Signal Stability of the DELPHI/STIC

(Calorimeter)

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Outline:

- Detector Description
- Interpretation - preliminary
- Summary
DELPHI STIC Collaboration

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INTRODUCTION

**STIC - SMALL ANGLE TILE CALORIMETER**
was installed at DELPHI (LEP) in 1994 to measure the absolute luminosity with an error <0.1%

- This goal was achieved by an accurate detector assembly and control of all systematic errors.

- A regular calibration of the STIC response is performed to precisely define the energy scale.

- If no recalibration is applied the signal shows a systematic decrease in function of time.

A detailed investigation on the origin of this effect is presented and results are discussed in terms of the performance of this scintillator - WLS fiber detector.

- A detailed investigation but not complete
Detector Description

- STIC consists of 2 cylindrical lead/scint. shashlik type calorimeters placed at 2.2 m on each side of the interaction point.
  - Each calorimeter is made of 47 sampling layers - total depth ~27X0 -
    - 1 layer:
      - * 3.4 mm thick continuous absorber (3mm thick lead plate enforced by 100um steel foils)
      - * 3 mm thick scintillating tiles

- STIC internal geometry controlled to better than 50um.

- Scintillation light collected by WLS fibers ~50cm long, readout by Hamamatsu phototetrodes (5~16 inside 1.2T magnetic field)
  - Y T (non S) WLS fiber till 96
  - Y11 (300)H5 with 200 ppm AlN site 97


DELPHI

DELPHI STIC

Z = ±220 cm
29 mrad < θ < 188 mrad

STIC - SMALL ANGLE TILE CALORIMETER
Energy Response Uniformity

- $R$ from Si juststrip telescope (SR = 50 mm)
- Continuous converter no tower structure
- Non-uniformity $\Rightarrow$ enhanced light collection Eff near fibers

$E$ vs $R, \phi$ (2nd ring)

- $R, \phi$ measured by STIC
- Energy correcting map $E = E_{\text{meas.}} \cdot \frac{E_{\text{beam}}}{f(R, \phi)}$

Fibers modulation in LEP (1994)
Uniformity and Energy Resolution

- STIC signal increases near fibers
- Non-uniformity is partially corrected by mapping average signal modulation
- 1994: $\frac{S}{E}$ for 45 GeV electrons (Bhabha scattering)
  - Improves from 3.1% before correction to 2.7% after energy map correction
- Before correction $\frac{S}{E}$ worse, (in outer rings)
Energy calibration

Non radiative Bhabha events selected for STIC calibration

For each channel, $j$, a calibration coefficient, $c_j$, is found by minimizing:

$$\sum_{i=1}^{N_{\text{ev}}} \left( E_{\text{meas}}^i - E_{\text{beam}}^i \right)^2$$

$$E_{\text{meas}}^i = \sum_{j=1}^{N_{\text{chan}}} c_j \times \text{ADC}_j$$

STIC channels are recalibrated once every month

Without recalibration (i.e. by "freezing" the calibration coefficients) STIC energy response to Bhabha events shows a systematic decrease in function of time.
**STIC Response to Bhabha Electrons**

Variation with time, with constant calibration coefficients

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<th>May</th>
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$\sqrt{s} = 91 \text{ GeV}$

$\tau = 26\text{ years}$

$\sqrt{s} = 161.6 \text{ GeV}$

$\sqrt{s} = 173 \text{ GeV}$

$\tau = 22\text{ years}$

$\sqrt{s} = 182 \text{ GeV}$

$\tau = 16\text{ years}$

1994+1995: Calibration coeff. fixed at values found in beginning 94

1996: Calib. coeff fixed at values found in beginning 96

1997: Calib. coeff.
Without recalibration the STIC signal shows a systematic decrease in function of time. 

\[ t = \frac{\Delta t}{\Delta E/E} \ \text{(days)} \ \text{and} \ \gamma = \frac{\Delta \gamma}{\gamma} \ \text{(years)} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>$\Delta t$ (days)</th>
<th>$\Delta E/E$</th>
<th>$\gamma$ (years)</th>
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<tbody>
<tr>
<td>1994</td>
<td>170</td>
<td>2%</td>
<td>26 y</td>
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<td>1995</td>
<td>150</td>
<td>2%</td>
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<td>1997</td>
<td>60</td>
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(*) $\gamma_{17}$ is compatible with signal decrease during first 60 days of 1994.

