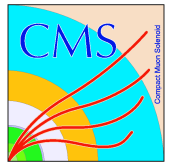

Search for energetic Z bosons from new physics

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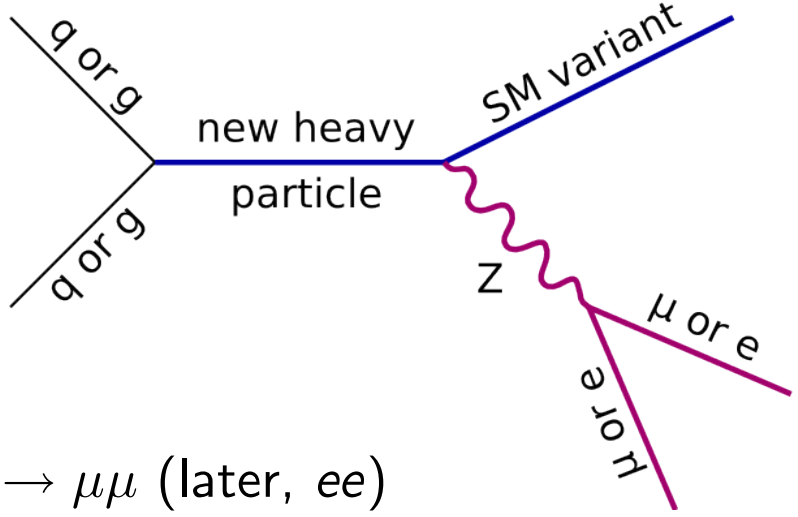
New Analysis: high p_T Z bosons

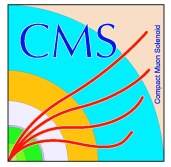
- Object-based search for $Z \to \mu\mu$ with unusually high p_T
- New particles that are "heavy versions" of SM particles can spectroscopically decay to their SM variants by radiating a Z

  Example: $q^* \to q\,Z$



- First Stage: only reconstruct the $Z \to \mu\mu$ (later, ee)
- If there's an excess, look at the rest of the event to try to identify the "SM variant"
  - an energetic jet?
  - a massive jet? (may be $Z \to jj$ or $W \to jj$ if $M_{\text{jet}} > 50$ GeV)
  - a lepton? multiple leptons?
  - missing energy?
  - multiple jets? (David Stuart's analysis)
- Second Stage: if no excess in Z-only channel, explicitly reconstruct "SM variants" in broad categories

