The BaBar Electromagnetic Calorimeter: Status and Performance Improvements

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IEEE Nuclear Science Symposium 2005 Puerto Rico

October 26, 2005

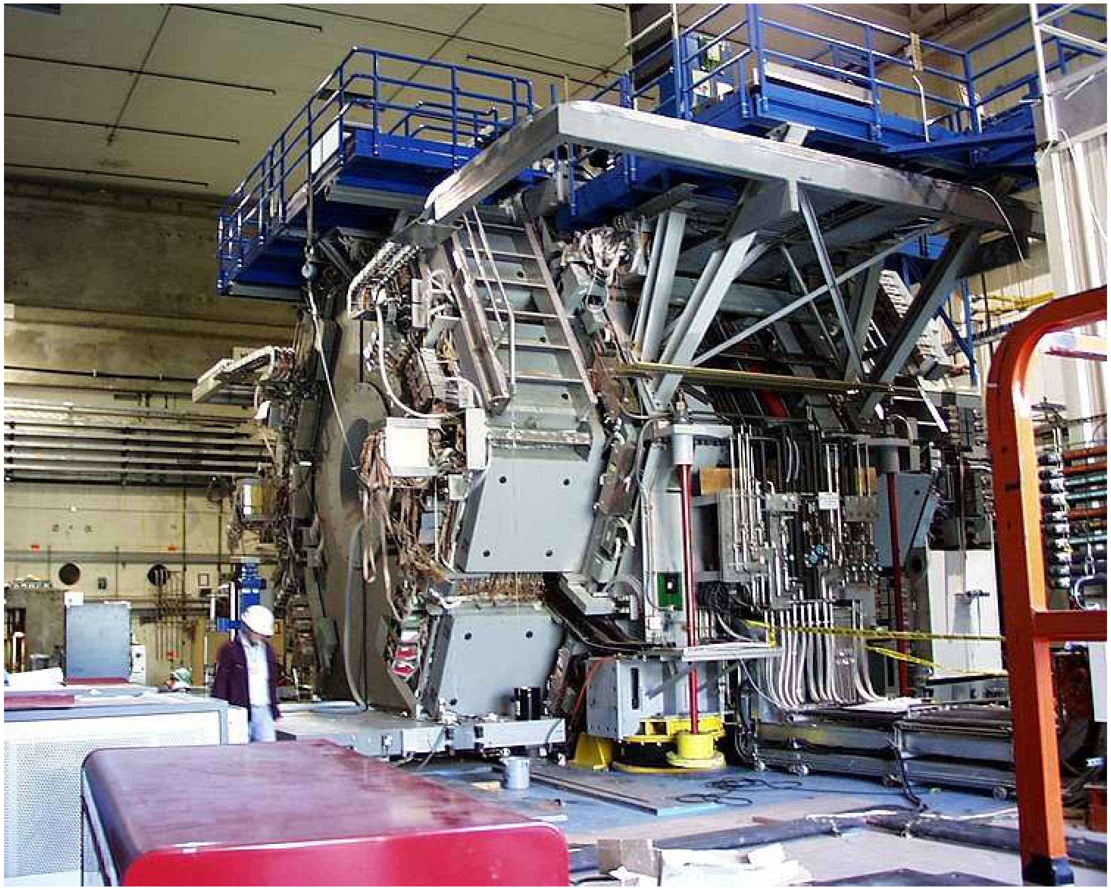
Outline:

1. Introduction to Experiment
2. Performance of Hardware
3. Calibrations of Individual Crystals
4. Cluster Calibrations
5. Recent Improvements in Software
6. Additional Studies and Future Goals
7. Conclusion

