Normalized Background Tolerance Levels in ILC Tracking Detectors

- Introduction: motivation & methodology
- Detector tolerance levels
  - naive detector model
  - pain-threshold estimates
    - 1% "generic"
    - detector-specific (where available)
- Comparison with predicted pair-induced background levels
- Conclusions

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Introduction

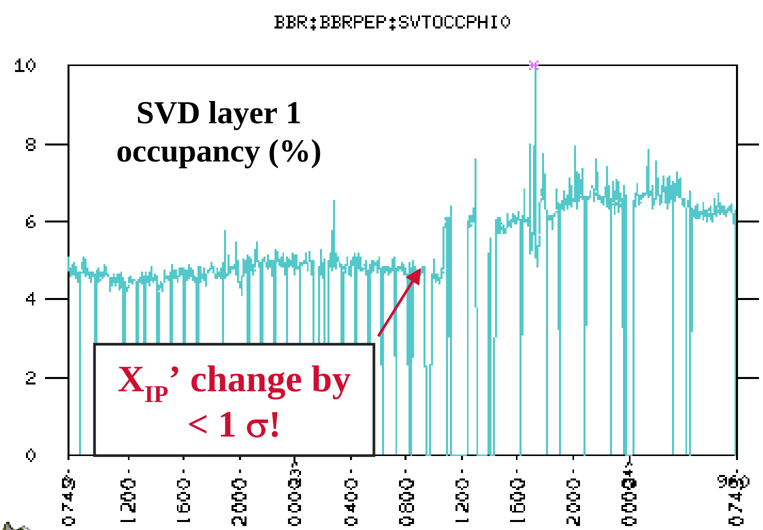
- **Motivation**
  - **assess detector sensitivity to IR design changes (e.g. DID) on a scale 'normalized' to relevance**
    - **10 x a "very small" number may just be a "small" number, rather than a problem**
  - **compare the sensitivity of various detector concepts (or subdetector technologies) to background levels in a given IR configuration**
- **Methodology**
  - **define tolerance level, either**
    - **in a generic fashion: 1% occupancy - allowing for a factor of ~ 10 contingency for surprises & unknown effects**
    - **using estimates supplied by the Detector Concept Groups**
  - **compare background levels predicted by simulation, to tolerance levels ('pain thresholds') in various subdetectors, in a consistent fashion**
  - **so far limited to**
    - **tracking detectors**
    - **pair-induced backgrounds from ideal beams (no fluctuations)**

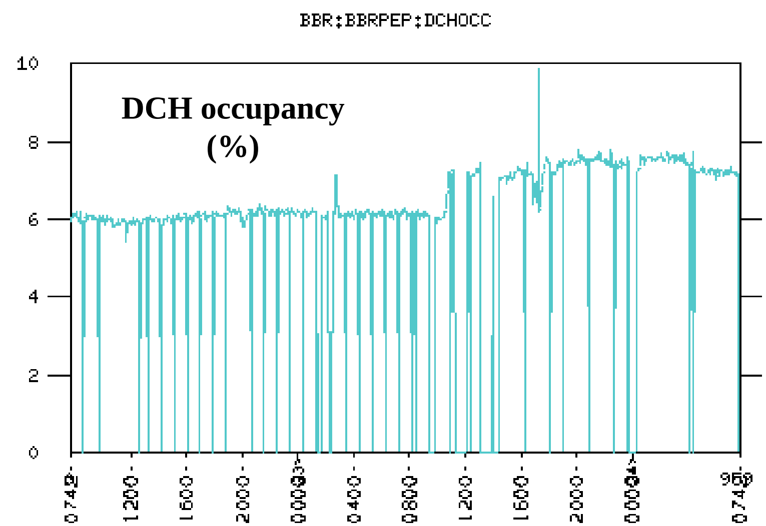
Acknowledgements

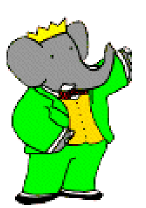
- Much of what follows draws heavily on
  - the hard work of the people who produced the plots shown today
  - Karsten's &Takashi's presentations last week: thanks!

A naive detector-tolerance model

Subdetector	Tolerance criterion
Vertex detector and/or Silicon Tracker	Rad. damage (worst-case: CCD's) : < 3-10 x 10^9 n cm^{-2} Occupancy (pattern recognition): < 1% (2-d hit density) Occupancy (pile-up): 1 hit / channel ("buffered")
Time Projection Chamber	Occupancy (pattern recognition): < 1% (3-d density) ? *Experts disagree on impact on reconstruction + space charge*







Detector-response model (*)

(*) *As per R. Settles et. al., TESLA St Malo workshop. Checked with R. Settles & P. Colas @ Snowmass '05.*

Subdetector	Granularity	Sensitivity window	Fract'l sensitivity
Vertex detector (Layer 1)	20 μ x 20 μ pixels = 2500 pixels/mm^2	50 μs (~ 150 bunches)	Chgd trks: ε = 1.0 (4 pixels) γ: ε = 0.02 (4 pixels)
TPC	1.5 10^6 pads x 10^3 time buckets = 1.5 10^9 voxels		Chgd trks: ε = 1.0 (3 p x 200 r x [5-10] tb) γ: ε = 0.02 (3 p x 200 tb) n: ε = 0.01 (3 p x 200 tb) μ: ε = 1.0 (6 p x 1000 tb)

→ "1% generic"

Background tolerance levels (*)

(*) As per R. Settles et. al., TESLA St Malo workshop
Detector-specific data from T. Maruyama + detector response to MDI questions, Aug 05.

