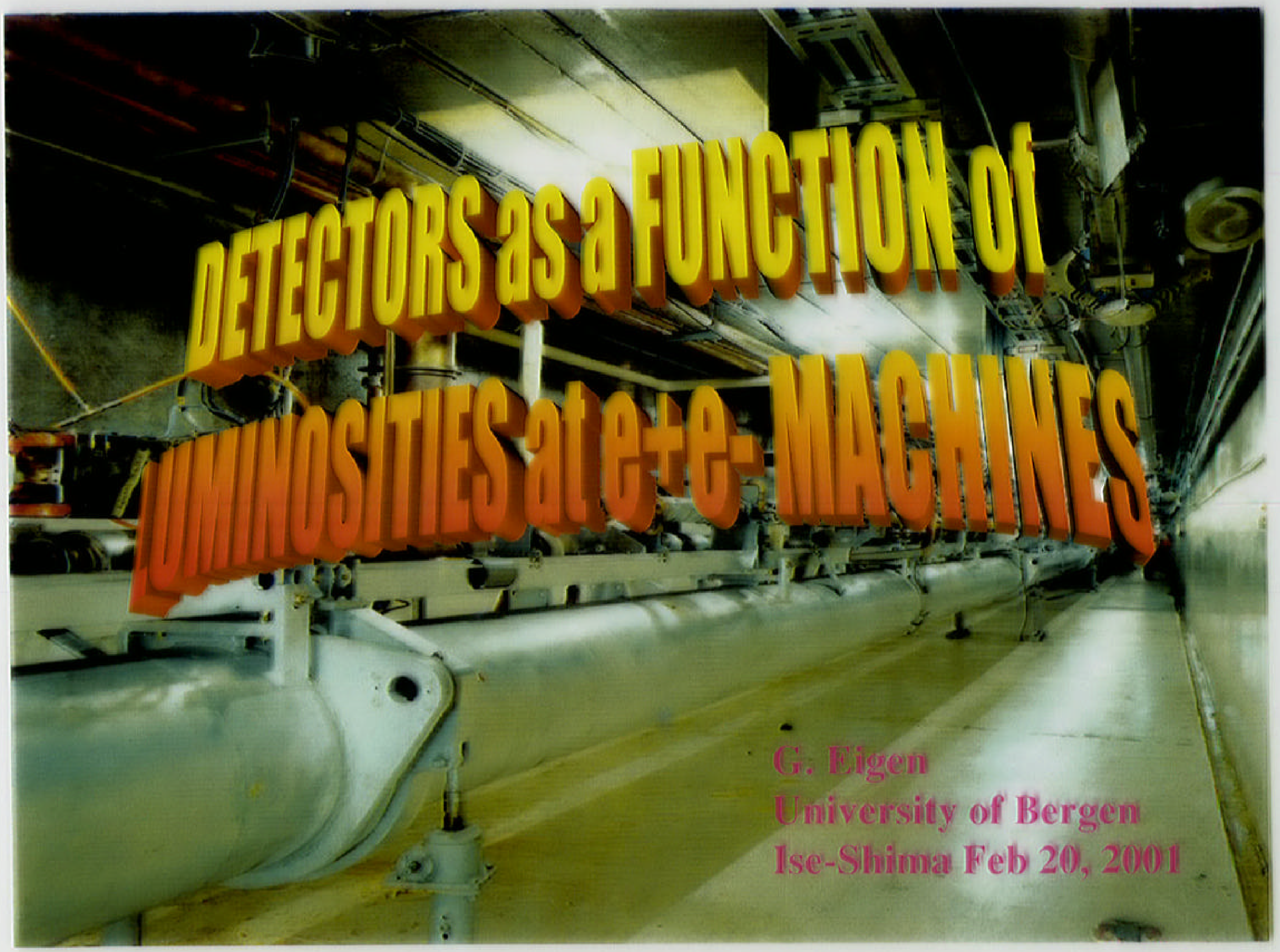

DETECTORS as a FUNCTION of
LUMINOSITIES at e+e- MACHINES
G. Eigen
University of Bergen
Ise-Shima Feb 20, 2001

OUTLINE

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

Introduction

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

- Results are my personal views based on BABAR studies
  (Report of the High-Luminosity Background Task force,
  C. Hast, W. Kozanecki (chair), A. Kulikov, T.I. Meyer, S. Petrak,
  T. Schietinger, S. Robertson,M. Sullivan, J. Va'vra, BaBar Note 522)

- 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 $\pounds_{peak} > 1\times10^{35}$

- 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

Date	$£_{peak}$ [cm^{-1} s^{-1}]	$£_{peak}$ [cm^{-1} s^{-1}]
June 2002	4×10^{33}	6.5×10^{33}
August 2005	$0.6\text{-}1.7\times10^{34}$	1.5×10^{34}
August 2008	$1.7\text{-}7.0\times10^{34}$	5.0×10^{34}
some date after 2009?	$1.0\text{-}4.0\times10^{36}$	$>1.0\times10^{35}$

- The peak luminosities shown in blue were given by Ian Shipsey as guideline
- The peak luminosities shown in green are those I considered

