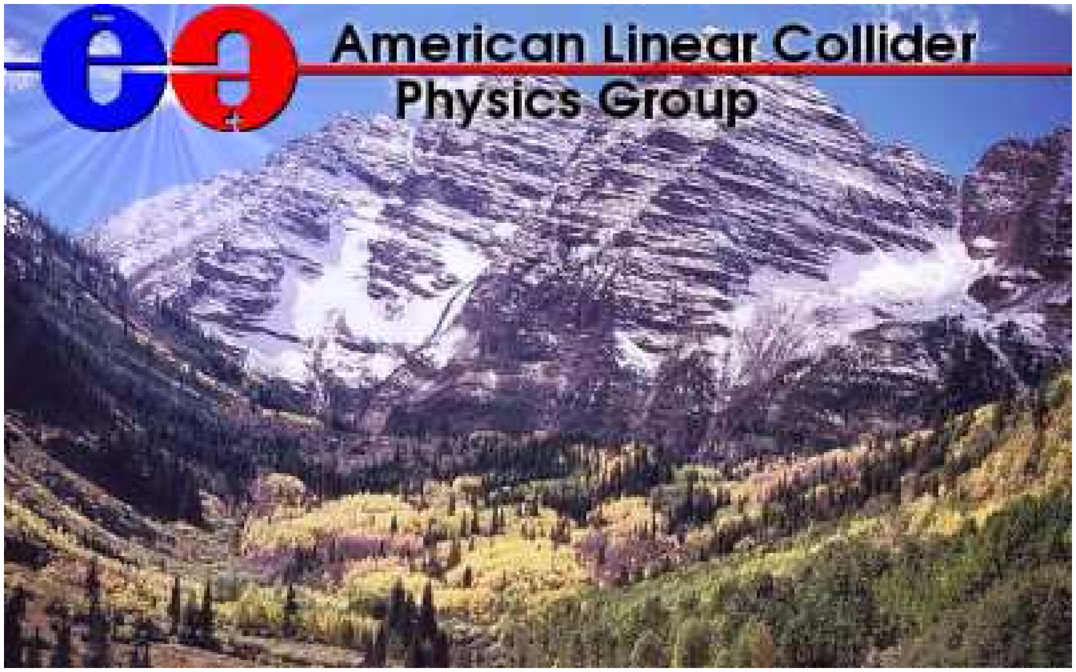
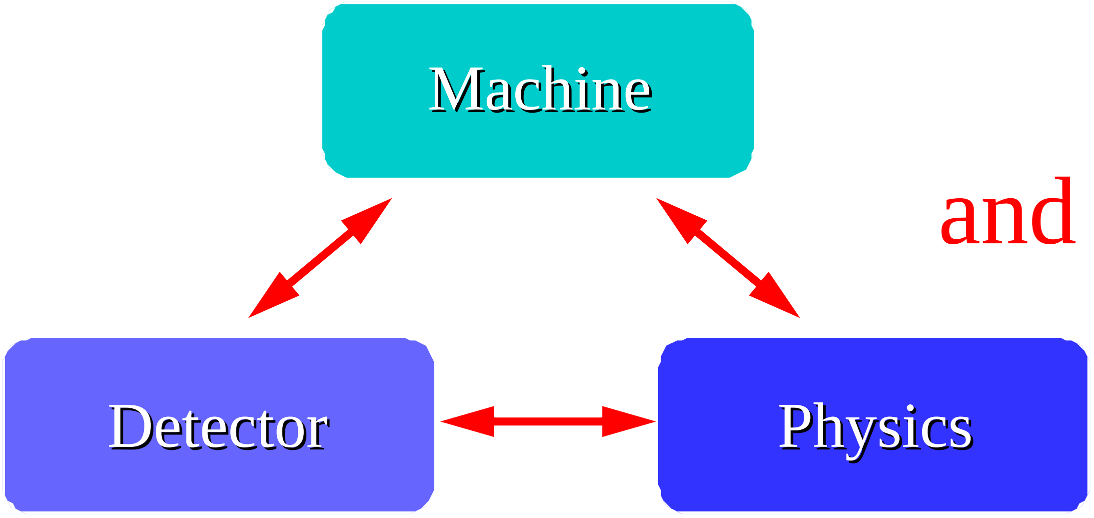
Interaction Regions, Backgrounds, IP Beam Instrumentation



2005 International Linear Collider Physics and Detector Workshop
and Second ILC Accelerator Workshop
Snowmass, Colorado, August 14-27, 2005

Eric Torrence
University of Oregon

Machine Detector Interface



and Cost!