- Exponential fit to last 4 months of 1994 yields $\gamma \approx 45$ years.
- For $\gamma=45$ years a variation of $\sim 2\%$ in 1 year is expected.
Possible sources of signal variation

\[ \text{Radiation Damage} \]

- Bhabha scattering electrons
  - Rate \( \approx 1 \) Hz
  - Stronger effect at small radii
    \[ \frac{d\sigma}{d\Omega} \propto \frac{1}{\theta^2} \]
  - Cylindrical symmetry
    no dependence with STIC sector

- Off momentum electrons
  - Rate \( \approx 20-200 \) Hz
  - Concentrated at small radius
  - Strong correlation with STIC sector:

\begin{align*}
\text{1994 and 1995} & : \text{STIC sectors: 1+16 8+9} \\
\text{1996 and 1997} & : \text{STIC sectors: 1+16 8+9 3+4+5+6 11+12+13+14}
\end{align*}
AGEING

- Possible variation with radius = stress
  - Fibres are more bent in outer rings
- No dependence with STIC sector

- Each envisaged source of damage gives a "well" identifiable signature in terms of signal variation vs. sector and ring.
- Such correlation will be investigated in order to establish the origin of signal variation
Dose in shower maximum scintillator

Bhabha scattering

\[ D(\text{rad}) = \frac{1800}{R^4 \sqrt{S}} \times \int \frac{dL}{dt} \]

\[ \text{cm} \quad \text{GeV} \quad \text{fb}^{-1} \]
DOSE FROM OFF-MOMENTUM ELECTRONS
(in shower maximum scintillator plane)

1994

\begin{itemize}
\item \(<E> \sim 20\ \text{GeV} \ (at\ \sqrt{s} = 90\ \text{GeV})\)
\item Dose is essentially deposited in Rings 1 and 2 and stic sectors close to LEP plane (horizontal)
\item In ring 1, asymmetry between Arm A and C
\end{itemize}
Dose from off-momentum electrons

1997

\[ \langle E \rangle_{\text{off-mom}} \sim 40 \text{ GeV} \quad (\text{at } \sqrt{s} = 180 \text{ GeV}) \]

- Off-momentum hitting also stic sectors in vertical plane: 3, 4, 5, 6 / 11, 12, 13, 14
- Since 1996 no tungsten mask on side C
Dose levels in STIC

--- Summary ---

Maximum doses corresponding to 6 months of operation

- Bhabha scattered: $D < 1\text{rad}$ electrons
- Off-momentum: $D < 500\text{rad}$ electrons

Estimated doses in STIC scintillator and WLS fibres are (in principle) small to explain observed signal variation along the time.
**Signal Variation in One Year**

Measured for Bhabha Events hitting a given ring and sector

**1994**

- **Arm A**
- **Arm C**

- Variation measured during STIC operation extrapolated to 1 year assuming linear dependence with time.

- No correlation is observed between signal decrease and sectors or rings with maximum dose.
Signal variation in one year measured for Bhabha electrons hitting a given ring (any sector).

- Variation in one year, assuming linear dependence with time.
- Poor statistics in outer rings: $\frac{1}{\theta}$ dependence of Bhabha scattering cross-section.
- No correlation is observed between signal variation and ring, indicating an effect due to fiber stress.

(Additional notes on poor statistics could be included.)
Summary

- Signal decreasing characterized by a time constant $[\tau_1]$, such that:
  - $\tau_1 \approx 15$ years during initial 2 months
  - $\tau_1 \approx 45$ years in remaining period of operation (4 months)
- We don't observe a clear correlation between this effect and radiation damage or fiber stressing.
- Assuming that no uncontrolled changes occurred between 1994 and 1995, no ageing was observed when the detector was not operating.
- STIC signal performance during 1996 presents a puzzling discrepancy (no variation!)
- Even in a pessimistic scenario (by 20 years), STIC energy resolution will not degrade until year 2000.
- Systematic survey of the STIC signal stability will continue.