Limits are expressed in # particles either per sensitivity window [SW] (typically 50 μs ≈ 150 bunches in VXD/TPC), per bunch train [tr], or per bunch crossing [BX]

Subdetector	Charged hits	γ	n (~ 1 MeV)	Model
Vtx detector (L1)	6 mm^{-2} / SW 100 mm^{-2} tr^{-1}	300 mm^{-2} /SW	3 x 10^7 mm^{-2} 10^8 mm^{-2} (/y?)	1 % generic GLD
Si tracker	Pile-up: 0.2 / 1.0 mm^{-2} tr^{-1}	*Pile-up:* *10/50 mm^{-2} tr^{-1}*		SiD: analog/digital
TPC (/SW)	1.5 x 10^7 voxels 2.5 - 5 10^3 tracks	1.25 x 10^6 γ	2.5 x 10^7 n	1 % generic

Notes

1. **No generic answers – depend strongly on subdetector technology**
2. **Need to clarify impact of TPC occupancy on track reco efficiency & space charge**
3. **Only rough estimates so far. Real answer needs detailed simulations, pattern recognition studies, space charge, understanding of background distribution....**
4. **1% may sound overconservative...but we need ~ x 10 safety factor!**

Assumed Vertex-Detector Geometries

Concept	GLD	LDC	SiD
Radius (cm)	**r1= 2.0**	**r1= 1.55**	**r1 = 1.40**
Full length (cm)		**L_z = 10.0**	**L_z = 12.5**
Area (cm^2)	*Use GLD-provided normalization*	**S = 97.4**	**S = 110**

e^+ - e^- Pairs

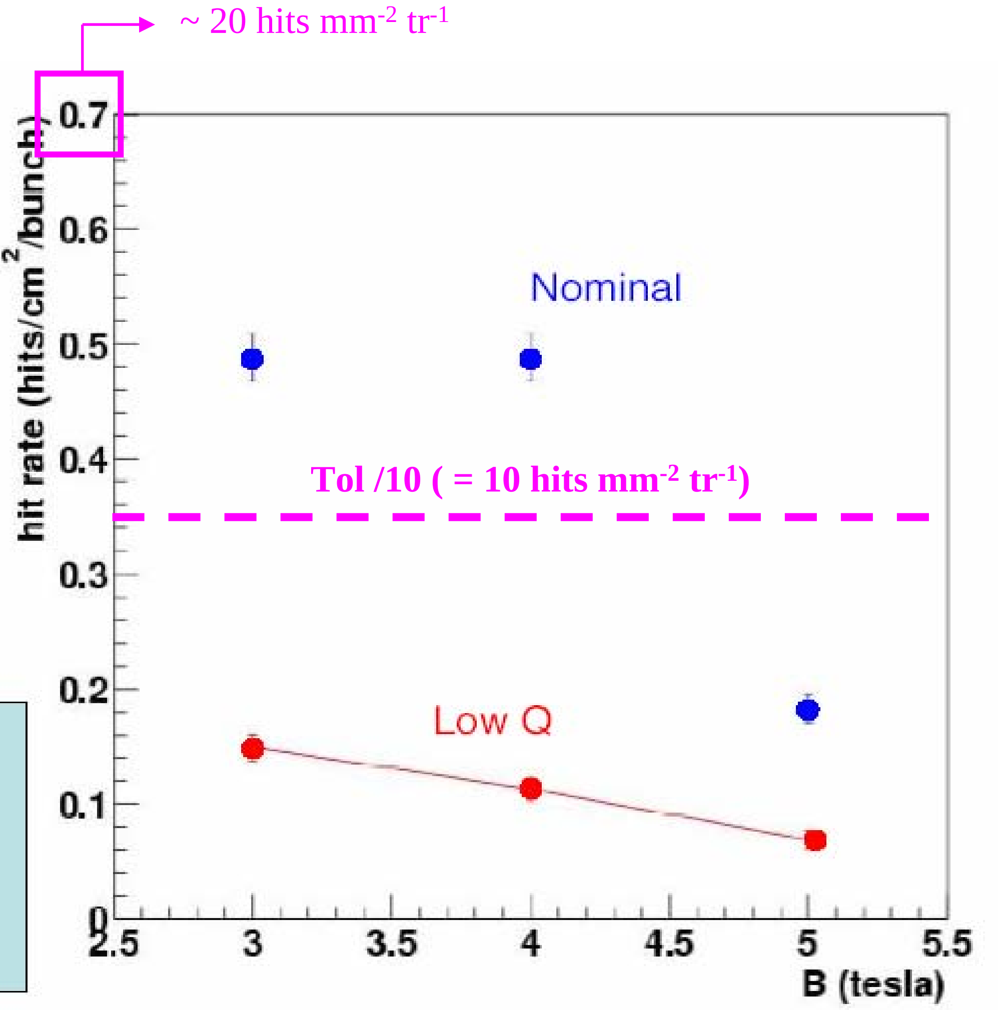
- Dominant background
- Very dependent on
  - Beam parameters
  - Solenoid field strength
  - Solenoid compensation (for 20 mrad)
  - VXD layer radius
  - Forward geometry