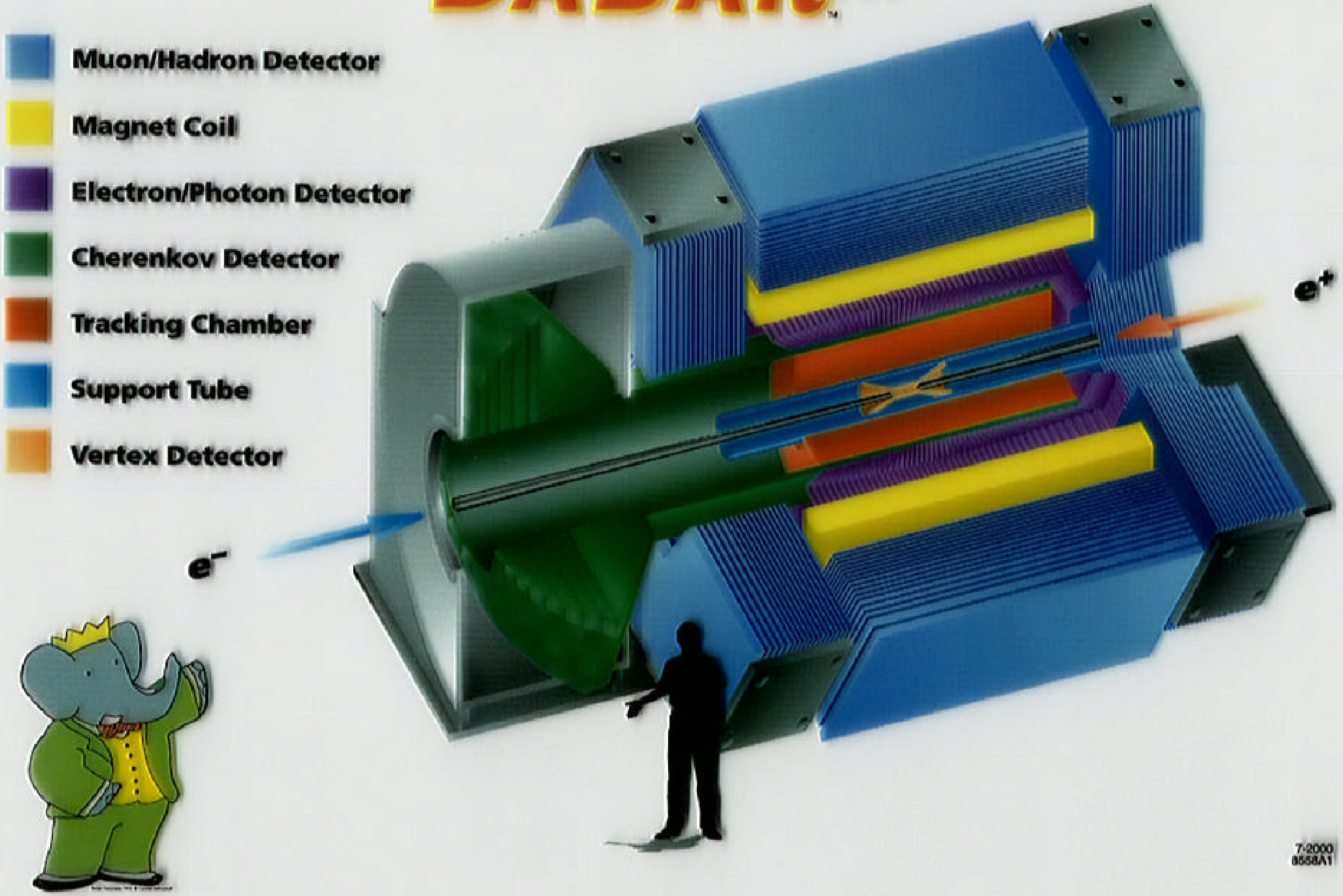
Sources of Machine Backgrounds

- 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:

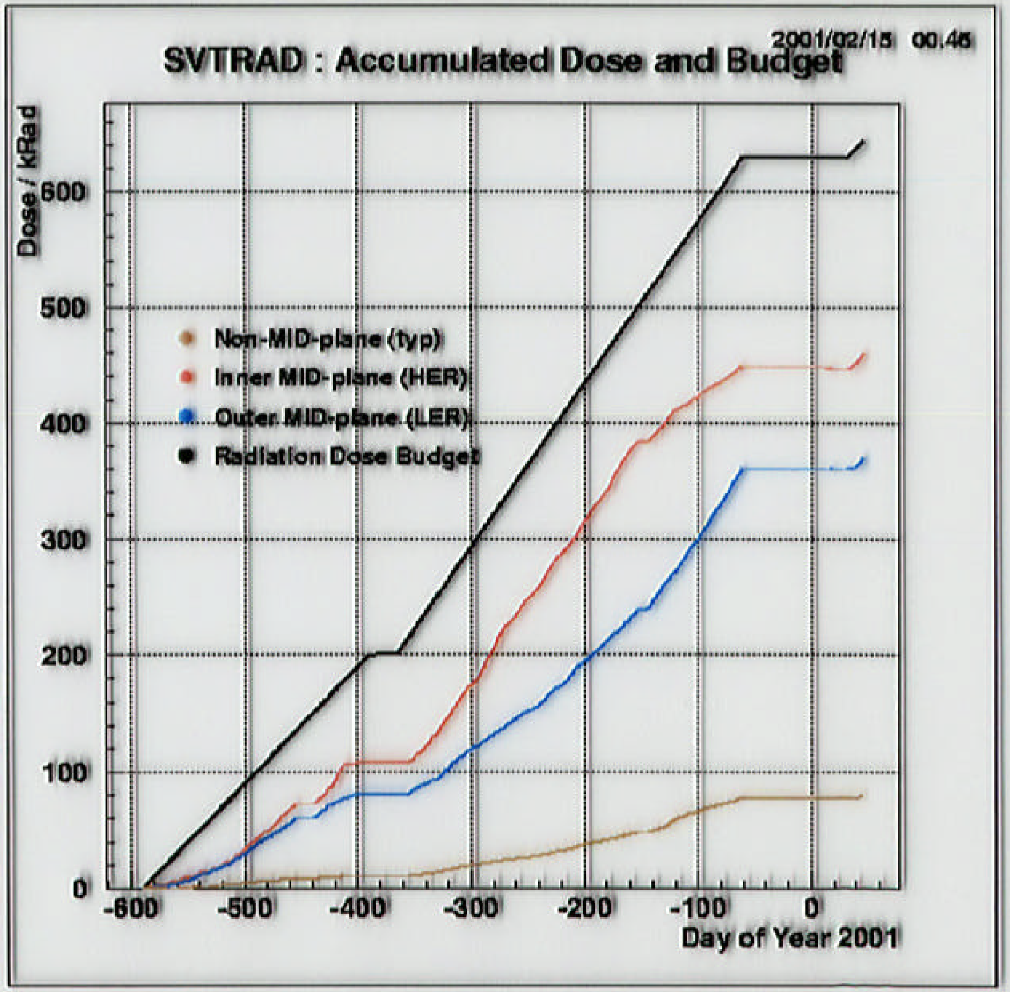
    no collision $\Rightarrow$ single beam backgrounds above plus beam-gas cross term
    in collision $\Rightarrow$ backgrounds from luminosity, beam-beam tails & above 3

