Status of Monte Carlo and Reach Calculation

Goal – Extract a small signal on top of a large background

Test run – Assume the QED background in a window is given by a 7^{th} order polynomial with a Gaussian signal shape

For APEX run – Use QED Monte Carlo to guide or even better give the background shape and magnitude

Reminder of the how the reach calculation was done for test run

Running MadGraph4 on Jlab farm

Sample of invariant momenta from MG4 with angle and fermion momentum cuts

Current activity, problems/issues on the farm

Longer term plans

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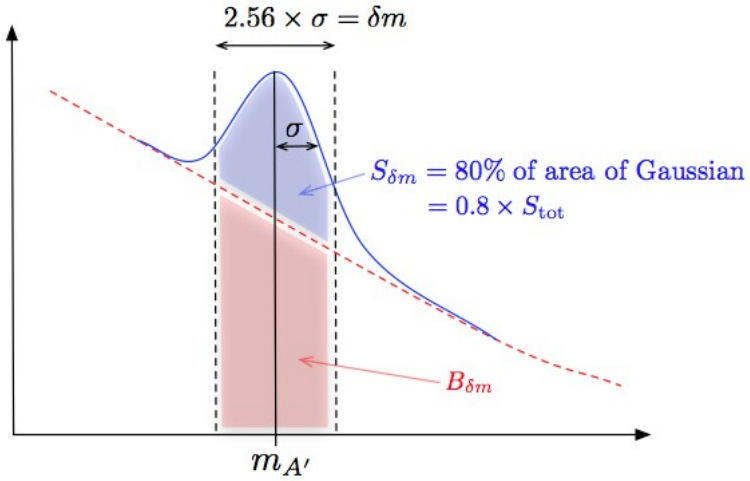
Upper limit on S yields an upper limit on ϵ^2

$$\epsilon^2(m_{A'}) = \frac{S_{\delta m}}{B_{\delta m}} \frac{F(m_{A'})\,\delta m}{m_{A'}} \left(\frac{2N_{\rm eff}\alpha}{3\pi}\right)$$

δm = mass window = $2.56 \times \sigma$ σ = width of Gaussian ~ 1 MeV (mass-dependent)

Background factor: $F \sim 5$ (mass-dependent) $N_{\rm eff} = 1$



James Beacham's report April, 2014

Parameters of interest (POI), set to values for null hypothesis (S = 0)

Conditional MLE of nuisance parameters (i.e., for S = 0)

$$\lambda(S) = \frac{L(S, \hat{\hat{B}}, \hat{\hat{a}}_i)}{L(\hat{S}, \hat{B}, \hat{a}_i)}$$

MLE of POI

MLE of nuisance parameters

Test statistic based on **Profile Likelihood Ratio**

Probability model:

$$P(m_{e^+e^-} \mid m_{A'}, \sigma, S, B, a_i) = \frac{S \cdot \mathrm{N}(m_{e^+e^-} \mid m_{A'}, \sigma) + B \cdot \mathrm{Polynomial}(m_{e^+e^-}, a_i)}{S+B}$$

This becomes a likelihood function, *L*, as a function of the model parameters.

How should we handle background?

Polynomial fit

- Easy to incorporate into fitting procedure.
- Parameters can be adjusted to account for equipment efficiency effects in experimental invariant mass spectra shapes.
- Coefficients of polynomial are nuisance parameters which may lead to systematic errors by hiding structure in spectrum's shape.

How should we handle background?