Machine Detector Interface is a complicated optimization problem. Need best configuration for the physics program

Example MDI topics

- Crossing Angle - Final Focus Layout
- Final Doublet L*
- Machine Backgrounds
- IP Beam Instrumentation (Energy, Polarization)
- Luminosity Spectrum Determination
- Instrumentation in Forward Region

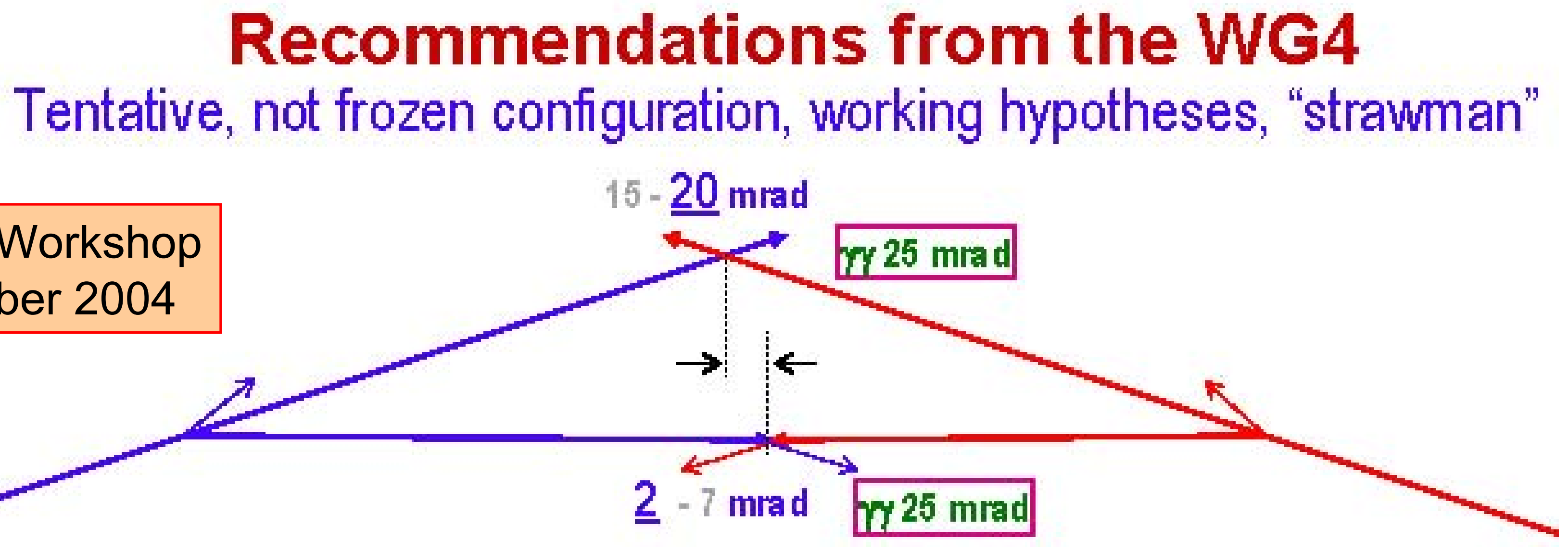
Way too much information to cover.
Couldn’t even attend all relevant sessions...