Multipurpose Detector for e+e-Collisions at 10GeV

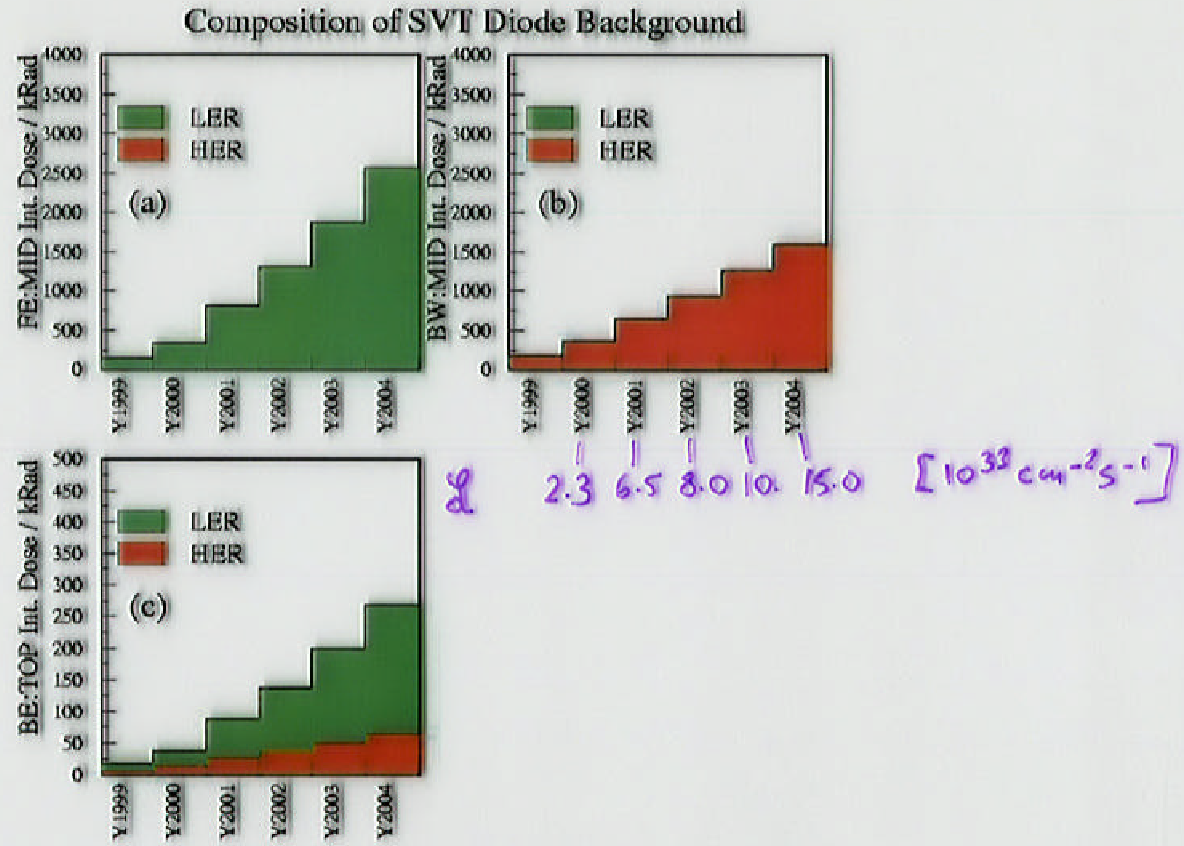
BABAR



Silicon Vertex Detectors



Silicon Vertex Detectors



- ❒ **SVT dose rate: FE MID [kRad/y] =128 I_{LER} + 16 I^2_{LER}**
  BW MID [kRad/y] =246 I_{HER} + 9.1 I^2_{HER}

Conclusion Silicon Vertex Detectors

$\mathcal{L}_{peak}$ [cm^{-1} s^{-1}]:	6.5×10^{33}	1.5×10^{34}	5×10^{34}	$>1\times10^{35}$
$\int\mathcal{L}dt$ [fb^{-1}]:	55	400	2000	?
I_{LER}/I_{HER} [A]:	2.8/1.1	3.7/1.3	4.6/1.5	?
D_{SVT} [kRad/y]:	480/280	690/ 340	1300/930	?