Introduction to Experiment

SLAC B-Factory

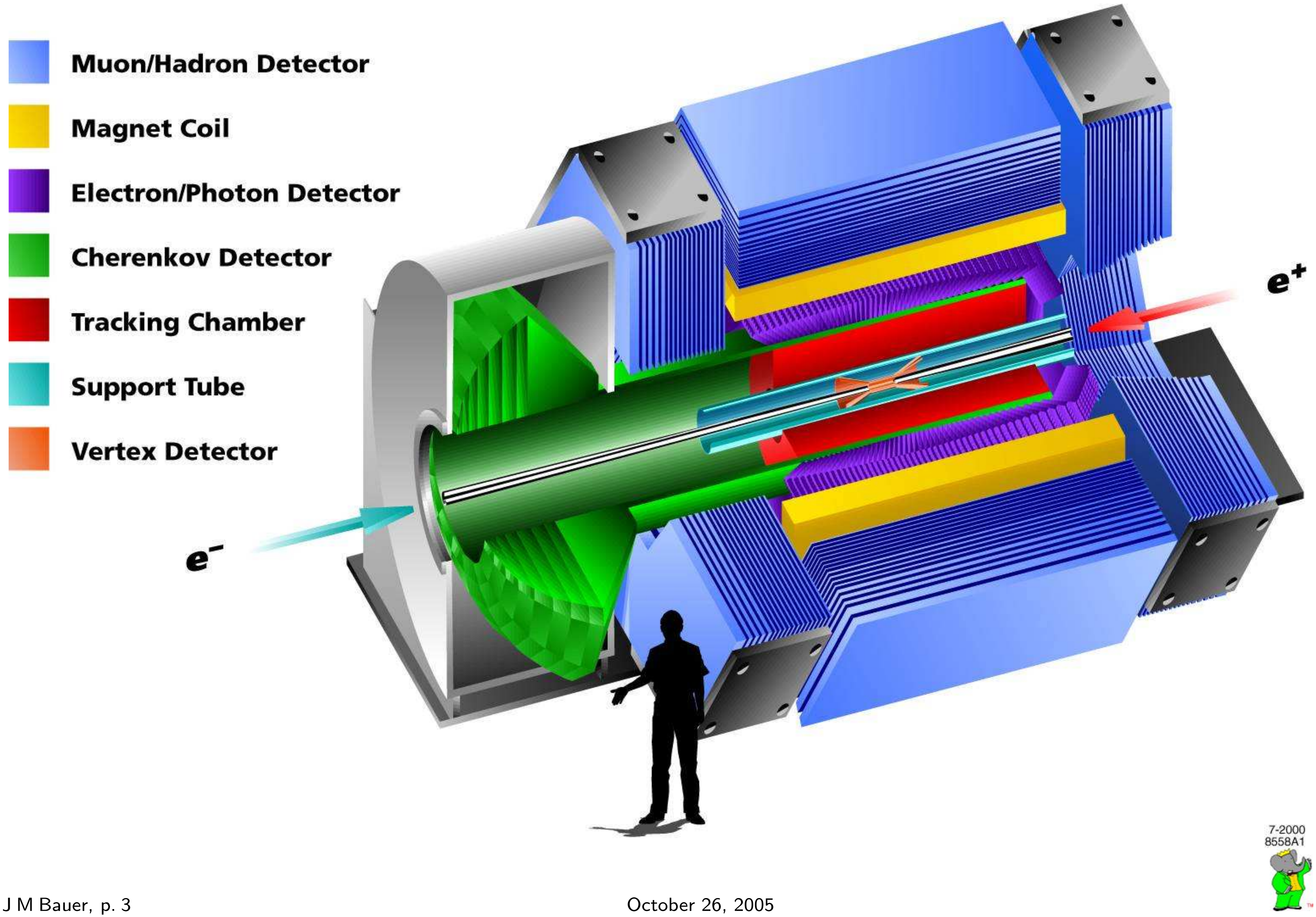
- Asymmetric energy:
  9.0 GeV e^-
  3.1 GeV e^+
- Total energy:
  10.58 GeV $\equiv$
  $\Upsilon(4S)$ resonance
- B^+B^- and $B^0\overline{B}^0$
  pairs to study
  CP violation
  and many other
  things



BABAR Detector

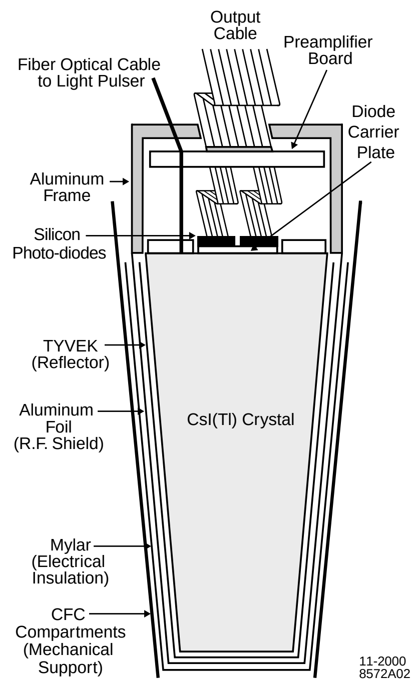
SLAC-PUB-8569, NIM A479, 1 (2002)