QED Monte Carlo

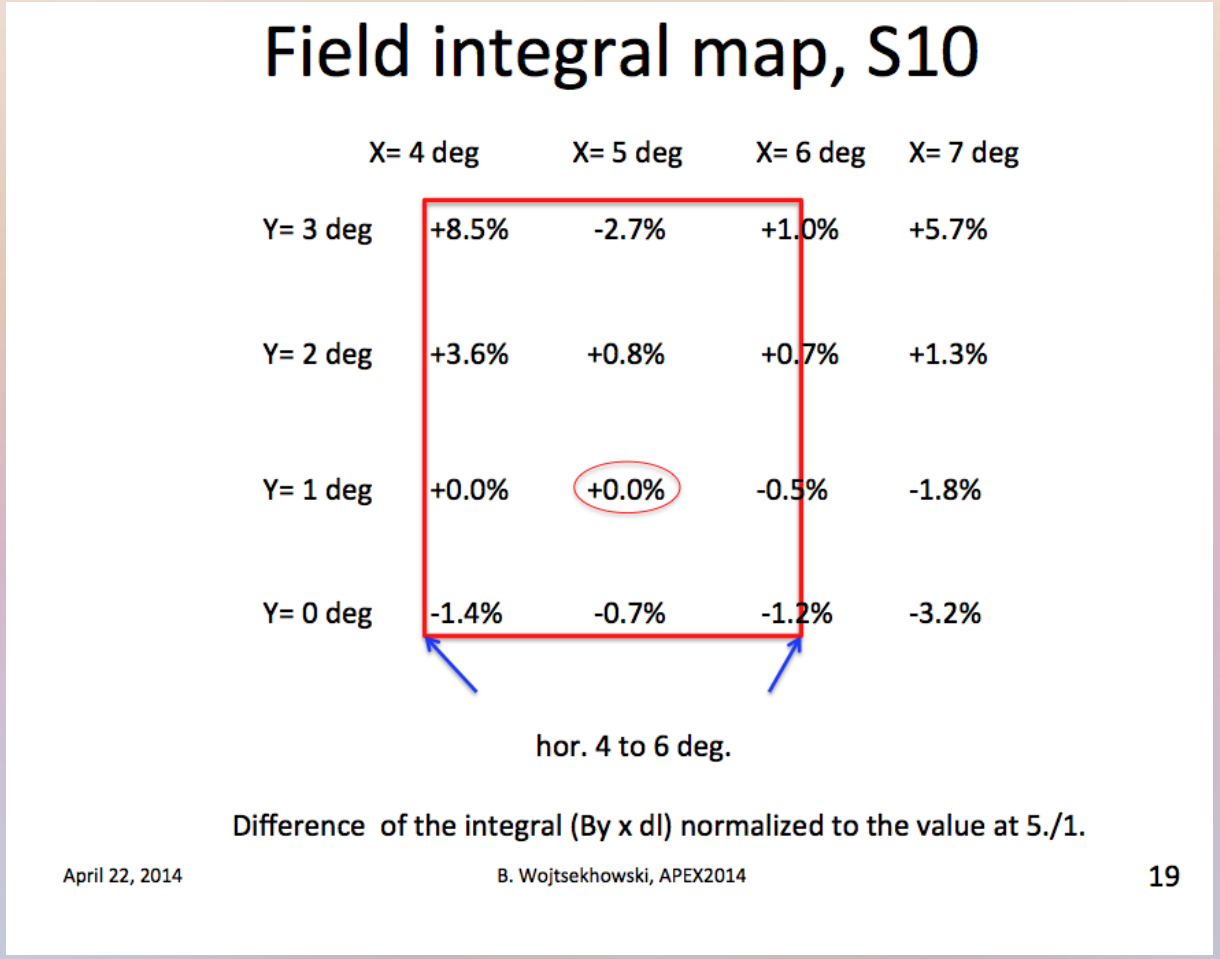
- In principle we can calculate the shape and magnitude of the background. Nuisance parameters are statistical only.
- For APEX extended target the QED strong angle dependence needs to be carefully accounted for in describing the background.
- Experimental efficiency effects may still need extra fitting beyond QED predictions. However, some of the efficiency issues may be resolved because the MC gives us the electron and positron momenta at the target foils and the scintillating fibers will provide benchmarks for the spectrometer calibrations.

Madgraph 4 and Madevent

- Test run used 30K Madgraph4 runs
- APEX run has 4 beam energies and significantly more statistics.
- Madgraph4 runs done now at JLab's farm. 50K runs available with radial angle cuts and fermion momenta cuts for p within +- 0.045*Ee/2 at Ee = 2.2 GeV.

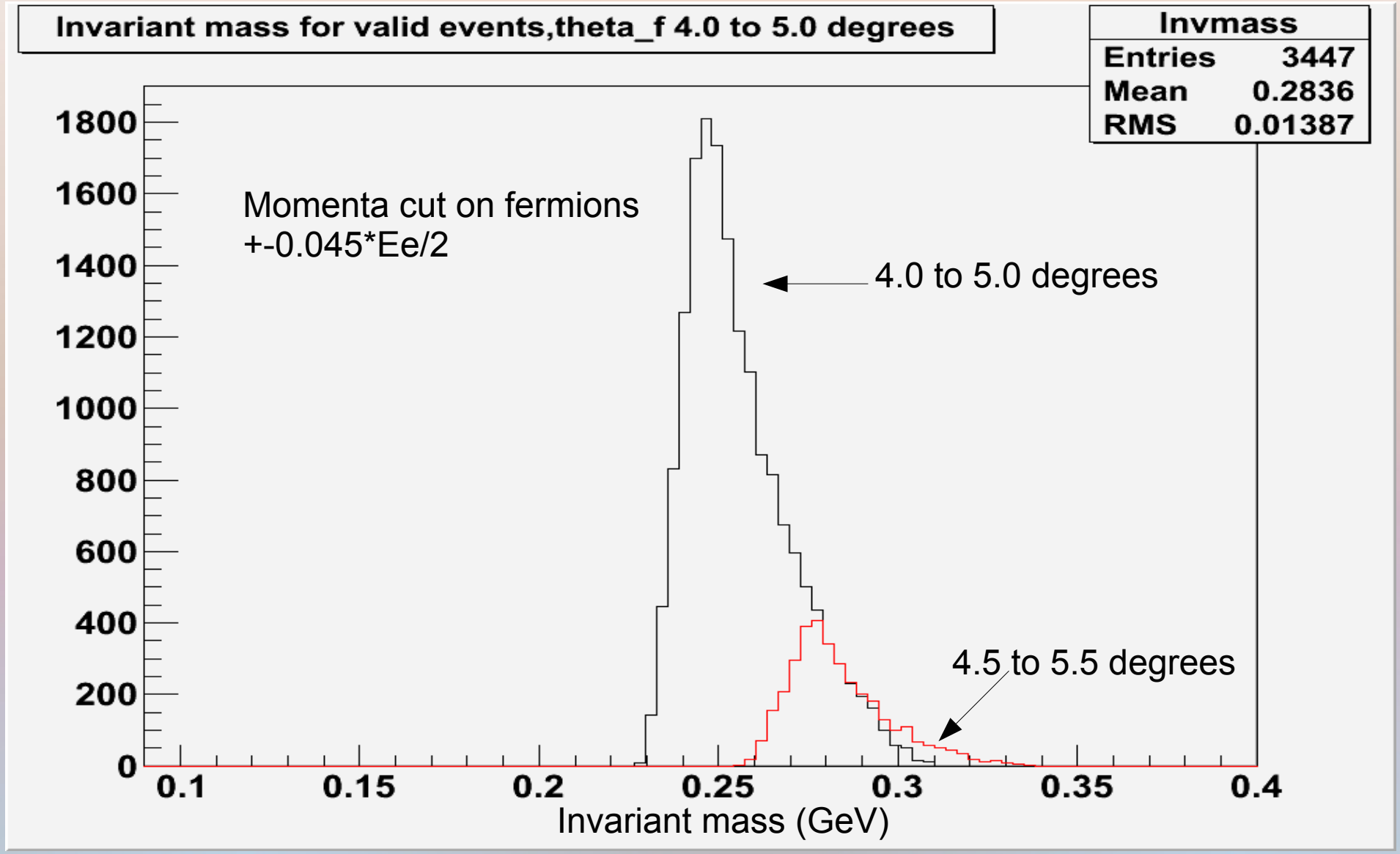
Statistics for 1000 Runs and 10M events	3.15 to 7.45 degrees	4.0 to 5.0 degrees	4.5 to 5.5 degrees
Number of events Passing cuts	249904	17061	3447
Centroid of invariant mass distribution	0.209 GeV	0.256 GeV	0.284 GeV