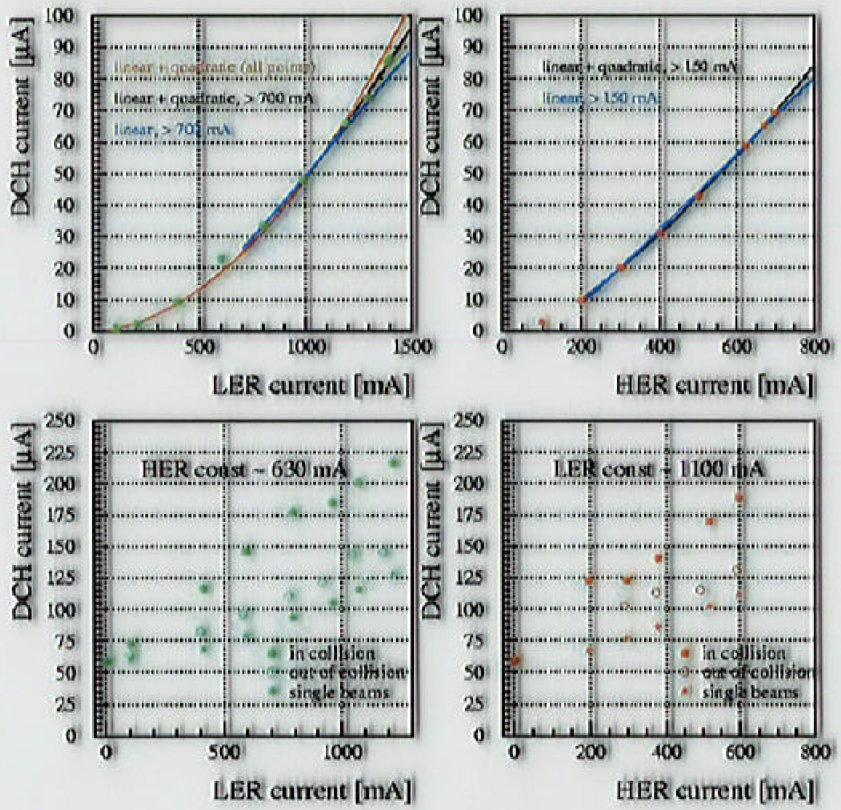
- Radiation levels depend very strongly on layout of IR, They are lower at KEKB than at PEP II
- In BABAR silicon detectors are expected to survive a total dose of 2MRad The FE:MID and BW:MID receive highest doses $\Rightarrow$ With replacements of detectors in the MID plane BABAR SVT is expected to survive luminosities of $1.5\text{-}3\times10^{34}$
- R&D at LHC has demonstrated that silicon detectors can survive high hadronic radiation levels, question is the electronics
- So for $\mathcal{L}_{peak}$ ~ $1\text{-}10\times10^{35}$ silicon detectors probably work

Drift Chambers

- 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,
    $\Rightarrow$ above limit chamber becomes non operational!
    $\Rightarrow$ high currents also contribute to aging of chamber!
    $\Rightarrow$ 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



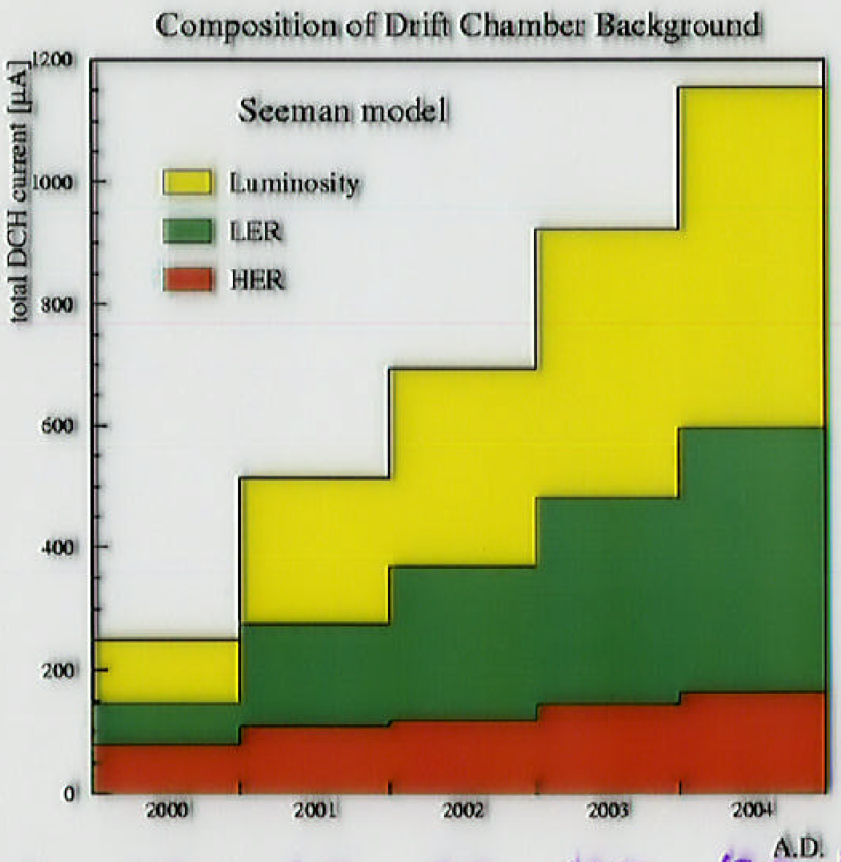
- For HV=1960V scale current by factor 1.67

- $I_{DCH}\,[\mu A] = 35.3\, I_{LER} + 23.5\, I^2_{LER} + 77.2\, I_{HER} + 46.3\, I^2_{HER} + 41.9\, \mathcal{L}\ -14$ with currents in [A] and luminosity in units of [$10^{33}\, cm^{-1}\, s^{-1}$]