	Beam	# e^+/e^-/BX	Total energy
500 GeV	Nominal (N)	98 K	197 TeV
	Low Q (Q)	38	86
	High Y (Y)	104	191
	Low P (P)	232	709
	High Lum (H)	268	944
1 TeV	Nominal	174	1042
	Low Q	73	486
	High Y	229	1356
	Low P	458	4596
	High Lum	620	7367

VXD hits (GLD)

- Pair background hit rate on the 1st layer of the Vertex Detector (R=24mm)
- Simulation using CAIN and JUPITER
- Hit rate of the Low Q option is ~1/3 of the nominal option, as expected

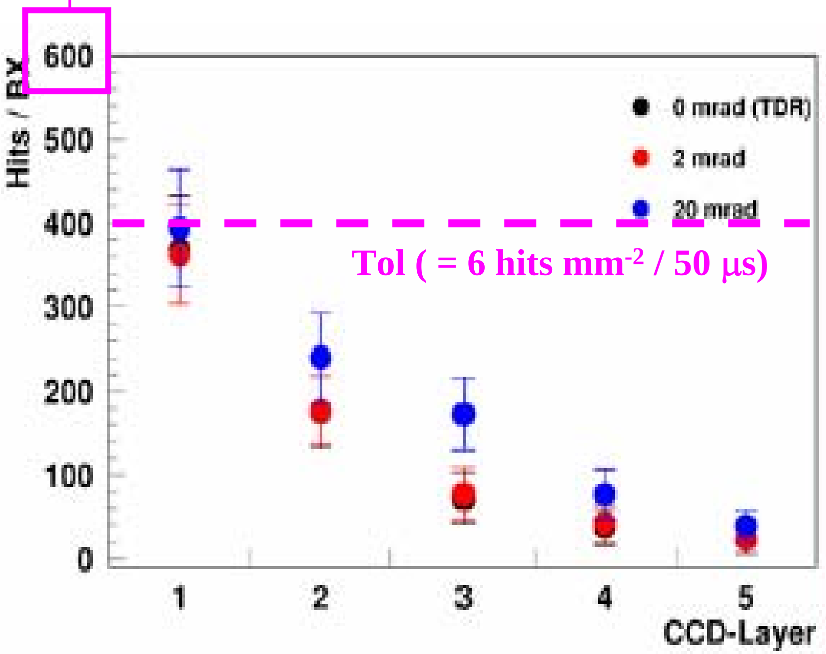
Pair B.G. hit rate (/cm^2/bunch)		
B(tesla)	Nominal	LowQ
3	0.488	0.149
4	0.48	0.113
5	0.183	0.069



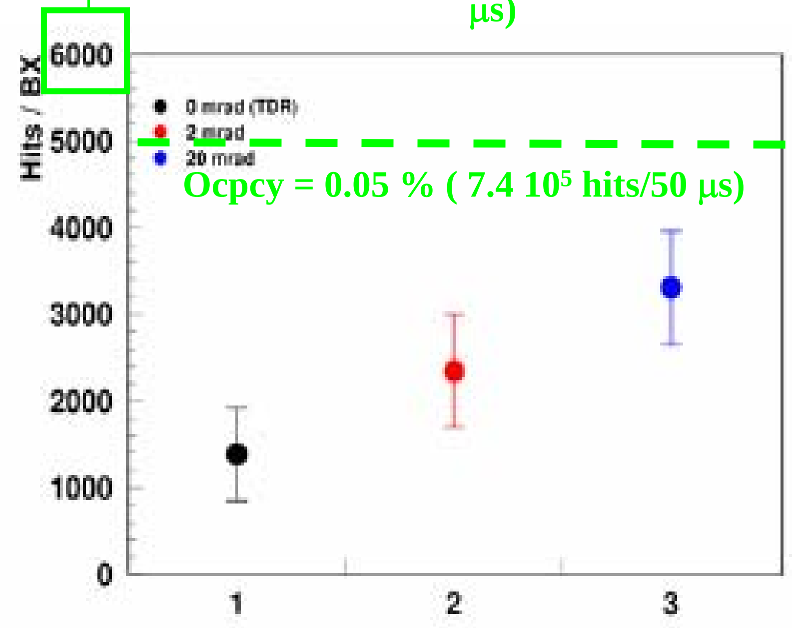
Crossing-angle dependence (LDC)

TESLA Beam parameters
VXD tolerance: 1% generic
TPC tolerance: tbd

~ 173 hits mm^{-2} tr^{-1} (<u>but</u>: hot spots!?)



~ 8.9 10^5 hits (≈ 4.5 10^7 γ) / SW (50 μs)



