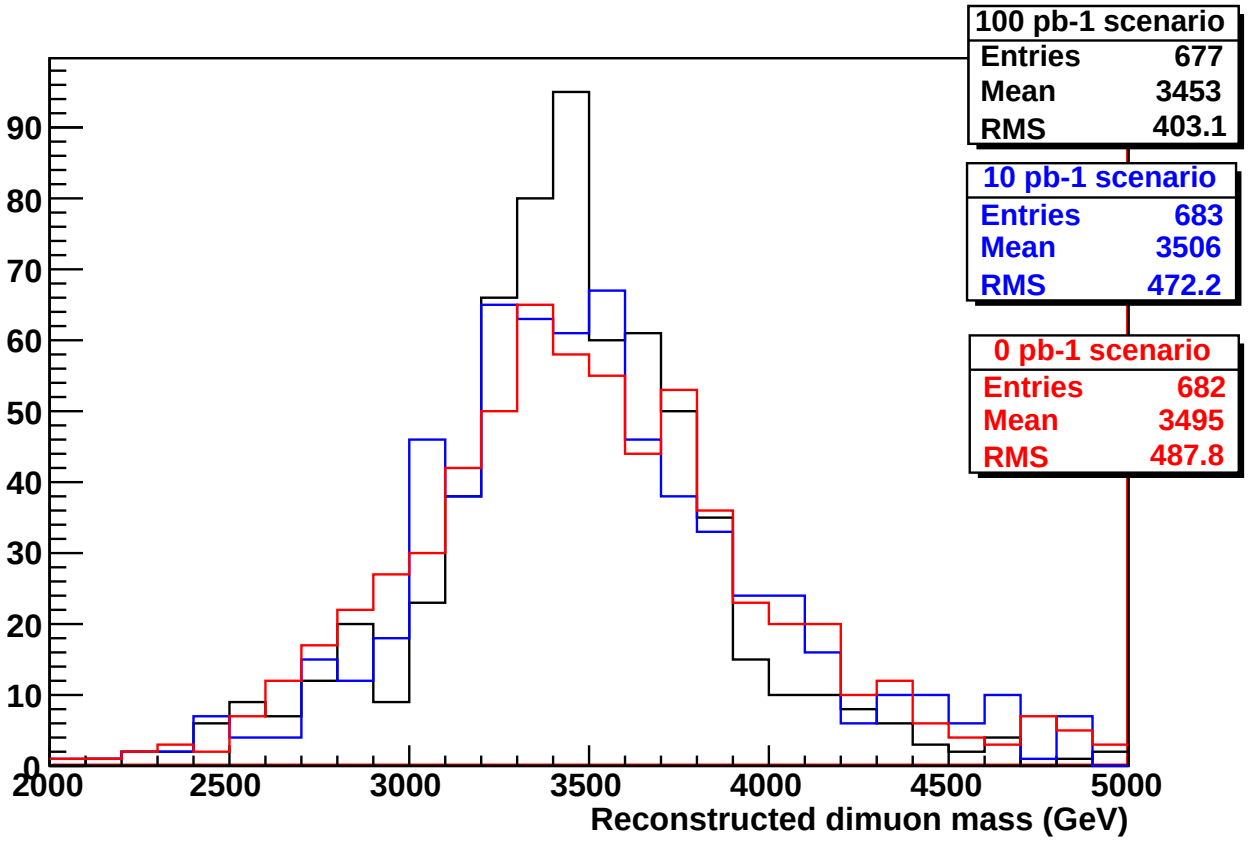
- Comparison of 10 and 100 pb^{-1}
- Plot from CMS AN 2007/038 (internal)



- Bottom line: track-based test confirms that misalignment scenarios are in the right ballpark

New CSA08 scenarios

Check that they scale appropriately with a 3.5 TeV Z'