Drift Chamber Backgrounds

- Seeman model for HV=1900V

- At HV=1960 background levels are expecetd to be 65% higher



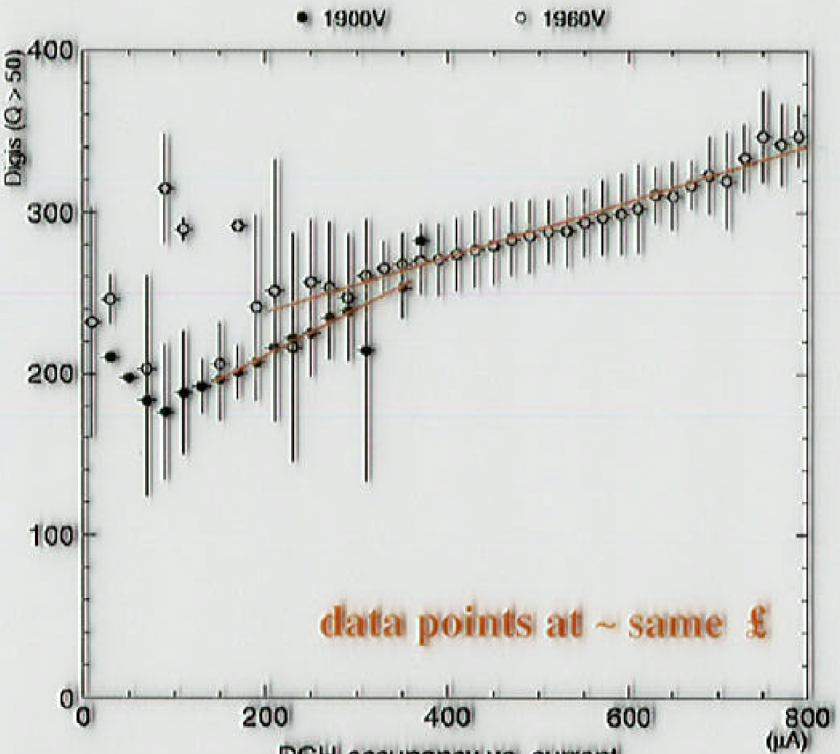
$\mathcal{L}$ 2.3 6.5 8.0 10.0 15.0 $[10^{33}\, cm^{-2} s^{-1}]$

Drift Chamber Occupancy

- **At HV=1900V (Jan-July):**
  $N_{DCH} = 158 + 0.27\ I_{DCH}$ (<350μA)

- **At HV=1960 V(July-now):**
  $N_{DCH} = 203 + 0.18\ I_{DCH}$ (>200μA)

- **Large spread**
  ⇒ extrapolation difficult



DCH occupancy vs. current

- $N_{DCH} = 0.044 + 0.191\ I_{LER} + 0.0402\ I^2_{LER} + 1.03\ I_{HER} + 0.113\ I^2_{HER} + 0.147\ £$
  with occupancy in [%], currents in [A], luminosity in units of [10^{33} cm^{-1} s^{-1}] at 1900V

Conclusion on Drift Chambers

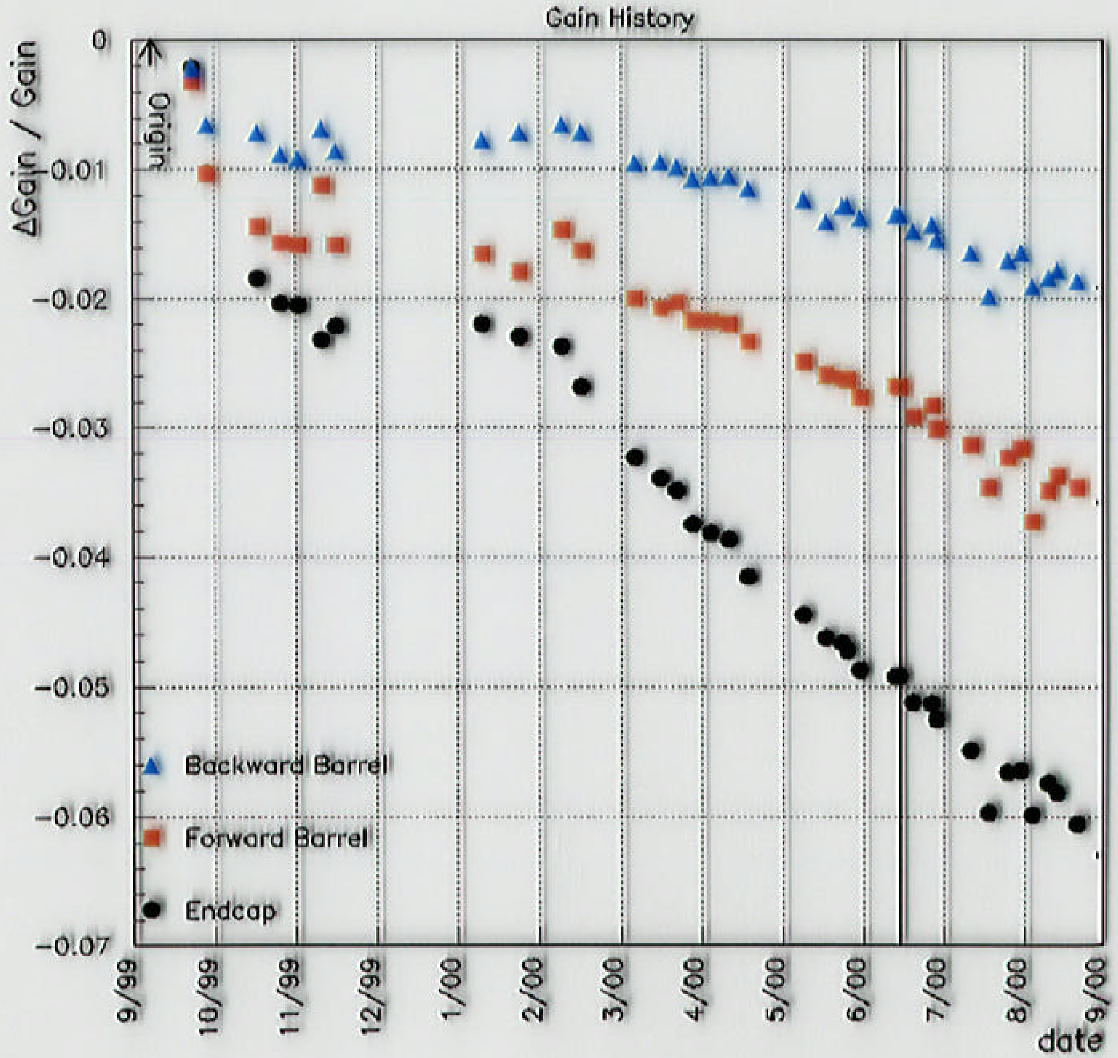
$\pounds_{peak}$ [cm^{-1} s^{-1}]:	6.5×10^{33}	1.5×10^{34}	5×10^{34} *	$>1\times10^{35}$
$\int\pounds dt$ [fb^{-1}]:	55	400	2000	?
I_{LER}/ I_{HER} [A]:	2.8 /1.1	3.7/1.3	4.6/1.5	
I_{DCH} [μA]:	680	1250	3000	?
N_{DCH} [%] :	3.1	5	10	?
Q_{wire} [mCb]:	~15	50	>100	?
Dose [Rad]	275	2000	10000	?