ILC Working Group 4

Beam Delivery and Interaction Region

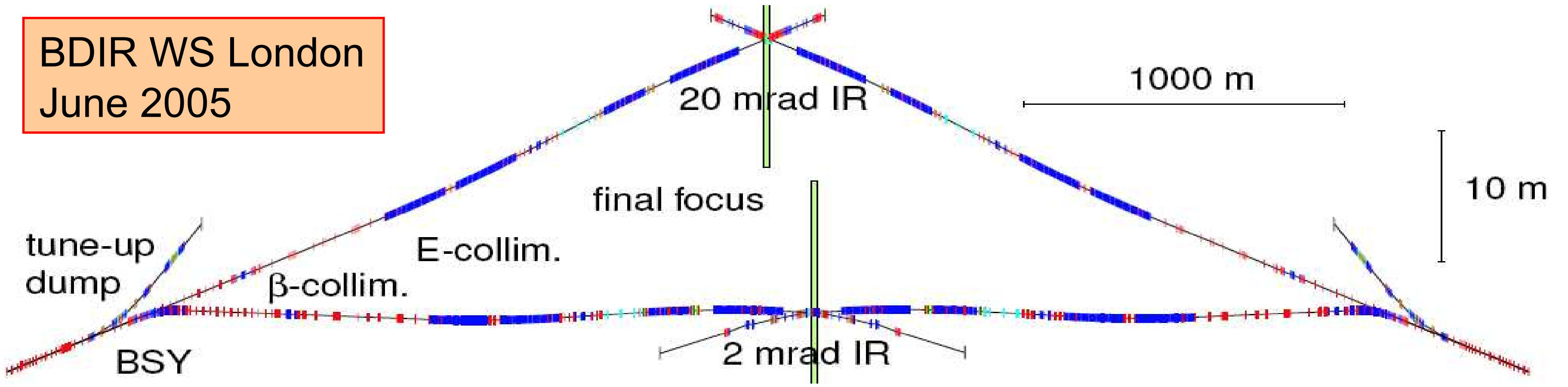
see also A. Seryi WG4 Summary August 19th

From Cartoon at KEK



1st ILC Workshop
November 2004

to Design at RHUL



BDIR WS London
June 2005

Full optics for all beamlines,
2 mRad and 20 mRad designs explored in detail,
up/downstream instrumentation present for both IRs.

Working now on refinements, evaluating performance of designs

Crossing Angle Comparison

20 mRad crossing angle

- Separate incoming and extraction beamlines
- More amenable to high luminosity?
- Cleaner downstream diagnostics?
- May be compatible with $\gamma\gamma$ and > 1 TeV
- Expect good operational margins and flexibility

but

- Reliance on crab cavity
- Reduced detector hermeticity
- Need to correct solenoid crossing (DID or other)
- Somewhat higher pair backgrounds