First Stage: just $Z \rightarrow \mu\mu$

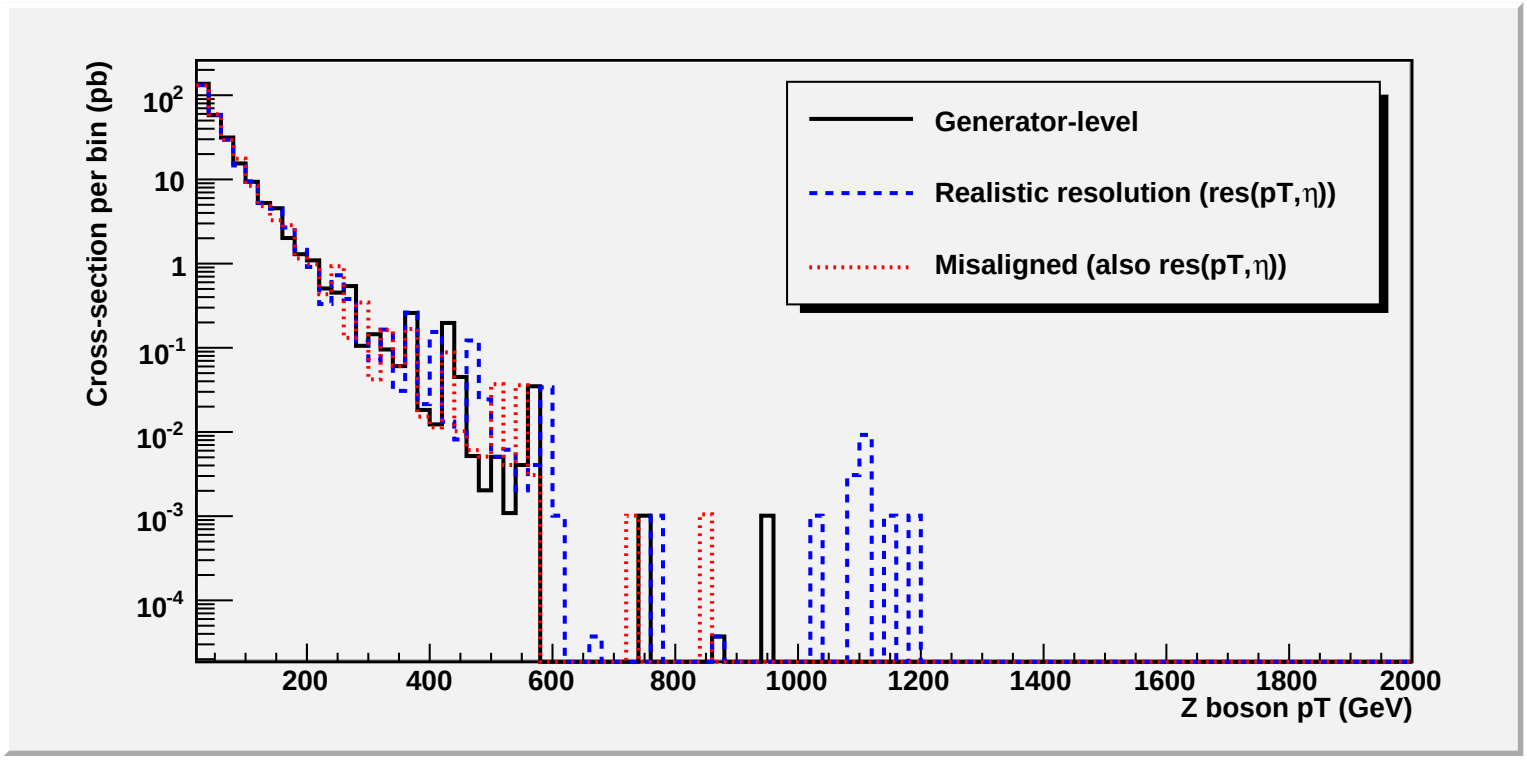


- Signal: two muons with invariant mass near Z, no other restrictions
  - Need to be careful about defining isolation around the muons, to allow the muons to be arbitrarily close to one another
- Reducible backgrounds:
  - muons from jets: no charge correlation, look at same-sign sample
  - $Z \rightarrow \tau\tau$, $t\bar{t}$, W^+W^-: control with dimuon mass sideband
  - cosmic rays: out-of-time and offset vertex control regions
- Irreducible backgrounds: Standard Model Z, WZ, and ZZ
  - Standard Model Z is likely the most significant background
- Energetic muons have the same efficiency and resolution issues as they do in TeV dimuon analysis
  - SM Z distribution not expected to smear much due to resolution
  - muon $\vec{p}$ resolution is additionally important for narrowing Z mass peak and cutting reducible backgrounds

Simulation of SM Z

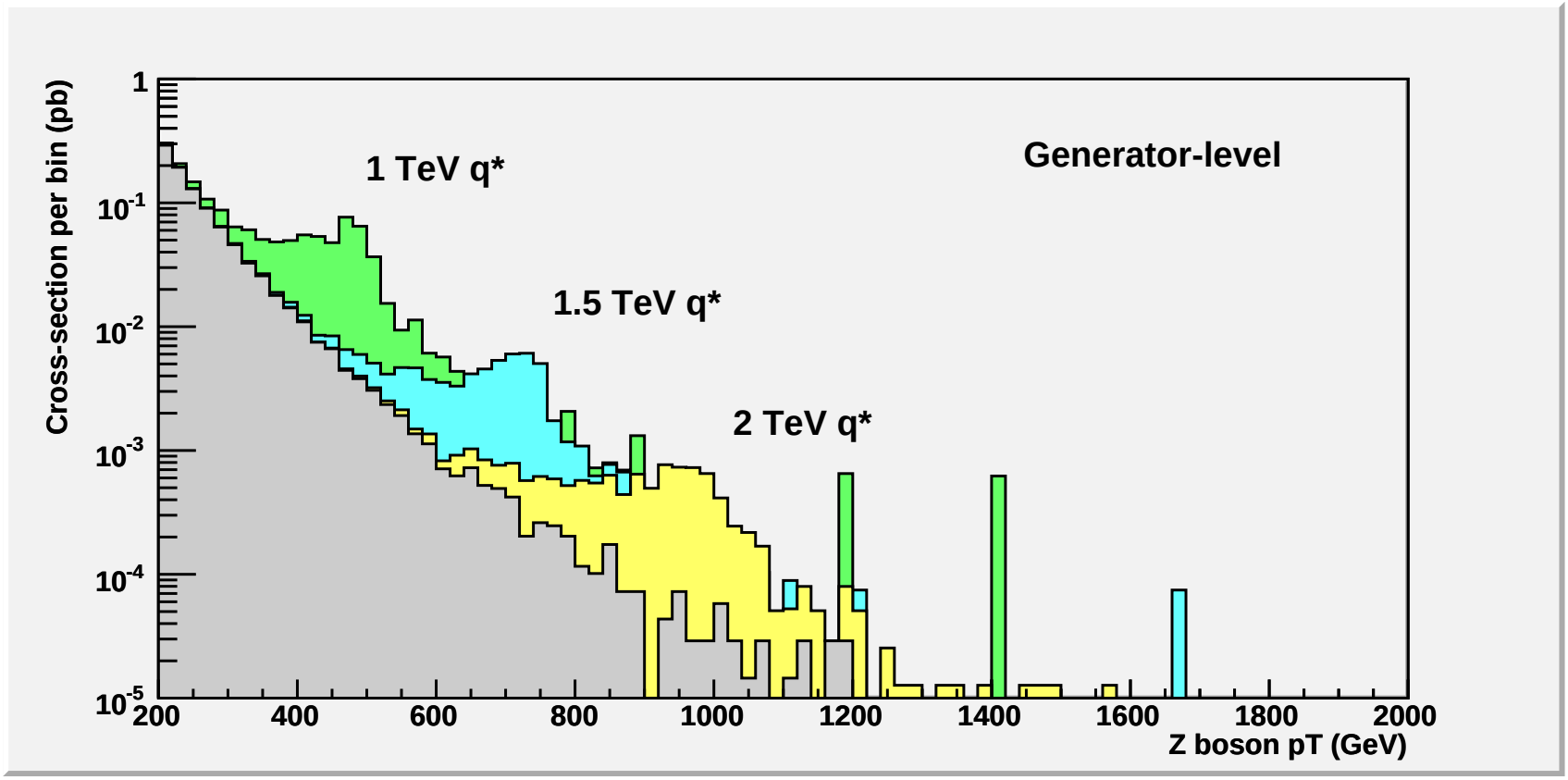
- Alpgen MC simulation of all $pp \to Nj\,Z$ and $pp \to q\bar{q}\,Nj\,Z$ diagrams
  - where "j" is a parton (q or g)
  - for all N from 0 to 6 (inclusive sum of channels)
  - ignore jets and jet-merging, $Z \to \mu\mu$ is good at generator-level
- Also study realistic distribution by smearing the generator-level muons with resolution(p_T, η) distributions from CMSSW ("FasterSim")

Effective cross-section of $pp \to X\,Z \to X\,\mu\mu$ per 20 GeV bin versus Z p_T



Benchmark model: $q^* \longrightarrow q\,Z$

- Excitation of quarks due to substructure on a scale $\Lambda \approx M_{q^*}$
- Clearly visible above SM Z distribution
- $\Lambda = 1$ TeV should be visible in 100 pb^{-1} (these are 10 TeV collisions)
- Misalignment doesn't broaden peaks much (p_T distributions are already rather broad)