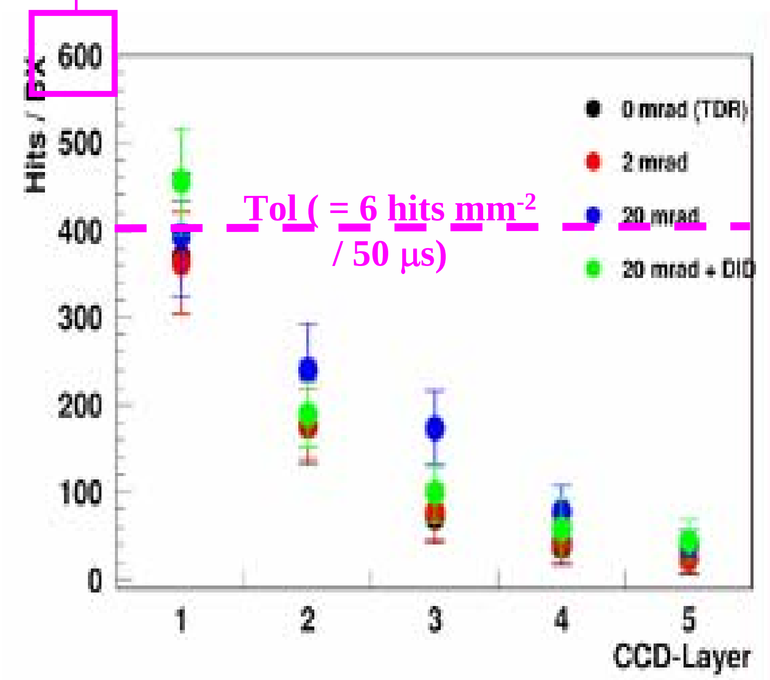
- **VXD hits**
  - **No difference between 0 mrad and 2 mrad**
  - **x 1.5-2 higher background in 20 mrad**

- **TPC hits: <u>converted</u> γ only (no *n*'s) from elm effects (pairs)**
  - **Twice as much in 2 mrad than in 0 mrad**
  - **Twice as much in 20 mrad than in 2 mrad**
  - ***neutrons*: under study (gas, ECAL…)**

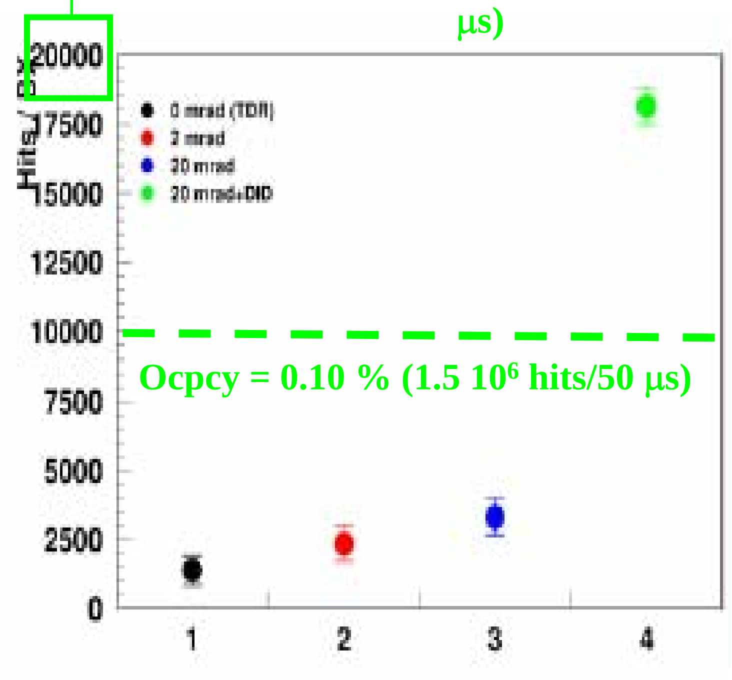
DID effect on VXD & TPC hits (LDC)

TESLA Beam parameters
VXD tolerance: 1% generic
TPC tolerance: tbd

~ 173 hits mm^{-2} tr^{-1} (but: hot spots!?)



~ 3.0 10^6 hits (≈ 1.5 10^8 γ) / SW (50 μs)