* Extrapolation is uncertain due to IR configuration and > 2 orders of magnitude scaling

- Extrapolations to $\pounds_{peak} > 1\times10^{35}$ make no sense
  expect additional backgrounds due to luminosity lifetime
  (see M. Sullivan's talk at Homestead)

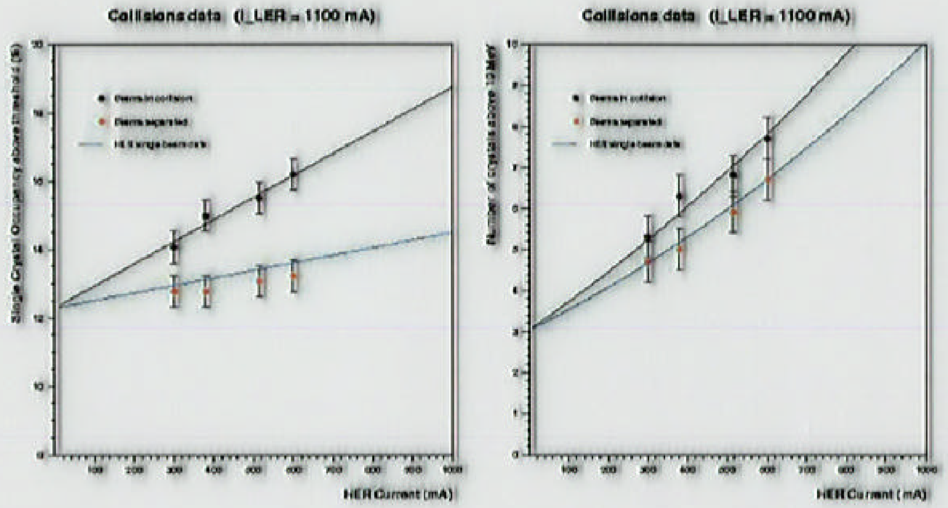
- For $\pounds_{peak} > 1\times10^{35}$ it is very unlikely that drift chambers will work
  Like at LHC one needs to consider solid state devices ? (Multiple Scattering)

Light Yield Changes in EMC



Average Occupancy in EMC Crystals

Single Crystal occupancy

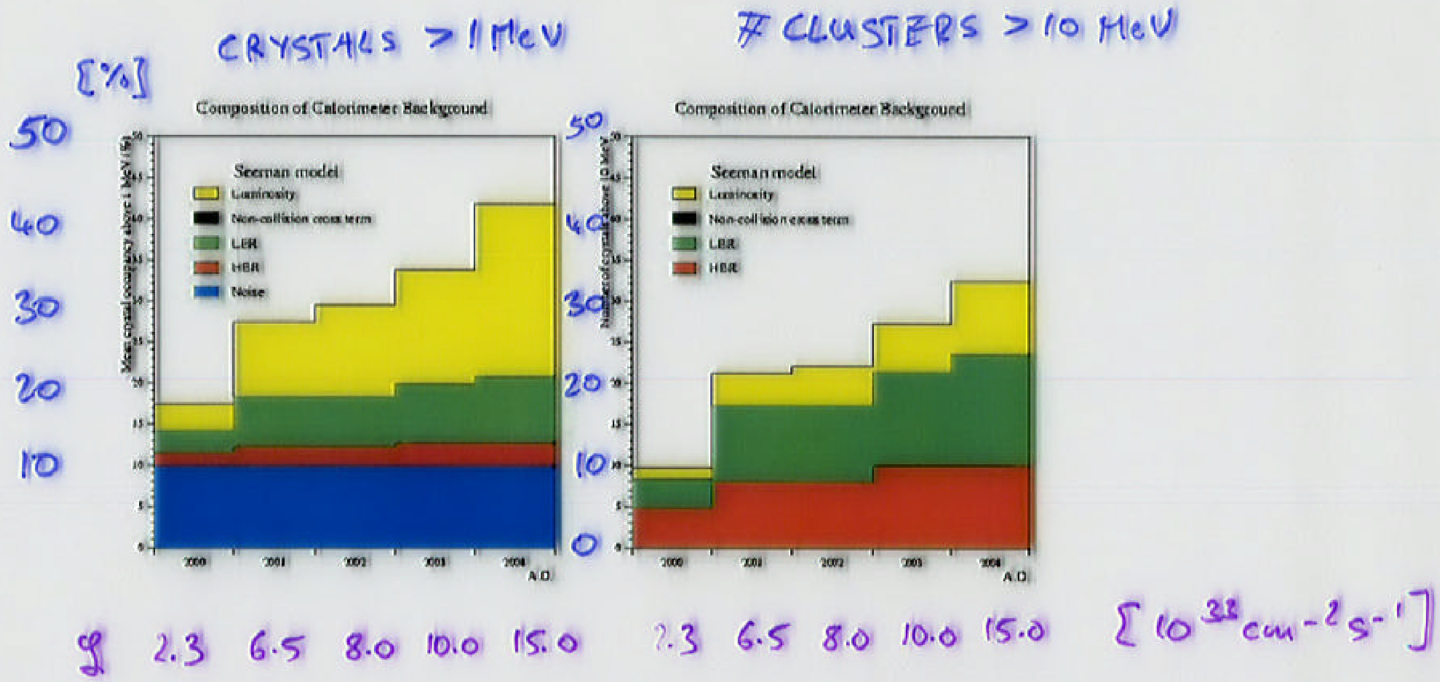


 # Crystals with > 10 MeV

- N_{EMC} (E> 1MeV)= $9.8 + 2.2\, I_{HER} + 2.2\, I_{LER} + 1.4\, \mathcal{L}$
  N_{EMC} (E> 10MeV)= $4.7\, I_{HER} + 0.23\, I^2_{HER} + 2.4\, I_{LER} + 0.33\, I^2_{LER} + 0.6\, \mathcal{L}$

with beam currents in units of [A] and luminosity in units of [10^{33} cm^{-1} s^{-1}]