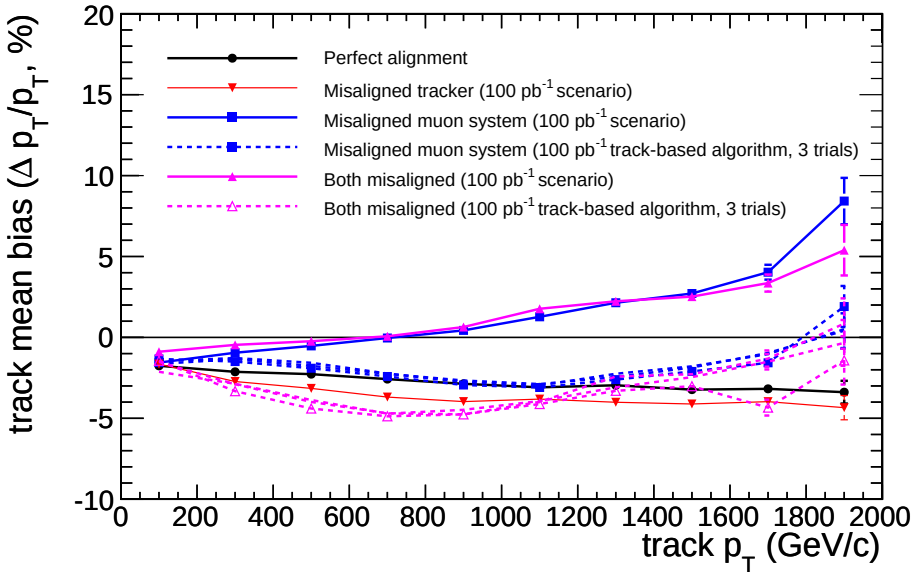


ideal (not shown)	100 pb^{-1}	10 pb^{-1}	0 pb^{-1}
5%	11.5%	13.5%	13.9%

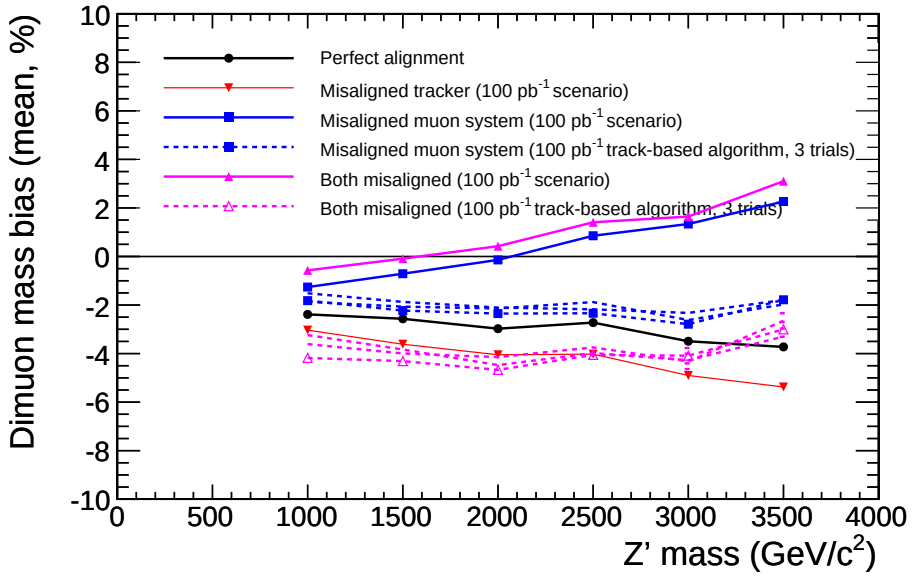
Effect on energy scale

"Bias": shift in mean of momentum/mass relative to generated

Track momentum

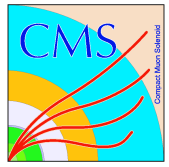


Dimuon mass



- Dimuon bias follows track momentum bias
- Track-based results and ideal are both negative (about −3%)
- Misalignment scenarios are both positive
- Nothing is more than 5% (Δ/total)

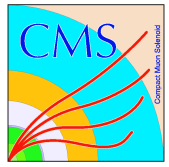
Open projects in resolution



Listed by Slava as "no one working on it, as far as I know"

- Determining resolution from data
  - Perhaps a bottom-up approach: measure residuals and misalignments, then infer track resolution from MC?
- TeV momentum scale
  - "Bias" described on previous slide is the first correction
  - Can this be determined from data?

Conclusions



- TeV muon resolution is key for early physics
- Intrinsic resolution ∼5% due to muon showering
  - Can be reduced to ∼2.5% by dropping excess hits
- Misaligned resolution ∼7.5 to 15% (1 to 3.5 TeV)
  - CSA07 scenarios and track-based output in rough agreement
  - Does not include known improvements
- Mistake in the CSA07 scenarios led to 10 pb^{-1} being better than 100 pb^{-1}
  - Mistake has been corrected in CSA08
  - CSA08 scenarios include more information about distribution of uncertainties, with guidance from track-based output
- There are at least two open projects

Backup slides

Effect on efficiency?

- Misalignment has a negligible effect on trigger efficiency
- and reconstruction efficiency: