Examples of "fast" / "parametric" simulation, from M_W analysis (and cousins)

At least five different such simulations existed!

- **μ-channel W, Z simulation (can also do e)**
- **e-channel W, Z simulation (bremsstrahlung)**
- **$\mu\mu$ resonance simulation**
- **My $\sim$ QFL-like e, γ simulation**
- **QFL itself**

μ-channel W, Z simulation (can also do e)

- Evolved from UA2 M_W analysis!
- Internally calls UA2 W, Z generator
- Structured around $W, Z \to \ell\nu, \ell\ell + 1, 2\gamma$
- Model e, μ acceptance (can be complicated)
- Resolution: stochastic $\oplus$ constant for calorimeter; QFL-style for tracks
- External brem by sampling y_{brem} histogram
- Model $\epsilon_{\mathrm{track}}$ vs η for "lost Z;" also CFT vs η_μ
- z-vertex, luminosity sampled from histograms
- Logic to decide whether ℓ, γ overlap in calorimeter
- Custom $\not{E}_{\mathrm{T}}$ model (not relevant here, but note that effect of wide-angle brem on $\not{E}_{\mathrm{T}}$ is modeled)
- Output is high-statistics histograms
  - Can re-use each event to fill grid of distributions with two variables changing, e.g. M, Γ, resolutions
  - Allows 2D likelihood fit (scale,resol), (M,Γ), etc.
  - Fast! $\sim$ 10M events/day on a 200MHz SGI R4400
- Unfortunately, few if any reusable parts

e-channel W, Z simulation

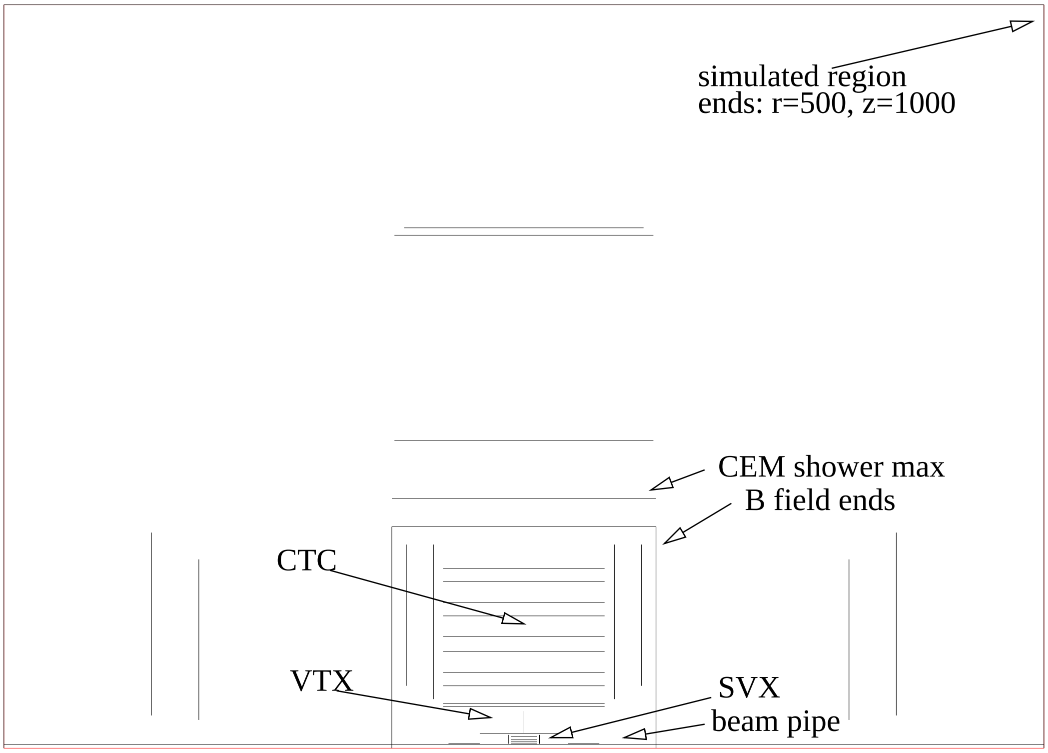
- Evolved from Ia M_W(e) analysis
- Reads file of 4-vectors,weights from UA2 W, Z generator
- Steps e, γ through ad-hoc detector geometry (regions bounded by constant r, z, ϕ)
  - Z, A, etc. from detector construction
  - density scaled to observed photon-conversion rate in each region
  - take steps of .0001 X_0
  - use Tsai brem rate: $\frac{dN}{dy} = \frac{1}{y}\left((1-y)(\frac{4}{3}+k)+y^2\right)$
  - use asymptotic conversion probability: $\frac{7}{9}dt$
  - brem in CTC modeled by averaging helices using inverse covariance matrices (assumes all hits used in fit)
  - consider photons down to $\sim$ 35 MeV
- QFL-style track smearing
  - picks SL hit patterns from actual W events
- CEM response
  - mimic tower clustering, N3D=1 cut
  - $(\sigma/E)^2 = (.135/\sqrt{E_T})^2 + \kappa^2$
  - assume linear response (40 MeV to 40 GeV)!
- Actual W events used to model some overlap effects

Dimuon Simulation

- Generates $V \to \ell\ell$ internally
  - $\ell \to \ell\gamma$ can follow (co-linear approx)
  - $\Rightarrow$ 2 momentum vectors + vertex
  - E_γ stored for possible E_{cal} cut
- Custom fiducial muon routine
  - extrapolates tracks as lines
  - applies acceptance & efficiency model
- QFL-style 5×5 track smearing (w/ eff. vs layer)
  - TRESMS adds MCS smearing
  - custom material map based on conversion data
  - dE/dx model applied to data, not simulation
  - BMFIT applies beam constraint
- Outputs ntuple, some histograms
- Some event reweighting to fix up acceptance
- Would be cleaner if vectors, 4-vectors, matrices were objects
- Possible to share material & fiducial models? Is "official" code always doomed to be too inflexible?

WJA Simulation (appendix B of my thesis)

- Input from HEPG bank (considers only e, ν, γ)
- Geometry = disks & shells; material concentrated in surfaces
- Trace helices through uniform B field
- Callbacks for material effects and detector response
- Use GEANT brem/conv/mcs routines
- CTC either QFL-style (using actual W hit patterns) or hit-level using CTADDH
- CEM resolution applied tower-by-tower
- Output TOWE, QTRK, TRKS (or CTCE), VTVZ, and OBSP-equivalent
- Hack ELES banks after reco to fudge ID variables
- Run same analysis code as data
- Speed OK: $\sim 100K$ ev/hr on 200 MHz R4400



Why (or why not) QFL?

- **Speed is not bad: $\sim 40K$ ev/hr for simple W, Z**
- **Concept of PAD-level bank output is good**
  - **It is much easier to screw up if you use different analysis code on data and MC**
- **EM cal model more complex than simple smearing; a bit trickier to tune to data**
- **File-based CES model should be replaced with something simpler**
- **Electron ID should be tuned to data; also crack response**
- **Not trivial to add new pieces to geometry**
- **Callback system would make it easier to add new detectors (e.g. hit-level CTC with material in active volume)**
- **Next time around, should document more explicitly which features of data are/aren't well reproduced**
- **Track simulation? Necessary detail for track simulation varies widely between analyses**
- **Calorimetry? I think TOWE output followed by clustering is the right choice (vs e.g. making electrons)**
- **Occupancy effects? Maybe a simple "event overlay" mechanism? Or e.g. Avi's "Q" variable for tracks**

Do we need ad-hoc simulations?

- **Better to have a flexible/hackable "QFL++" so that they're not needed**
- **But sometimes e.g. ultra-fast template generation is needed**
- **At least some shared ingredients could reduce the number of duplicated lines of code**
  - **Seed particle from $\vec{p}, \vec{x}$**
  - **What does it hit?**
  - **(These are already done nicely for Run II silicon)**
  - **Integrate material; calculate dE/dx**
  - **Covariance-based track smearing**
  - **Basic vectors, 4-vectors, etc! ($\exists$ standard?)**
- **Maybe make it easy to make fake HLOs (to run same analysis code, or borrow offline code)**
- **It's nuts for everyone to have her own model of inner detector material / muon acceptance / etc.**