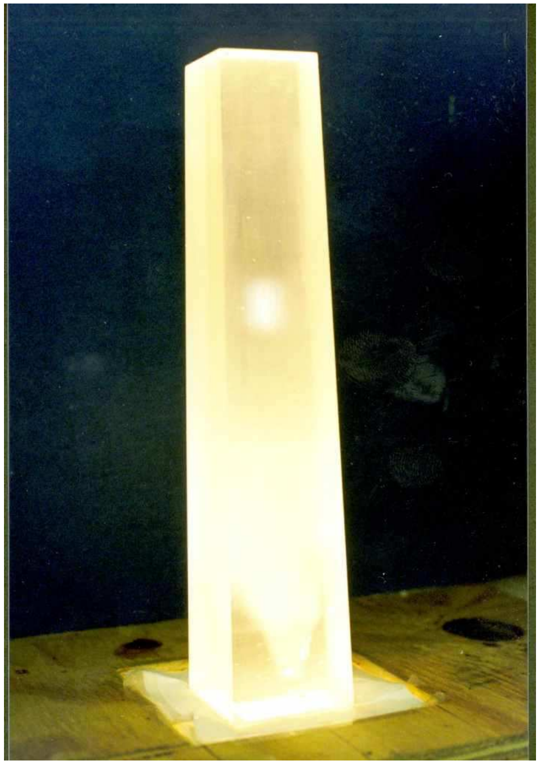
BaBar Detector



Electromagnetic Calorimeter (EMC)

- CsI(Tl) crystals
  - high light yield (50,000γ/ MeV)
  - long decay time (940 ns)
- 16 to 17.5 radiation lengths
- 6580 crystals pointing close to interaction point
- Photo diodes and pre-amplifier attached to back of crystal ($\sim$7,300 photo-e^-/ MeV)

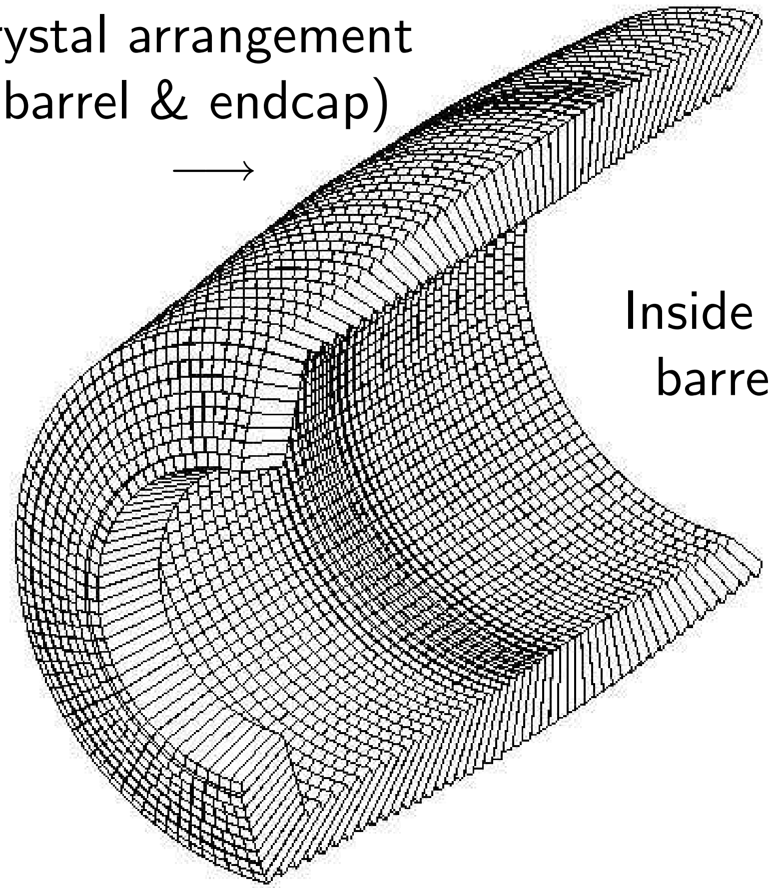




- 10-bit ADC + two range bits $\Longrightarrow$ 18-bit dynamic range
- Measuring photons from 20 MeV to 8 GeV
- $\sigma_E/E = 2.3\%/\sqrt[4]{E(\mathrm{GeV})} \oplus 1.35\%$
  $\sigma_\theta = \sigma\phi = 4.16\,\mathrm{mrad}/\sqrt{E(\mathrm{GeV})}$