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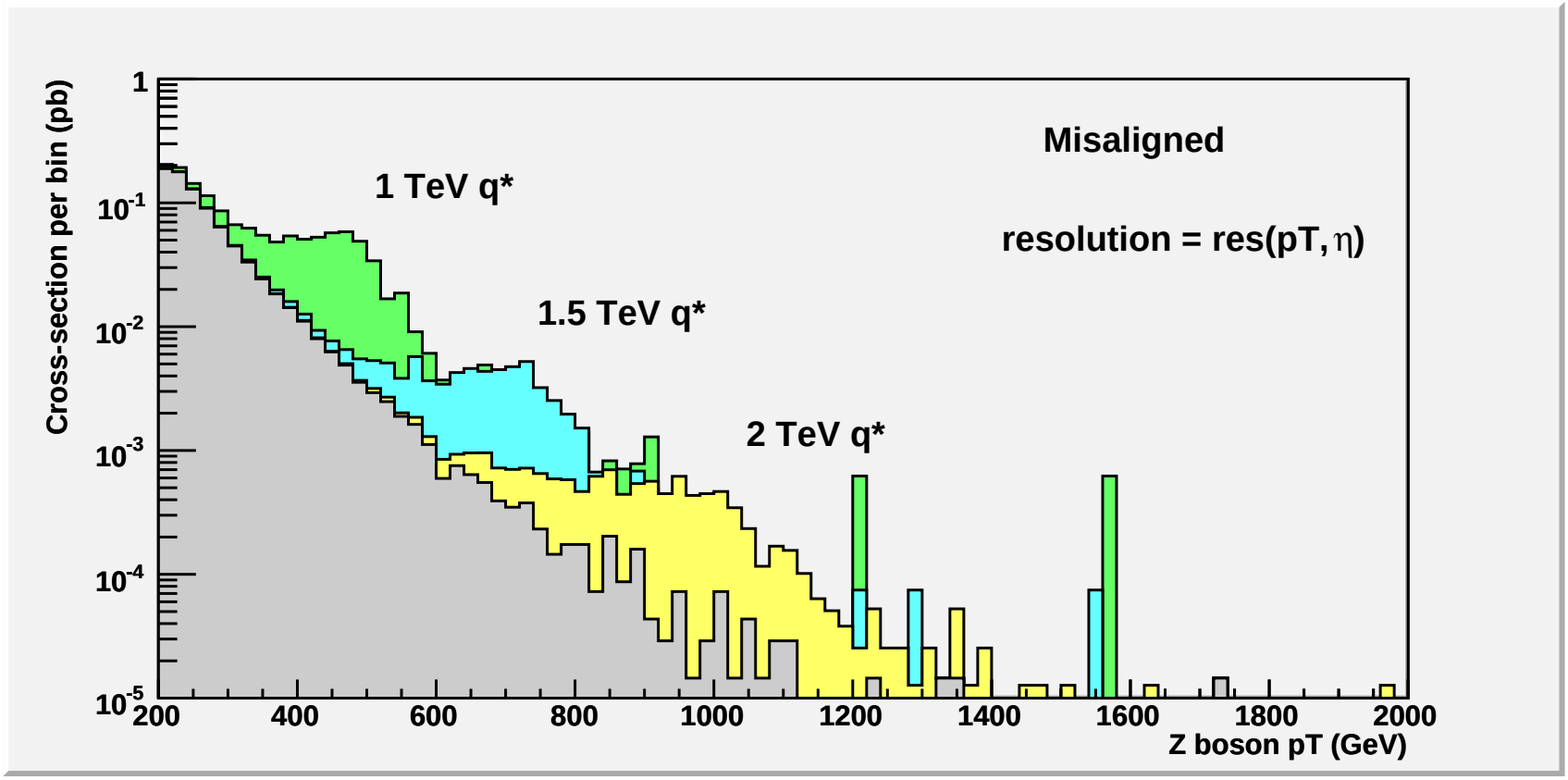
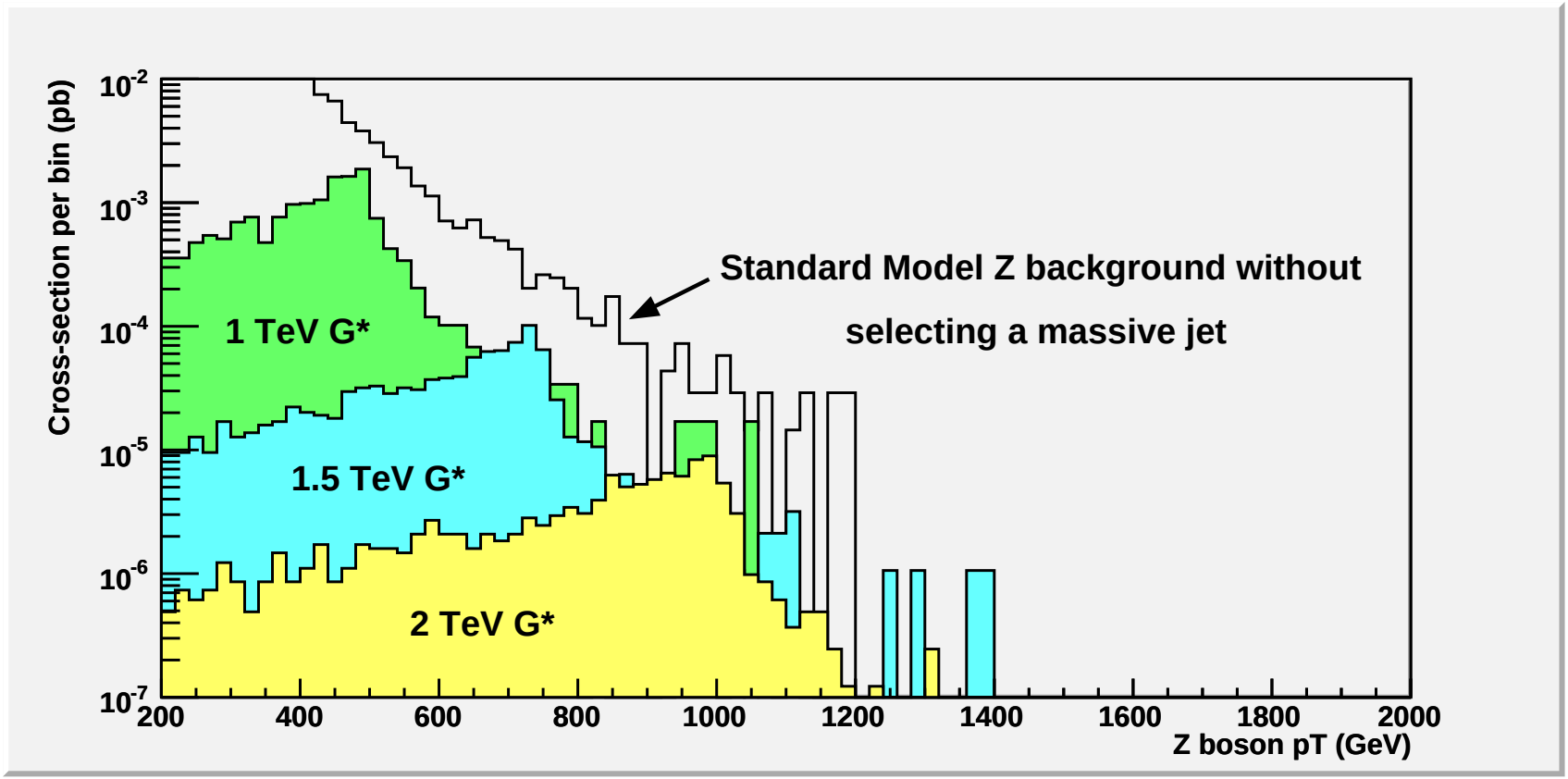


Would this find a graviton?

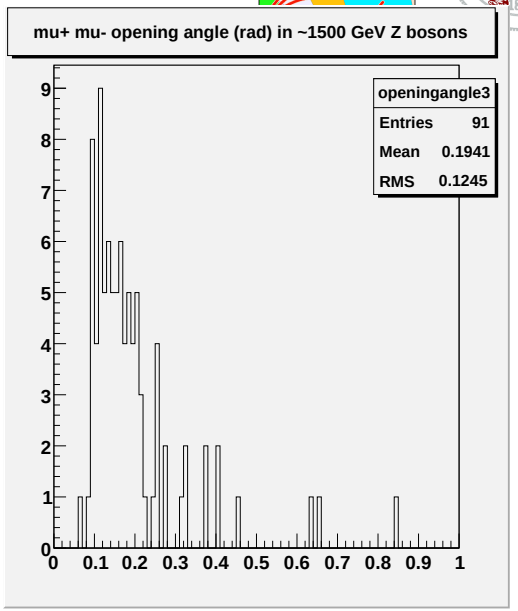
- $\mathcal{B}(G^* \to ZZ) = 2 \times \mathcal{B}(G^* \to \mu\mu)$, but $\mathcal{B}(Z \to \mu\mu) = 3.4\%$
- Nevertheless, ZZ mode remains a good way to distinguish G^* from Z'
- Would a search for only one of the two Z bosons be significant? ($c = 0.1$)



- An explicit $G^* \to ZZ \to \mu\mu jj$ search (where jj can be a fat jet) would be more sensitive

Overlapping muons?

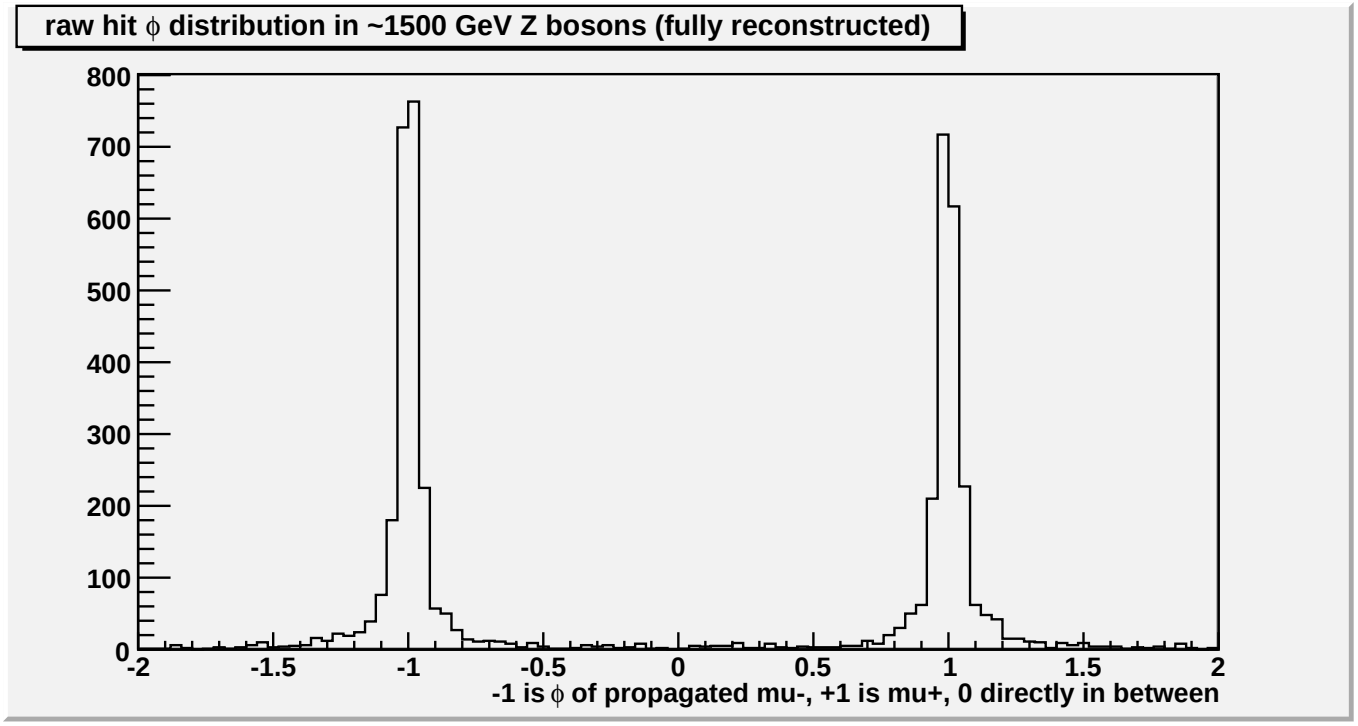
- If the Z is very boosted, would its daughter muons overlap?
  - TeV muons shower in the muon system: delta rays could in principle overlap
- But they don't: 1–2 TeV Z bosons have clearly-separated muons (angle $> 5°$), and lower momentum muons are cleaner than this



Hit distribution around the two muons

normalized to muon separation

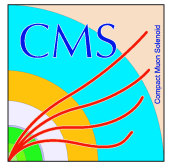
including hits not associated with tracks



Steps in First Stage analysis

1. Feasibility studies $\surd$
   - ~~Inclusive SM Z background distribution from Alpgen for high p_T~~
   - ~~Quantify discovery potential with a benchmark model~~
   - ~~Check for overlapping muon showers in full CMSSW~~
2. Study reducible backgrounds in large MC productions
   - Determine optimal muon isolation and Z mass cuts
   - Practice same-sign and sideband background estimations
3. Alpgen in full CMSSW? At least validate Pythia inclusive p_T spectrum
   - Z efficiency and muon charge misassignment versus p_T
   - Sensitivity to misalignment
4. Refinements
   - Define analysis in PAT, make sure PAT objects are sufficient
   - Quantify theoretical uncertainties in SM Z distribution (PDFs)
   - Calculate Z efficiency from data-driven muon efficiencies
   - Split search into η regions?
   - Define blinding procedure? ($p_T > 250$-300 GeV is new)
   - Limit calculations for signature and benchmark models

Conclusions



- Heavy versions of SM particles would radiate energetic Z bosons instead of photons to decay neutrally to their SM versions
  - Excited quark model is a good benchmark (excited leptons, too)
- Simplest search, asking only for the $Z \to \mu\mu$, is feasible and would find the benchmark
- $G^* \to ZZ \to \mu\mu jj$ can't be identified by the $\mu\mu$ alone: must also reconstruct jj (either in the Second Stage of this analysis or an exclusive search)
- I'm moving on to full-MC studies
- CDF and D0 Z samples reach up to $p_T \approx$ 250-300 GeV in 1 fb^{-1}

  We should see about 20$\times$ as many SM Z bosons in that energy range in 100 pb^{-1} at 10 TeV