From Bogdan's presentation in April 2014

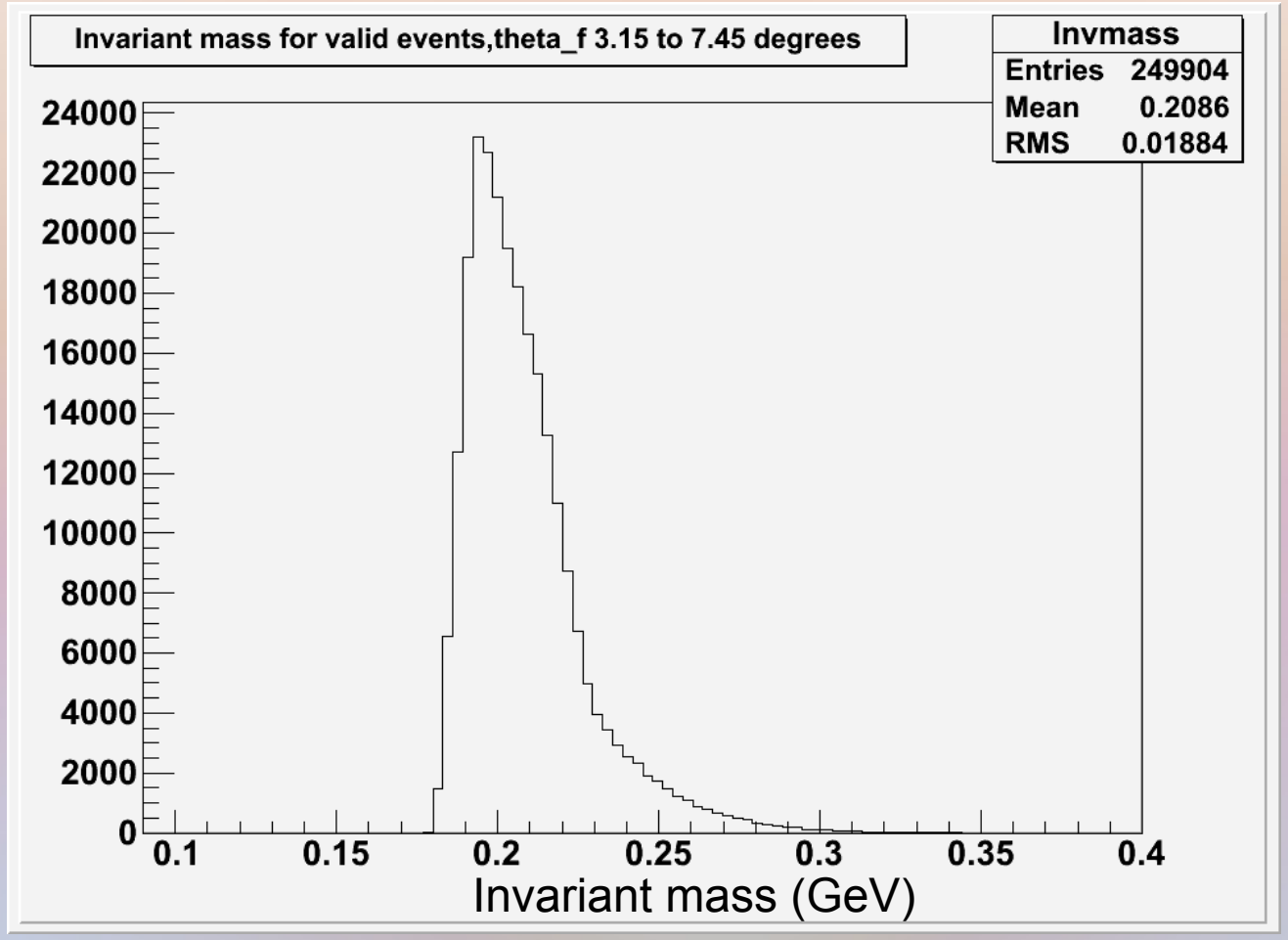


Angle cuts used in invariant mass calculation. Ideal range is 4.5 to 5.5 degrees for a fermion in each aperture.

Invariant mass for 1000 MG4 runs. A 0.5 degree change in the angle cuts makes a factor of 5 in coincidence yield. The angle cut for the invariant mass requires that the electron and positron are separated between 8 and 10 degrees or 9 and 11 degrees.



Madgraph4 invariant mass generated with larger angles than for the experiment



Current activity and issues

- Creating 50 large files by merging 1000 MG4 runs at a time from the present batch of 50K MG4 runs. This merging will be done on Jlab farm.
- Sometime in the beginning of April some unidentified change occurred on the farm so MG4 no longer produces usable output. Experts can not identify any change. Ongoing problem!
- Problem with MadGraph4 may be due to compilation with gfortran? Farm computers seem to be failing making a proper executable.

Longer Term Plans

- Clearly the MadGraph4 Jlab farm problem must be solved.
- It is proposed that pair production from bremsstrahlung photons need to be included in MC
- Natalia is looking into writing a new QED MC. This could incorporate the bremsstrahlung photons that hit the downstream foils.
- I am in discussions with James about his calculations for the experiment's reach.