SLAC-PUB-10170

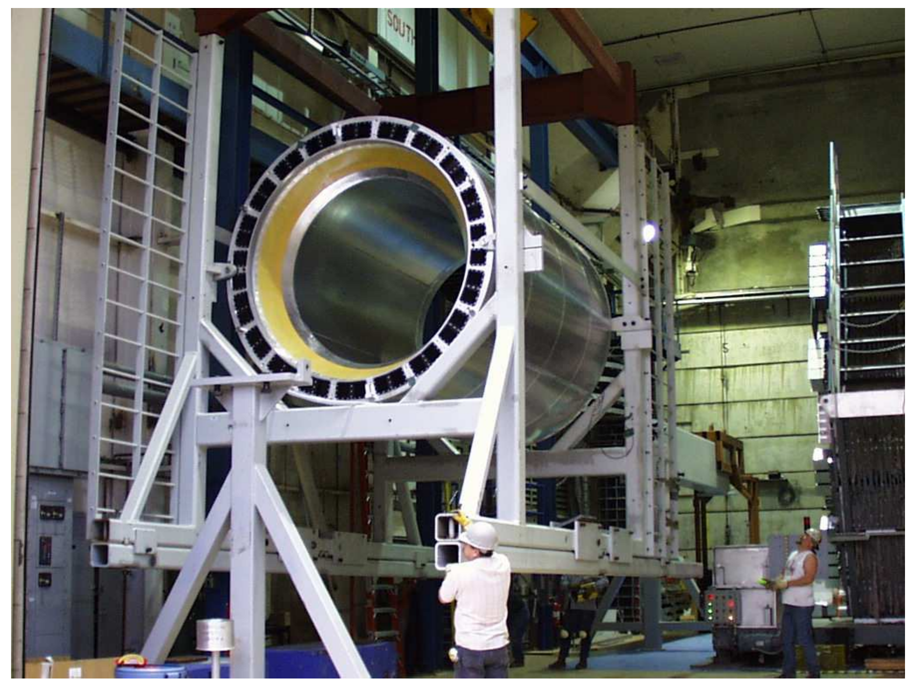
Crystal arrangement
(barrel & endcap)
$\longrightarrow$



Inside
barrel $\longrightarrow$

Crystals combined into
7×3 (or 6×3) modules

Final barrel $\longrightarrow$



Performance of Hardware

- Quite stable operation:
  - out of 6580 crystals, only one crystal completely dead
    currently four more dead, but might be recovered
  - 14 more crystals use only one of two diodes
  - some more crystals bad in one energy range, e.g. at low energy
  - from time to time ADC board noisy:
    in worst case masking out until next access
- Electronics regularly calibrated:
  - measuring pedestals
  - known charge injected into pre-amplifiers and read out
    to measure gain and linearity