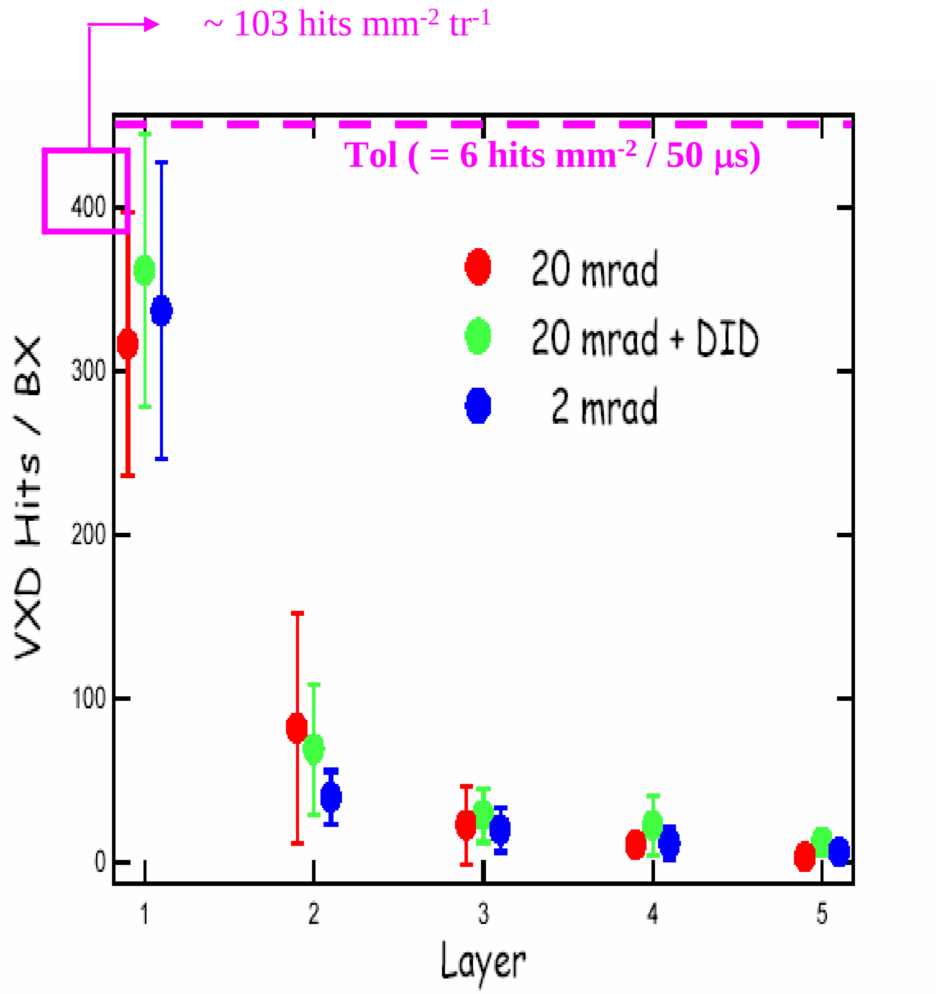


- **VXD hits**
  - **DID field reduces VXD hits to 2 mrad level in all but layer 1**

- **TPC hits: converted γ only (no *n*'s) from elm effects (pairs)**
  - **Significantly more TPC hits - but still a factor of 5 below the 1% occupancy tolerance**

Crossing-angle dependence (SiD)

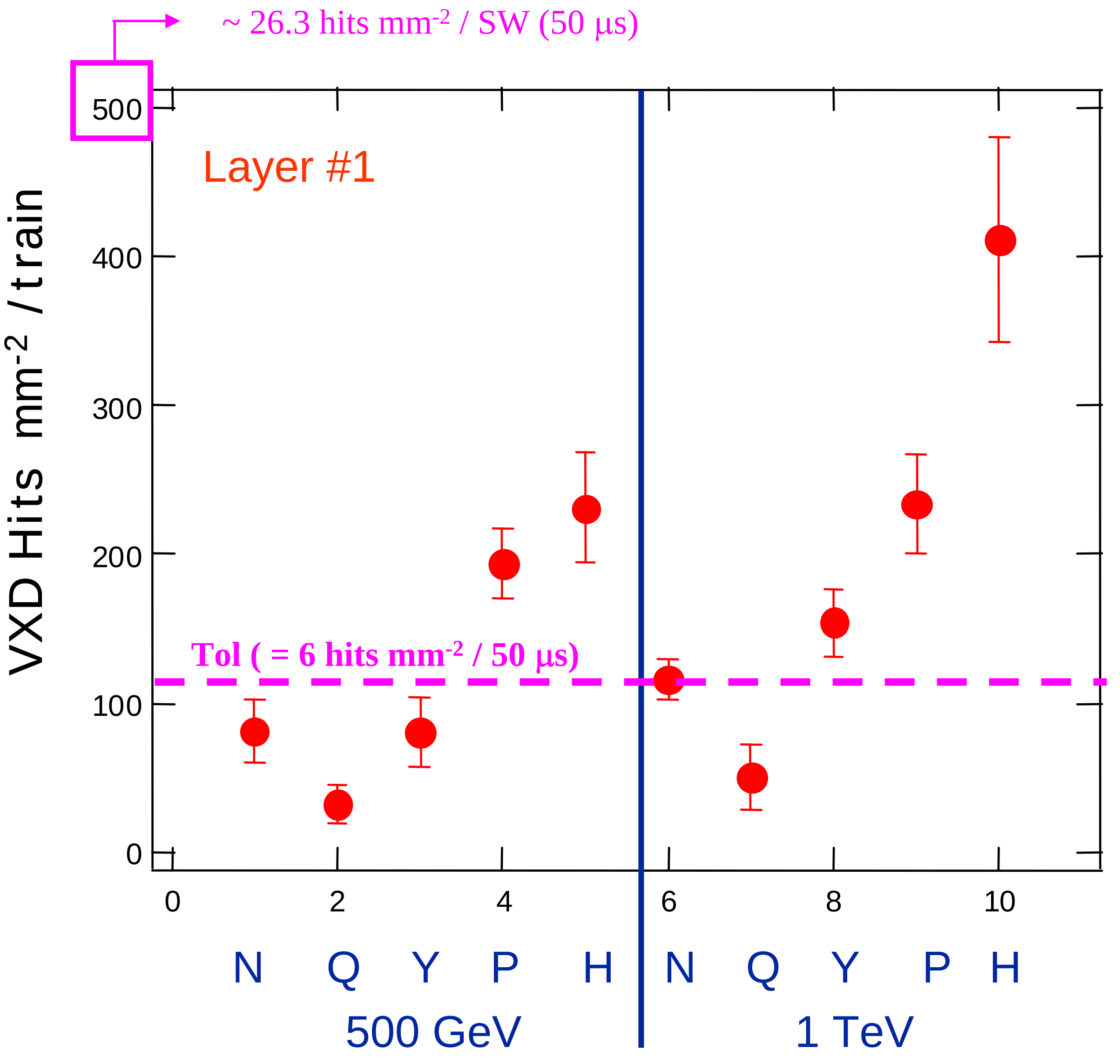
ILC 500 nominal parameters
VXD tolerance: 1% generic



- **Average and RMS from 20 BXs.**
- **20 mrad and 20 mrad + DID will have more VXD hits than 2 mrad.**
- **But bunch-to-bunch fluctuation is larger than the crossing angle difference.**

VXD hit density (SiD)