Composition of EMC Backgrounds



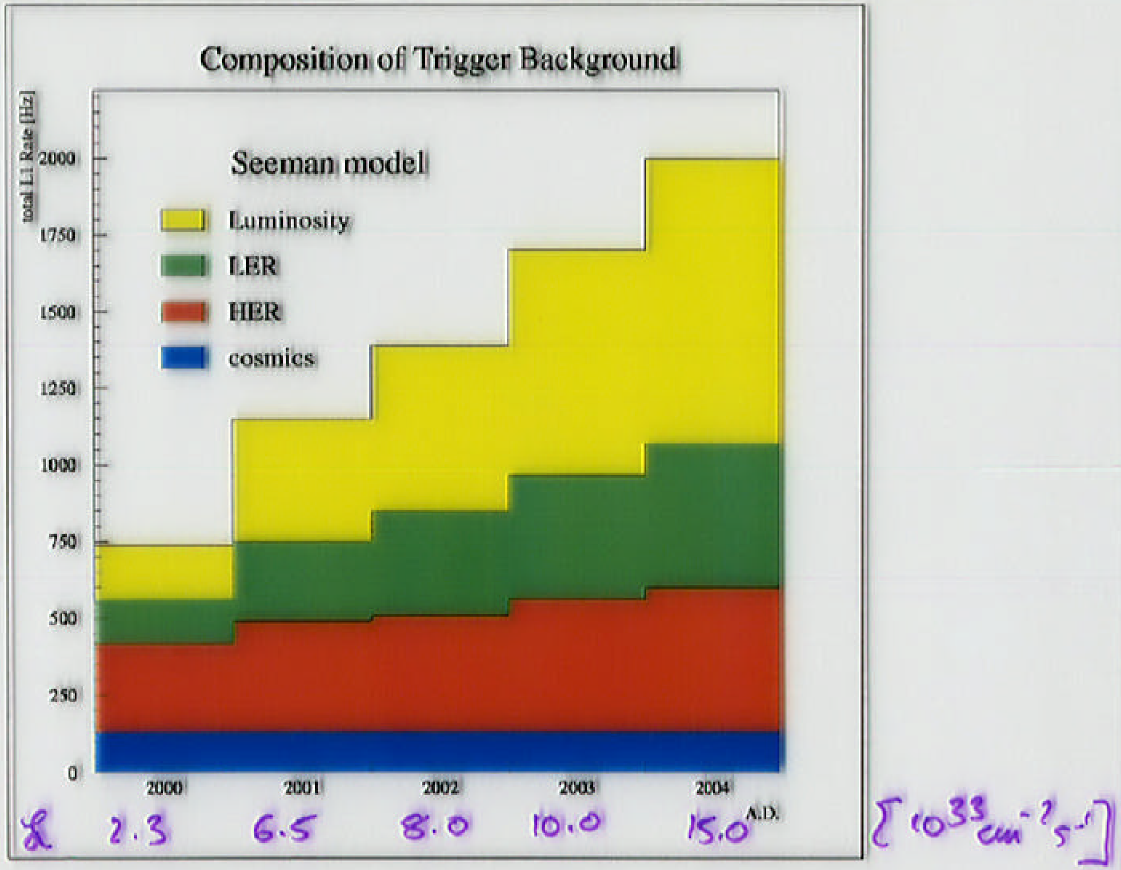
Conclusion on Electromagnetic Calorimeters

£$_{peak}$ [cm^{-1} s^{-1}]:	6.5×10^{33}	1.5×10^{34}	5×10^{34} *	$>1\times10^{35}$
$\int$£dt [fb^{-1}]:	55	400	2000	?
I_{LER} I_{HER} [A]:	2.8/1.1	3.7/1.3	4.6/1.5	
N_{EMC} [%]	28	42	93	?
$N_{cluster}$ [[redacted]]	21	32	56	?