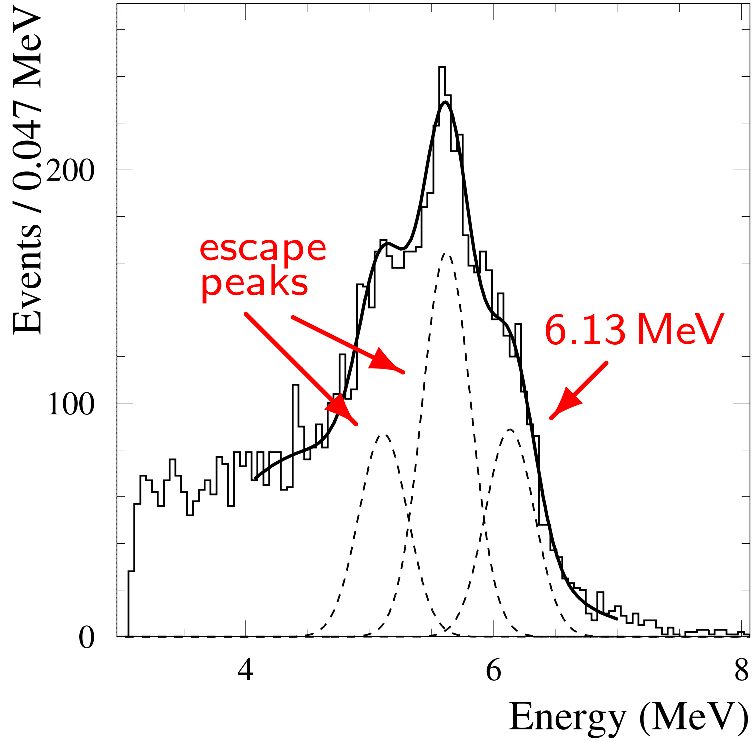
Calibrations of Individual Crystals

Basics

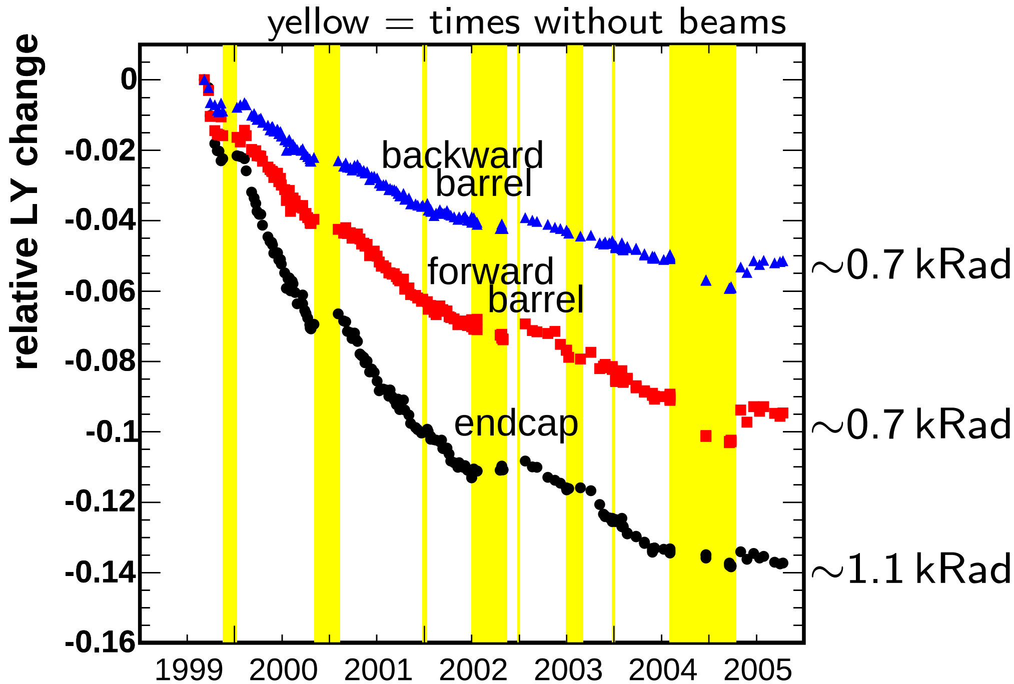
- Crystals have individual response to energy deposit
  (overall light yield differences and non-uniformities)
- Light yield decreases due to radiation damage
- Two absolute energy calibrations:
  - liquid source calibration at low energy
  - Bhabha calibration at high energy
- At intermediate energies interpolation linear in $\log E$

Liquid Source System

- Neutron generator surrounded by Fluorinert (FC77)
- $^{19}\mathrm{F} + \mathrm{n} \rightarrow {}^{16}\mathrm{N} + \alpha$
  $^{16}\mathrm{N}$ ($T_{1/2}$=7 seconds) decays to $^{16}\mathrm{O}$ + 6.13 MeV γ
- Pipe system transports radioactive liquid past front of crystals
- Detection of γ with regular DAQ system



Spectrum of crystal
with fit



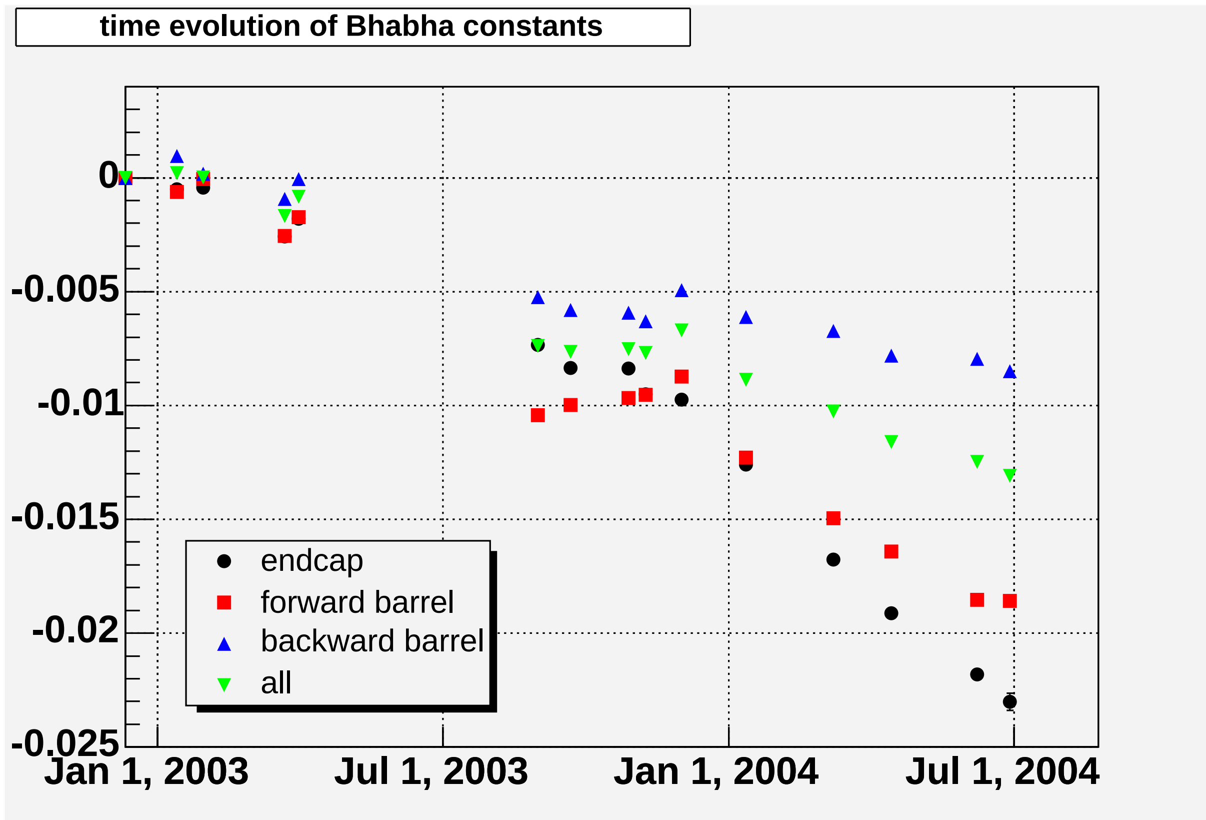
Relative drop in light yield
versus time