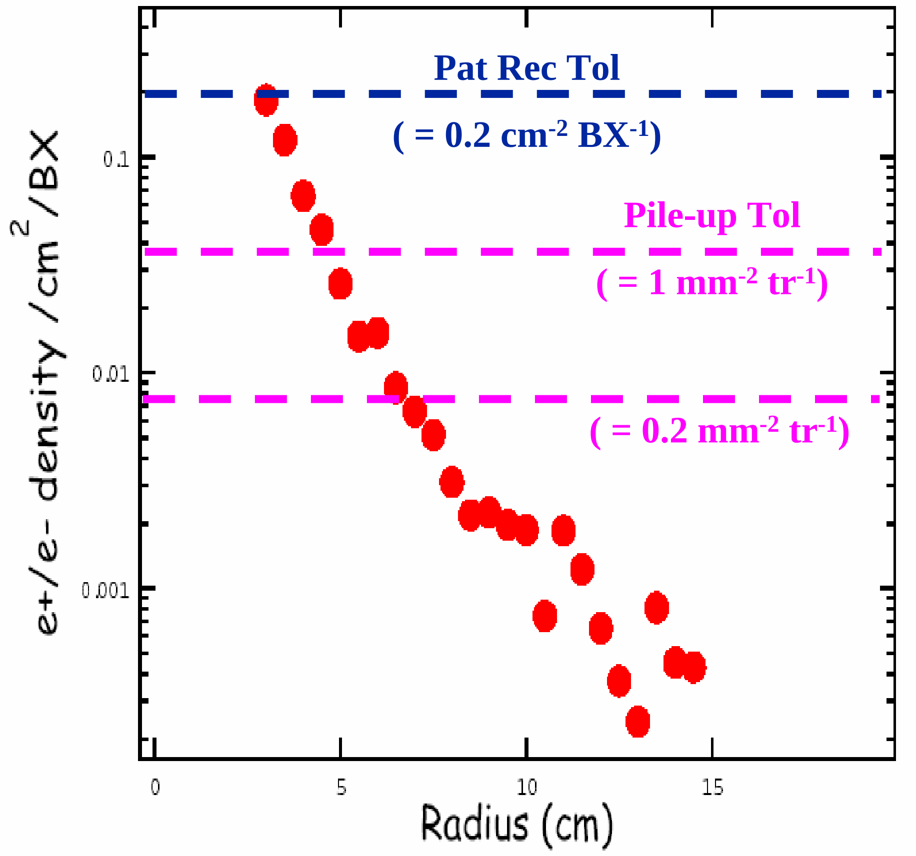
VXD tolerance: 1% generic
Pair background ~ Xing-angle independent (at least in set N)



e^+/e^- density in Si Tracker (SiD)

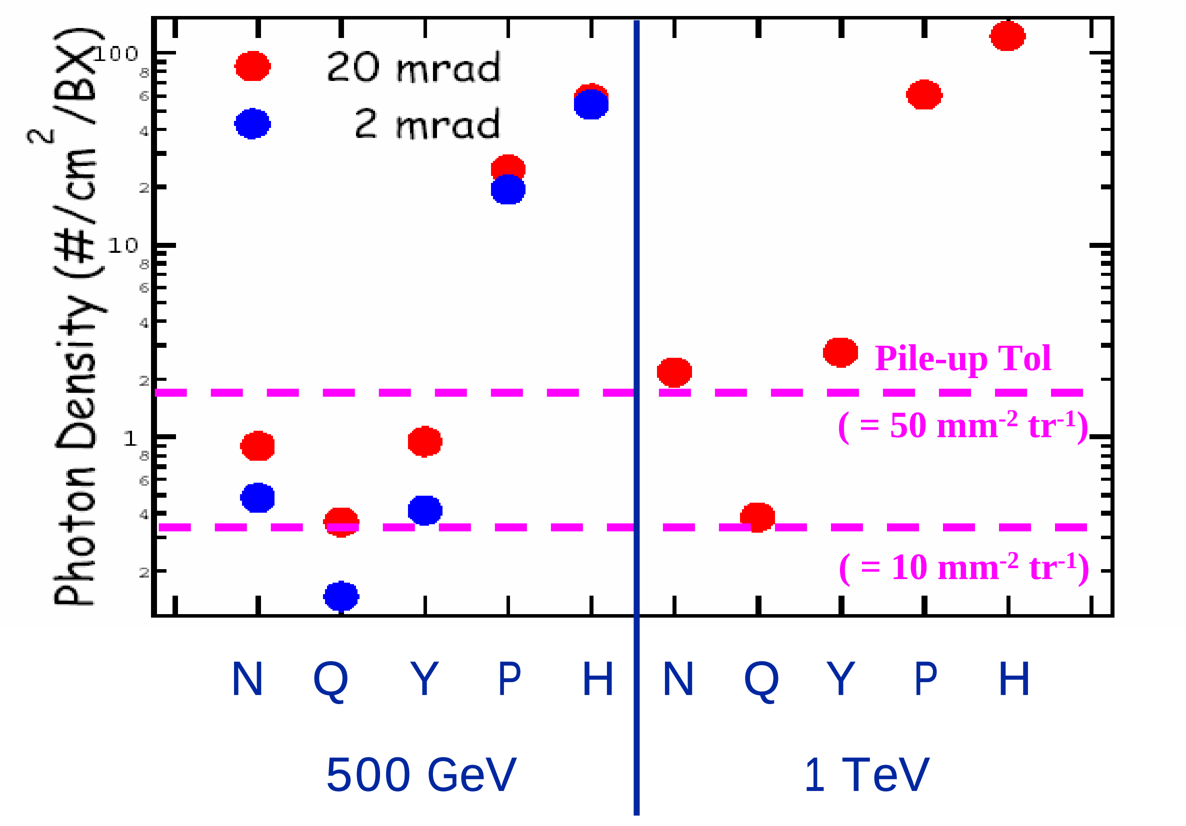
ILC 500 nominal parameters
Si tracker tolerance: SiD

Forward Tracker Layer #1 hits



- **Steep radial dependence**
- **Innermost region is at the tolerance level for pattern recognition (0.2 cm^{-2} / BX).**

Photons in Si Tracker (SiD)



- **Twice as many photons in 20 mrad than in 2 mrad**
- **More than the detector tolerance level for “Low Power” and “High Lum” options**

Open issues

- Tolerable TPC occupancy = ? (track reconstruction / space charge)
- Neutrons
  - background impact very sensitive to actual spectrum (*e.g.* TPC gas, plastic in calorimeter,..). Should be studied in calorimeter also!
  - present simulations often statistics limited
  - neutrons worse @ 1 TeV c.m. by ~ 1 order of magnitude?
  - can extraction-line losses contribute significantly?
- Synchrotron radiation
  - can we design a “bounce-proof” SR masking layout?
  - back-scattering from apertures!
  - edge- & tip-scattering off masks!
- Single-beam backgrounds: electromagnetic shower debris
  - halo scraping in or near final doublet (coupled to SR/collimation depth)
  - beam-gas
- Backgrounds in forward detectors?
- Hot spots & asymmetries (for all of the above): $\rightarrow$ 1 o.o.m? Impact?

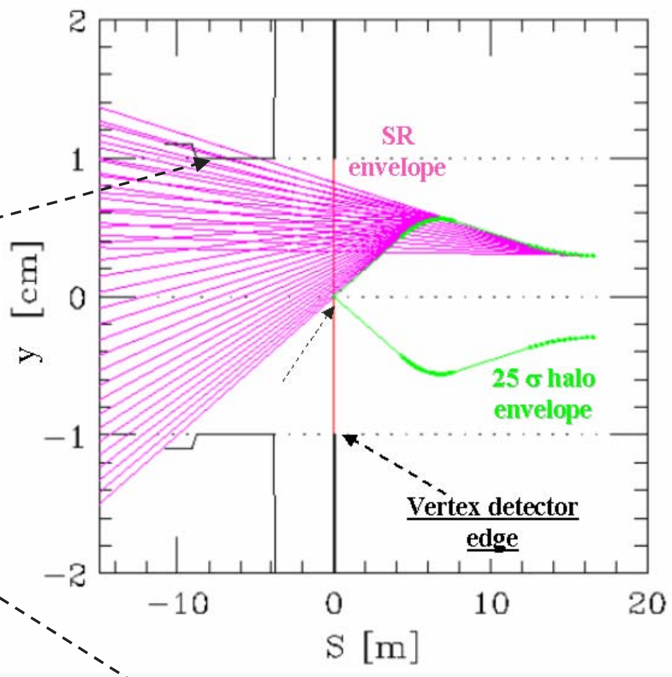
Summary

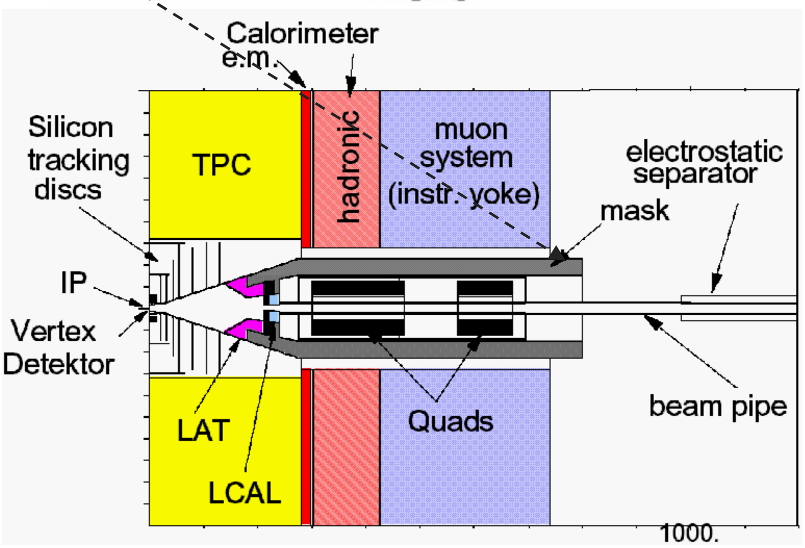
- Proposed a 'standardized' way to compare
  - background levels in a given detector, across IR designs
  - IR designs across detector concepts
- A '1 % occupancy limit' (per train or per SW), implying a 'x 10' safety factor are probably adequate, at this stage & in most cases, for the vertex detector & Si tracker
- Comparison of predicted pair-background levels to (conservative!) detector tolerance levels (aver'gd over X-angle):
  - vertex detectors:
    - LCD, SiD: layer 1 @ ~ occupancy tolerance (~ 1%)
    - GLD: layer 1 @ 1 order of magnitude below tolerance
    - all: high L/ low P parm sets → significantly higher occ'pcy
  - Si tracker (SiD): Pat Rec OK, pile-up x 5-10 > tolerance (⇔ buffering)
  - TPC:
    - predicted occupancy from e^+e^- pairs is at the level of 0.02% to 0.20% (DID)
    - however, impact of such occupancies on (i) track reconstruction efficiency and (ii) space charge, remain to be understood
- Several important open issues: let's go beyond pairs & trackers!