*Extrapolation is uncertain due to IR configuration, beam

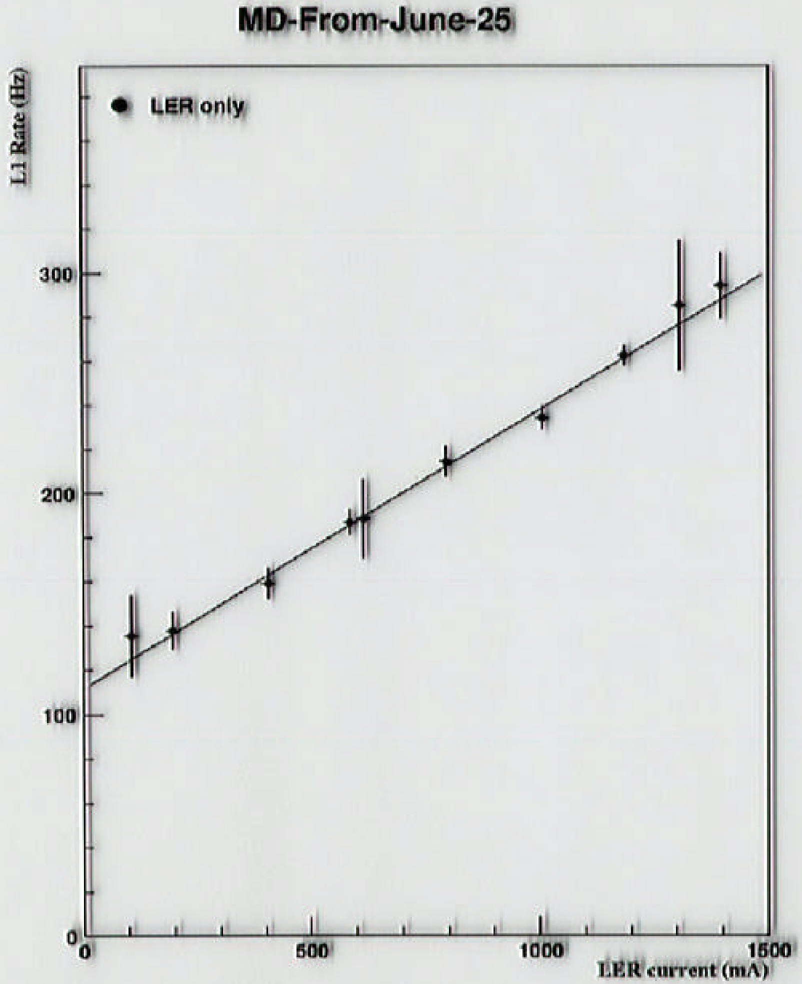
- For luminosities < 1.5×10^{34} integrated radiation dose for CsI(Tl) crystals is not expected to be a problem if observed light losses scale as expected
- Impact of large number of low-energy photons on EMC energy resolution depends on clustering algorithm, digital filtering, etc (needs further study) 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 $>1\times10^{35}$ 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?)

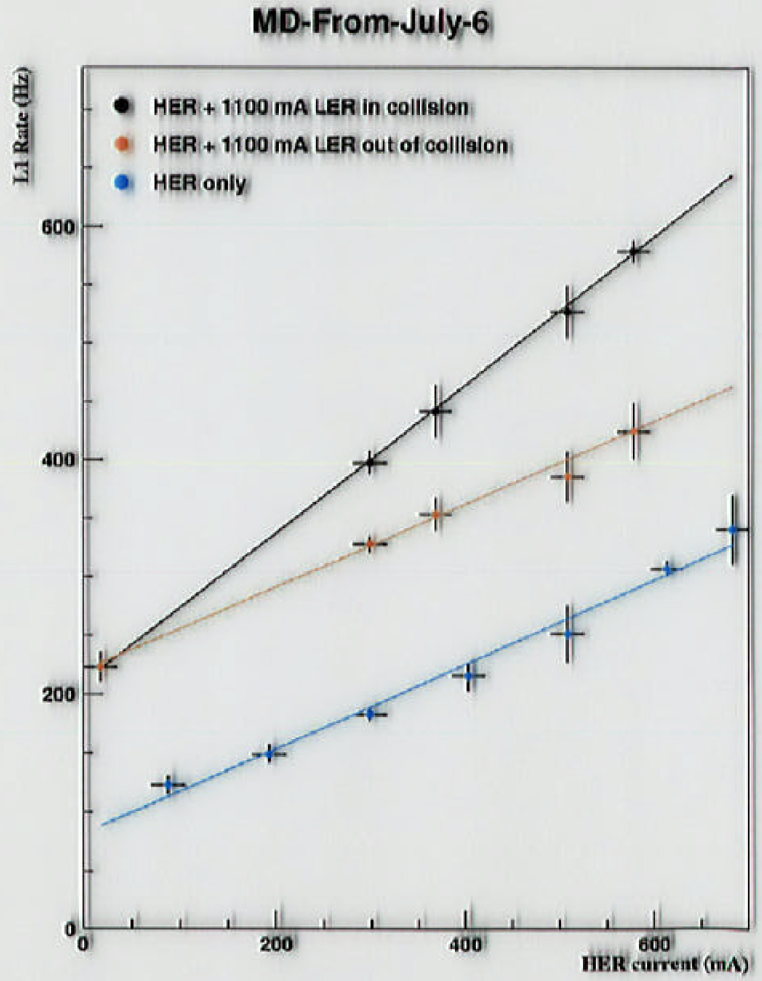
Composition of Trigger Backgrounds



❒ **Expected L1 trigger rate: L1 [Hz]=130 (cosmics)+ 130 I_{LER} + 360 I_{HER} + 70 £**

L1 Trigger Rate vs Current in Machine





Conclusion on Trigger Rates

$\mathcal{L}_{peak}$ [cm^{-1} s^{-1}]:	6.5×10^{33}	1.5×10^{34}	5×10^{34} *	$>1\times10^{35}$
$\int \mathcal{L}dt$ [fb^{-1}]:	55	400	2000	?
I_{LER}/I_{HER} [A]:	2.8/1.1	3.7/1.3	4.6/1.5	
L1 [Hz] :	1350	2130	4800	>8300

*Extrapolation is uncertain due to IR configuration

- For $\mathcal{L}_{peak}$ ~1.5×10^{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 luminosties of $£_{peak} \sim 1\text{-}10\times10^{35}$ (⇒ do R & D studies)

- **Drift Chambers:**
  - For $£_{peak} > 1\times10^{35}$ it is very unlikely that drift chambers will work
    Like at LHC one needs to consider solid state devices ? (Multiple Scattering ?)

- **Particle ID:**
  - With appropriate design of accepted counting rates, beam collimation & shielding DIRC type detectors probably work at $£_{peak} \sim 1\text{-}10\times10^{35}$

- **Electromagnetic Calorimeter:**
  - For $£_{peak} > 1\times10^{35}$ light loss due to radiation and occupancy levels for present CsI(Tl) crystals are not suitable (⇒ need R&D studies)
    explore other scintillators (pure CsI?, …)

- **Trigger:**
  - Based on LHC studies it should be possible to design trigger system for $£_{peak} > 1\times10^{35}$

- Muon System:
  - should be not a problem