- Calibration $\sim$ once a month to $\leq 0.5\%$ (syst. uncertainty 0.1%)
- Stable turn-key operation

SLAC-PUB-10289, IEEE Trans. Nucl. Sci., 51, 1596 (2004)

Bhabha Calibration

- Absolute energy calibration with $e^+e^- \rightarrow e^+e^-$ at crystal energies of 2.5 to 8 GeV (depending on polar angle due to boost)
- Requiring most crystals to have > 200 direct hits
  $\Longrightarrow$ 0.35% statistical error for each crystal
  systematic error $< 1\%$
- Run off-line up to once a month
- Calibration will soon be automated
- Change in constants similar as change in source calibration constants

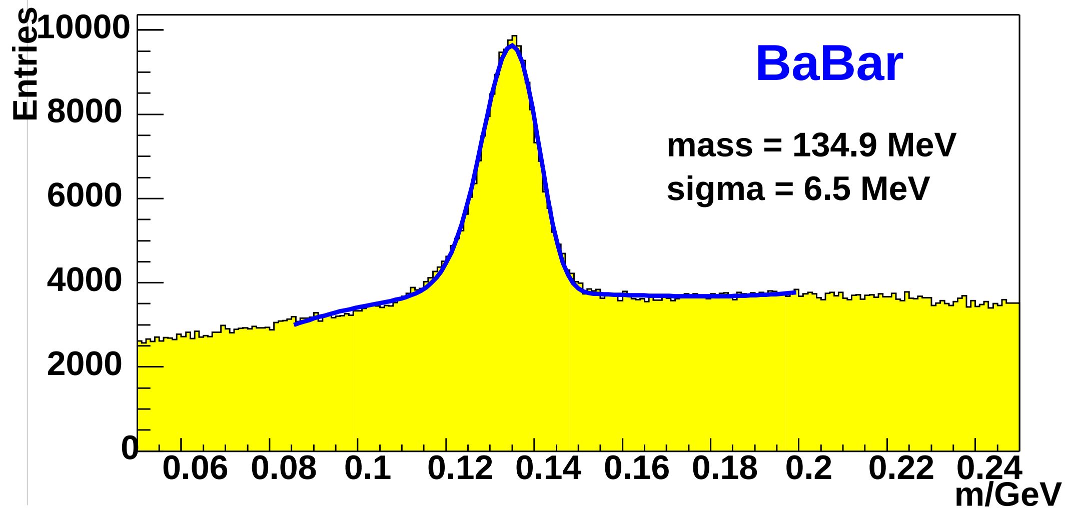


Cluster Calibrations

Necessary since not all energy captured inside crystals

Cluster Calibration with π^0 (up to 2 GeV)

- Correct to photon energies based on π^0 mass peak
- Corrections typically 6 to 8%
- Currently testing an improved version



Cluster Calibration above 2 GeV

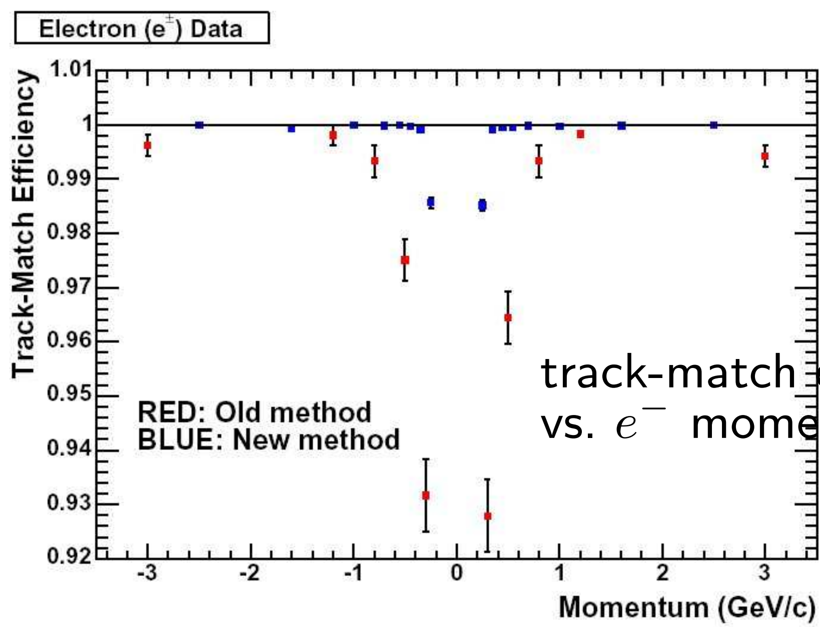
- Finding factors for calibration to single-photon Monte Carlo
- Applying same correction factors to data
- Soon using $e^+e^- \to \mu\mu\gamma$ events for calibration

