DETECTORS as a FUNCTION of LUMINOSITIES at e+e- MACHINES

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OUTLINE

- Introduction
- Silicon Vertex Detectors
- Drift Chambers
- Electromagnetic Calorimeters
- Trigger Rates
- Conclusion
Introduction

- How do present multipurpose detectors operating at $\sqrt{s} \sim 10\text{GeV}$ perform at high luminosities?


- Results shown in blue are those given in the above report. All results shown in green are my personal extrapolations. Estimated systematic uncertainty for BABAR results is factor of 2 (for my extrapolation also expect at least a similar uncertainty)

- It does not make any sense to extrapolate measurement to $L_{\text{peak}} > 1 \times 10^{35}$

- Extrapolations depend very much on layout of the IR. It is not trivial to predict background levels from BABAR study for other IR layouts such as eg BELLE
# Luminosity Considerations

<table>
<thead>
<tr>
<th>Date</th>
<th>$E_{\text{peak}}$ [cm$^{-1}$ s$^{-1}$]</th>
<th>$E_{\text{peak}}$ [cm$^{-1}$ s$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2002</td>
<td>$4 \times 10^{33}$</td>
<td>$6.5 \times 10^{33}$</td>
</tr>
<tr>
<td>August 2005</td>
<td>$0.6 - 1.7 \times 10^{34}$</td>
<td>$1.5 \times 10^{34}$</td>
</tr>
<tr>
<td>August 2008</td>
<td>$1.7 - 7.0 \times 10^{34}$</td>
<td>$5.0 \times 10^{34}$</td>
</tr>
<tr>
<td>some date after 2009?</td>
<td>$1.0 - 4.0 \times 10^{36}$</td>
<td>$&gt;1.0 \times 10^{35}$</td>
</tr>
</tbody>
</table>

- The peak luminosities shown in blue were given by Ian Shipsey as guideline.
- The peak luminosities shown in green are those I considered.
Sources of Machine Backgrounds

- Detector subsystems are subjected to different machine-related backgrounds
  - Electrons: \( \Rightarrow \) lost particles backgrounds (beam-gas bremsstrahlung, Coulomb scattering) and synchrotron radiation
  - Positrons: \( \Rightarrow \) lost particles backgrounds (beam-gas bremsstrahlung)
  - 2 beams:
    - no collision \( \Rightarrow \) single beam backgrounds above plus beam-gas cross term
    - in collision \( \Rightarrow \) backgrounds from luminosity, beam-beam tails & above 3
Multipurpose Detector for e+e- Collisions at 10 GeV

**BaBar**

- Muon/Hadron Detector
- Magnet Coil
- Electron/Photon Detector
- Cherenkov Detector
- Tracking Chamber
- Support Tube
- Vertex Detector
Silicon Vertex Detectors

SVTRAD: Accumulated Dose and Budget

- Non-MID-plane (typ)
- Inner MID-plane (HER)
- Outer MID-plane (LER)
- Radiation Dose Budget

Day of Year 2001

Dose / kRad
Silicon Vertex Detectors

Composition of SVT Diode Background

SVT dose rate: FE MID [kRad/y] = 128 I_{LER} + 16 I_{LER}^2
BW MID [kRad/y] = 246 I_{HER} + 9.1 I_{HER}^2
Conclusion Silicon Vertex Detectors

- \( \frac{\Phi_{\text{peak}}}{\text{cm}^{-1} \text{s}^{-1}}: \) 6.5\( \times \)10\(^{33}\) 1.5\( \times \)10\(^{34}\) 5\( \times \)10\(^{34}\) >1\( \times \)10\(^{35}\)
- \( \Phi_{\text{dur}} \) [fC\( \text{cm}^{-2} \text{s}^{-1}\)]: 55 400 2000 ?
- \( \frac{I_{\text{LER}}}{I_{\text{HER}}} \) [A]: 2.8/1.1 3.7/1.3 4.6/1.5 ?
- \( D_{\text{SVT}} \) [kRad/y]: 480/280 690/340 1300/930 ?

- Radiation levels depend very strongly on layout of IR, They are lower at KEKB than at PEP II

- In BABAR silicon detectors are expected to survive a total dose of 2MRad
  The FE:MID and BW:MID receive highest doses ⇒ With replacements of detectors in the MID plane BABAR SVT is expected to survive luminosities of 1.5-3\( \times \)10\(^{34}\)

- R&D at LHC has demonstrated that silicon detectors can survive high hadronic radiation levels, question is the electronics

- So for \( \Phi_{\text{peak}} \sim 1-10 \times 10^{35} \) silicon detectors probably work
Machine backgrounds affect operation of Drift Chamber in 3 ways:

- Total current $I_{DCH}$ in Drift Chamber drawn by wires is dominated by charge of beam-related showers
  - $I_{DCH}$ is limited by high-voltage system,
    - above limit chamber becomes non operational!
    - high currents also contribute to aging of chamber!
    - maximum $Q_{max}$: 0.1-1.0 Cb/cm of wire

- Occupancy in Drift Chamber due to backgrounds (hits, tracks) can hamper reconstruction of physics events

- Ionization radiation can permanently damage read-out electronics & digitizing electronics
Drift Chamber Currents

- Single beam and collision measurements taken June/July at HV=1900V

- For HV=1960V scale current by factor 1.67

\[ I_{DCH} [\mu A] = 35.3 I_{LER} + 23.5 P_{LER} + 77.2 I_{HER} + 46.3 P_{HER} + 41.9 \times 10^{-14} \]

with currents in [A] and luminosity in units of \([10^{33} \text{ cm}^{-2} \text{ s}^{-1}]\)
- Seeman model for HV=1900V

- At HV=1960 background levels are expected to be 65% higher
Drift Chamber Occupancy

- At HV=1900V (Jan-July):
  \[ N_{DCH} = 158 + 0.27 \ I_{DCH} \ (<350\ \mu A) \]

- At HV=1960 V (July-now):
  \[ N_{DCH} = 203 + 0.18 \ I_{DCH} \ (>200\ \mu A) \]

- Large spread
  \[ \Rightarrow \text{extrapolation difficult} \]

\[ N_{DCH} = 0.044 + 0.191 \ I_{LER} + 0.0402 \ I_{LER}^2 + 1.03 \ I_{HER} + 0.113 \ I_{HER}^2 + 0.147 \ \£ \]

with occupancy in \[%\], currents in \[A\], luminosity in units of \[10^{33} \text{ cm}^{-2} \text{ s}^{-1}\] at 1900V
Conclusion on Drift Chambers

$\xi_{\text{peak}}$ [cm$^{-1}$ s$^{-1}$]: $6.5 \times 10^{33}$  
$|\xi_{\text{dwell}}|$ [fbr$^{-1}$]: 55  
$I_{\text{LER}}/I_{\text{HER}}$ [A]: 2.8/1.1  
$I_{\text{DCH}}$ [$\mu$A]: 680  
$N_{\text{DCH}}$ [%]: 3.1  
$Q_{\text{wire}}$ [mCb]: ~15  
Dose [Rad]: 275

$5 \times 10^{34}$  
$1.5 \times 10^{34}$  
$2000$  
$400$  
$4.6/1.5$  
$1250$  
$50$  
$10000$  
$\geq 1 \times 10^{35}$  
$?$  
$?$  
$?$  
$?$  
$?$  
$?$

* Extrapolation is uncertain due to IR configuration and $\geq 2$ orders of magnitude scaling

☐ Extrapolations to $\xi_{\text{peak}} > 1 \times 10^{35}$ make no sense
expect additional backgrounds due to luminosity lifetime
(see M. Sullivan’s talk at Homestead)

☐ For $\xi_{\text{peak}} > 1 \times 10^{35}$ it is very unlikely that drift chambers will work
Like at LHC one needs to consider solid state devices (Multiple Scattering)
Light Yield Changes in EMC

Gain History

ΔGain / Gain

-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0

9/99
10/99
11/99
12/99
1/00
2/00
3/00
4/00
5/00
6/00
7/00
8/00
9/00
date

Backward Barrel
Forward Barrel
Endcap
Average Occupancy in EMC Crystals

Single Crystal occupancy

$$N_{EMC} (E > 1\text{MeV}) = 9.8 + 2.2 I_{HER} + 2.2 I_{LER} + 1.4 \ell$$

$$N_{EMC} (E > 10\text{MeV}) = 4.7 I_{HER} + 0.23 I_{HER}^2 + 2.4 I_{LER} + 0.33 I_{LER}^2 + 0.6 \ell$$

with beam currents in units of [A] and luminosity in units of [$10^{33} \text{ cm}^{-2} \text{ s}^{-1}$]
Composition of EMC Backgrounds

Composition of Calorimeter Background

- Semenov model
- Leptonic
- Non-muon events
- LE
- NLHE
- Noise

\[ \text{[10}^{22} \text{cm}^{-2} \text{s}^{-1}] \]
### Conclusion on Electromagnetic Calorimeters

<table>
<thead>
<tr>
<th>$\xi_{\text{peak}}$ [cm$^{-1}$ s$^{-1}$]</th>
<th>$6.5 \times 10^{33}$</th>
<th>$1.5 \times 10^{34}$</th>
<th>$5 \times 10^{34}$ *</th>
<th>$&gt;1 \times 10^{35}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>\xi_{\text{cut}}</td>
<td>$ [fb$^{-1}$]</td>
<td>55</td>
<td>400</td>
</tr>
<tr>
<td>$I_{\text{LER}}$ / $I_{\text{HER}}$ [A]</td>
<td>2.8/1.1</td>
<td>3.7/1.3</td>
<td>4.6/1.5</td>
<td>?</td>
</tr>
<tr>
<td>$N_{\text{EMC}}$ [%]</td>
<td>28</td>
<td>42</td>
<td>93</td>
<td>?</td>
</tr>
<tr>
<td>$N_{\text{cluster}}$ [μ]</td>
<td>21</td>
<td>32</td>
<td>56</td>
<td>?</td>
</tr>
</tbody>
</table>

*Extrapolation is uncertain due to IR configuration, beam

- For luminosities $< 1.5 \times 10^{34}$ integrated radiation dose for CsI(Tl) crystals is not expected to be a problem if observed light losses scale as expected.

- Impact of large number of low-energy photons on EMC energy resolution depends on clustering algorithm, digital filtering, etc. (needs further study) Expect luminosity contribution to be dominant (BABAR).

- Expect reduction of background rates through improvements of vacuum near IR combined with effective collimation against e+ from distant Coulomb scattering.

- For luminosities $>1 \times 10^{35}$ light loss due to radiation and occupancy levels for present CsI(Tl) crystals are not acceptable $\Rightarrow$ need R&D studies and look into other scintillator (pure CsI?)
Composition of Trigger Backgrounds

Composition of Trigger Background

Seeman model

- Luminosity
- LER
- HER
- cosmics

Expected L1 trigger rate: \( L1 [\text{Hz}] = 130 \text{ (cosmics)} + 130 I_{\text{LER}} + 360 I_{\text{HER}} + 70 \text{ } \)
L1 Trigger Rate vs Current in Machine

MD-From-June-25

MD-From-July-6
## Conclusion on Trigger Rates

<table>
<thead>
<tr>
<th>$\mathcal{L}_{\text{peak}}$ [cm$^{-1}$ s$^{-1}$]</th>
<th>6.5x$10^{33}$</th>
<th>1.5x$10^{34}$</th>
<th>5x$10^{34}$</th>
<th>$&gt;$1x$10^{35}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\int \mathcal{L} dt$ [fb$^{-1}$]</td>
<td>55</td>
<td>400</td>
<td>2000</td>
<td>?</td>
</tr>
<tr>
<td>$I_{\text{LER}}/I_{\text{HER}}$ [A]</td>
<td>2.8/1.1</td>
<td>3.7/1.3</td>
<td>4.6/1.5</td>
<td></td>
</tr>
<tr>
<td>$L_1$ [Hz]</td>
<td>1350</td>
<td>2130</td>
<td>4800</td>
<td>$&gt;$8300</td>
</tr>
</tbody>
</table>

*Extrapolation is uncertain due to IR configuration*

- For $\mathcal{L}_{\text{peak}} \sim 1.5 \times 10^{34}$ in BABAR trigger needs to be upgraded to cope with high rates.

- For higher luminosities one could do more stringent prescaling of Bhabhas, radiative Bhabhas, beam gas.
  One needs to design appropriate tracking device used in trigger.

- LHC experiments can accept L1 trigger rates of 100 kHz (ATLAS) bunch crossing is 40 MHz.
Conclusions

- **Vertex detectors:**
  - Based on studies at LHC silicon vertex detectors probably will work at high luminosities of $L_{\text{peak}} \approx 1-10 \times 10^{35}$ \((\Rightarrow \text{do R & D studies})\)

- **Drift Chambers:**
  - For $L_{\text{peak}} > 1 \times 10^{35}$ it is very unlikely that drift chambers will work
  - Like at LHC one needs to consider solid state devices \((\Rightarrow \text{Multiple Scattering?})\)

- **Particle ID:**
  - With appropriate design of accepted counting rates, beam collimation & shielding DIRC type detectors probably work at $L_{\text{peak}} \approx 1-10 \times 10^{35}$

- **Electromagnetic Calorimeter:**
  - For $L_{\text{peak}} > 1 \times 10^{35}$ light loss due to radiation and occupancy levels for present CsI(Tl) crystals are not suitable \((\Rightarrow \text{need R&D studies})\)
  - Explore other scintillators (pure CsI?, ...)

- **Trigger:**
  - Based on LHC studies it should be possible to design trigger system for $L_{\text{peak}} > 1 \times 10^{35}$

- **Muon System:**
  - Should be not a problem