Spares

More on open issues & ‘sanity checks’ (I)

- **Synchrotron radiation**
  - **Concerns**
    - **backscattering** from downstream aperture limitations
    - **edge- & tip-** scattering from upstream SR masks
    - impact of a **partially-shared beam line** on SR masking (2mr)?
      - compatibility of stay-clear apertures (spent beam, pairs, beamstrahlung γ) with effective masking of incoming SR
    - any hidden alligators?
      - **consistency checks** between **independent** calculations **important** (e.g. TESLA TDR vs. A. Drozhdin’s results)

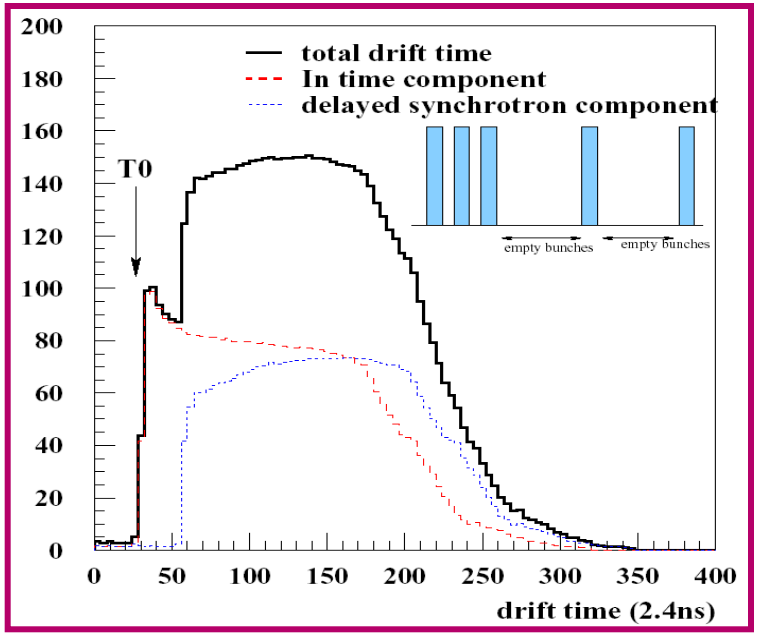




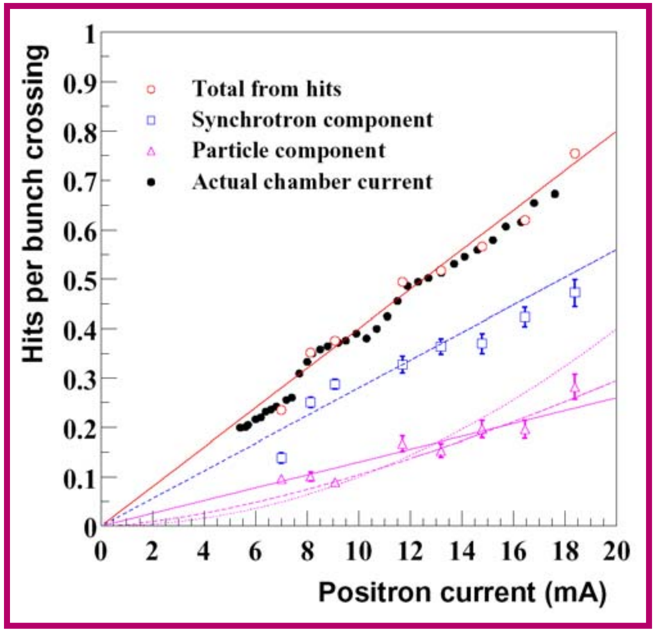
❍ Synchrotron radiation *(continued)*

◎ Lessons from existing detectors

- **BaBar design: SR background dominated by tip-scattering**
- **BELLE: 'fried' their first VDET by a combination of**
  - **improperly masked incoming-beam SR (very soft X-rays from XYCORs)**
  - **hard SR backscattered from the first beam-pipe wall on outgoing side**
- **Zeus + H1: SR – much of it backscattered – absorbs a large fraction of their 'background budget'**



Zeus CTD



More on open issues & ‘sanity checks’ (II)

- **Muons**
  - **Secondary $e^{\pm}$ energy cutoff (> 50 GeV in A. Drozhdin’s code in 2002) may be (have been ?) too high to realistically model ‘harmful’ μ production**
  - **tunnel modelling (wrt μ transport): a huge job by itself....**

- **Electromagnetic debris: production & transport**
  - **Is the showering in ‘thin’ machine elements (vacuum pipe, magnets) modelled with enough realism to be sure we are not overlooking potential problems?**
  - **High energy $e^{\pm}$ losses ‘near’ the IP:**
    - **what is reasonable tolerance level (TWM: ‘a few ten per train”?)**
    - **how near is ‘near’ ?**

How far upstream of the IP do electromagnetic debris matter ?

Can showers produced by full-energy e± 10-20 m from the IP on the <u>*incoming*</u> <u>*beam*</u> *side cause substantial backgrounds, in view of ?*