Recent Improvements in Software

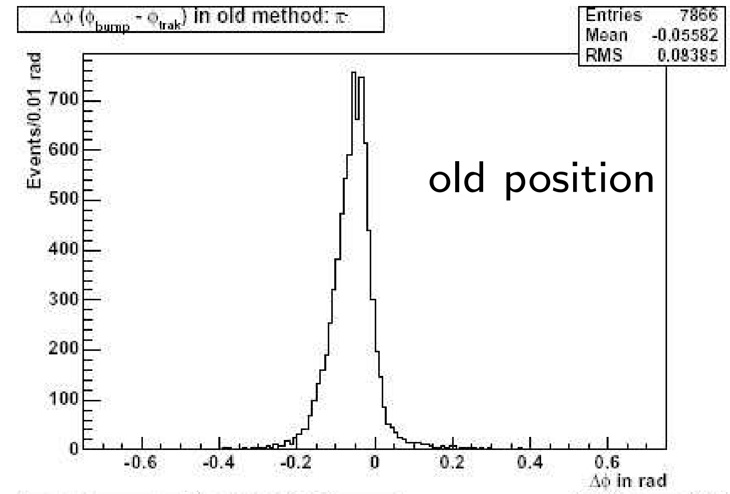
Position of Cluster Inside Crystals

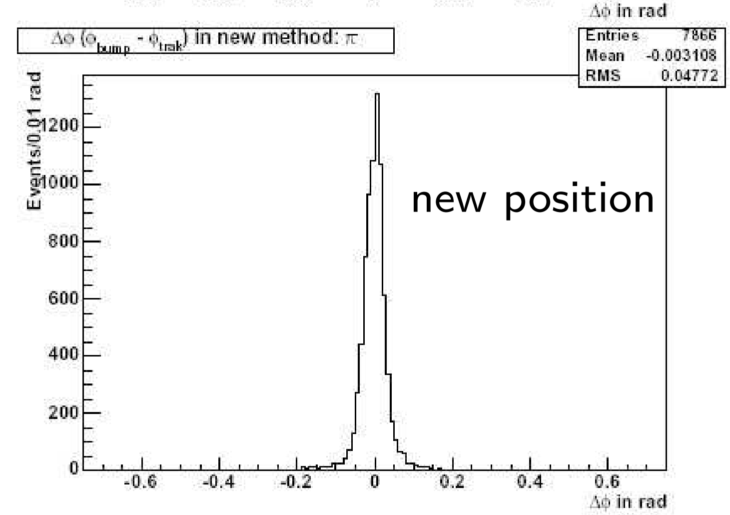
- Depth of cluster inside crystal at 12.5 cm
  before: cluster center projected to
  front of crystal

  $\Longrightarrow$ improvement in matching
  clusters and tracks



track-match efficiency
vs. e^- momentum



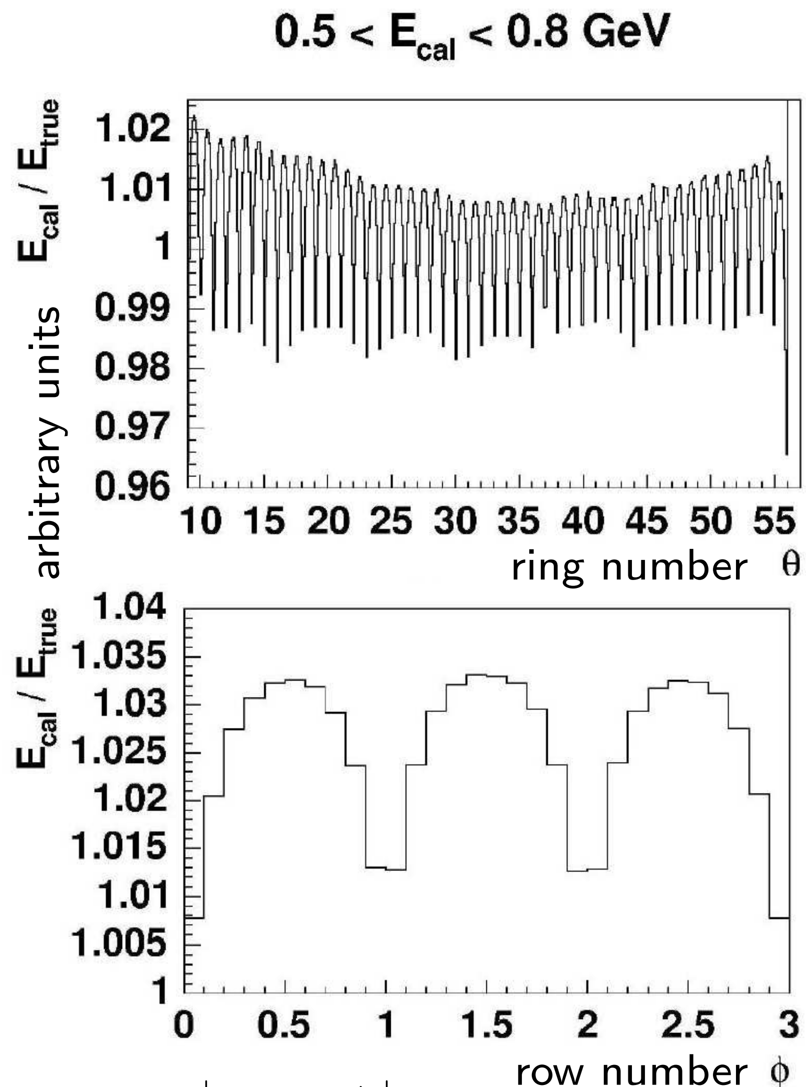


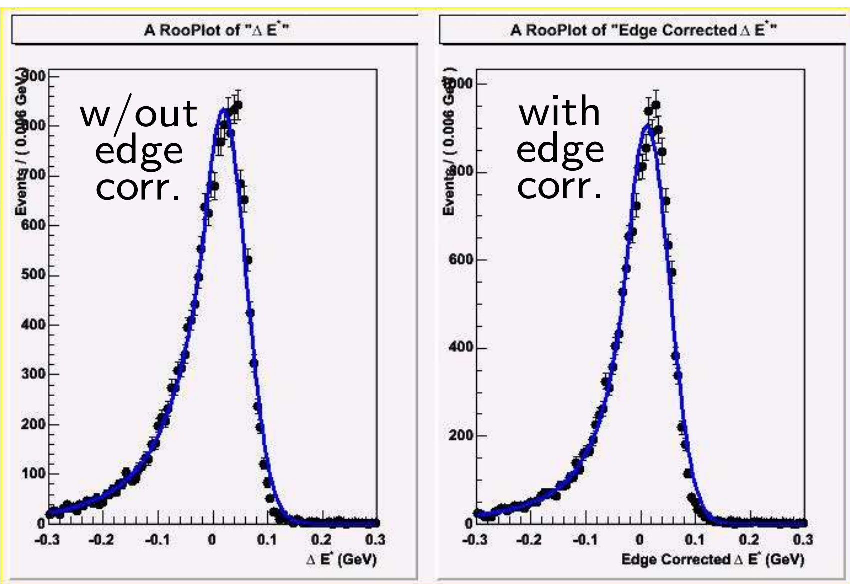
$\Delta\phi$ in rad

$=$ difference in ϕ angle of
of cluster position and
point where track
intersects with calorimeter

Edge Correction

- If photon hits close to edge
  between two crystals,
  up to $\sim$3% of energy
  is lost in gaps
- Dependence on θ position of crystal
- Module symmetry in ϕ:
  ϕ-dependence folded to
  just three "crystals"





$\leftarrow$ Monte Carlo $B^+ \to K^{*+}\gamma$:
FWHM/2.36 $= (45.1 \pm 0.7)$ MeV w/out edge corr.
FWHM/2.36 $= (42.0 \pm 0.6)$ MeV with edge corr.
$\Longrightarrow \Delta E$ resolution improved
by 7% in this case

ΔE (= measured B energy
minus known beam energy)

Additional Studies and Future Goals

- Many modes to study performance of EMC, *e.g.*,
  - $e^+e^- \to \mu\mu\gamma$ events
  - radiative Bhabhas $e^+e^- \to e^+e^-\gamma$
  - $e^+e^- \to \gamma\gamma$
  - $D^{*0} \to D^0\gamma$: $E_\gamma \sim 100 - 400\,\text{MeV}$
  - $\Sigma_0 \to \Lambda\gamma$: $E_\gamma \sim 50 - 250\,\text{MeV}$
- New cluster calibration will soon be implemented
- Bhabha calibration will soon be automated

Conclusion

- *BABAR* EMC operation stable, performance very good
- Radiation damage measured and calibrated out
- Enhancements made to reconstruction code
- Tweaking calibrations to improve analyses