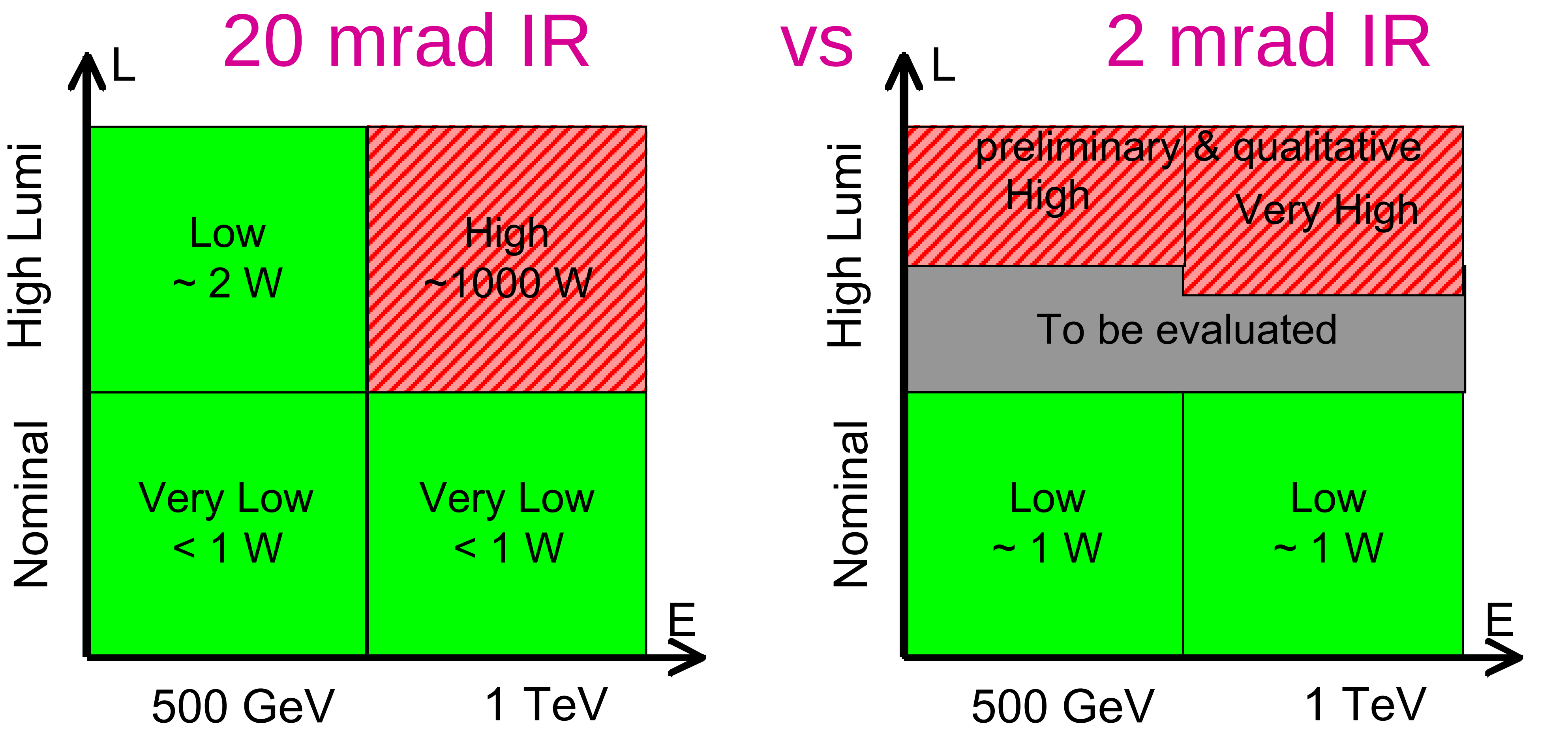
2 mRad crossing angle

- Lots of recent work (could still be improved?)
- Improves 20 mRad issues (crab, hermeticity, DID)
- Downstream instrumentation more difficult?
- More particle losses downstream, closer to IP
- More constrained design, problems with high Lumi

Derived from A. Seryi, other opinions exist...

Not at all obvious which is best in the big picture
continue to develop and understand both...

From A. Seryi



Numbers in Watts show losses on SC FD Magnets

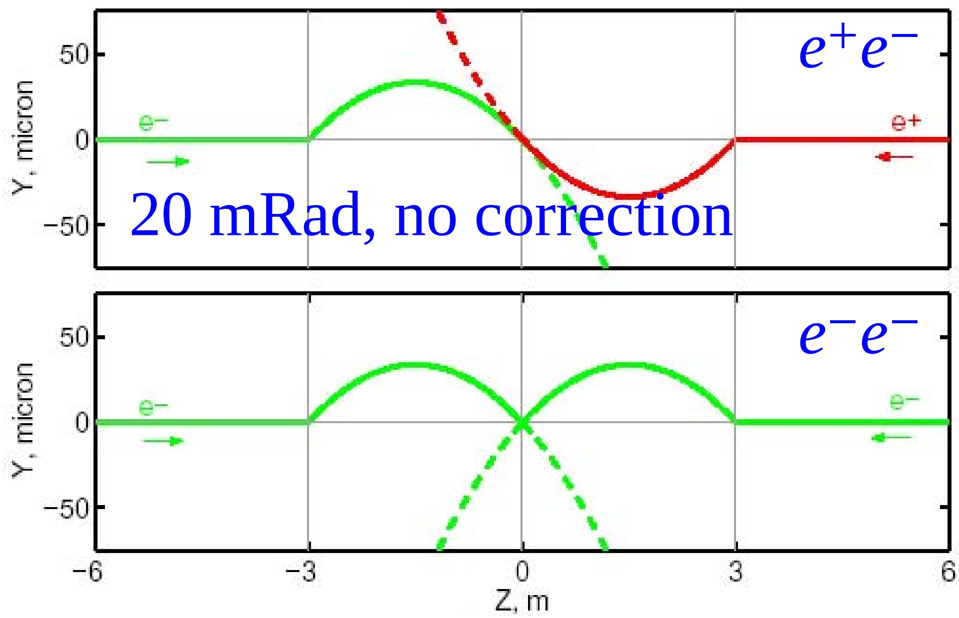
Personal Opinion: Current high Lumi parameter sets may be unrealistic, but they probably give a good indication of where the machine wants to go...

Remember: ILC Lumi = 10,000 x SLC Lumi
achieving this will be a major (the major?) challenge of ILC

20 mRad Detector Integrated Dipole

With 20 mRad crossing-angle

- Polarization vector is rotated (difficult for precision)
- Orbit bump causes synchrotron radiation - limits σ_y (30% lumi)

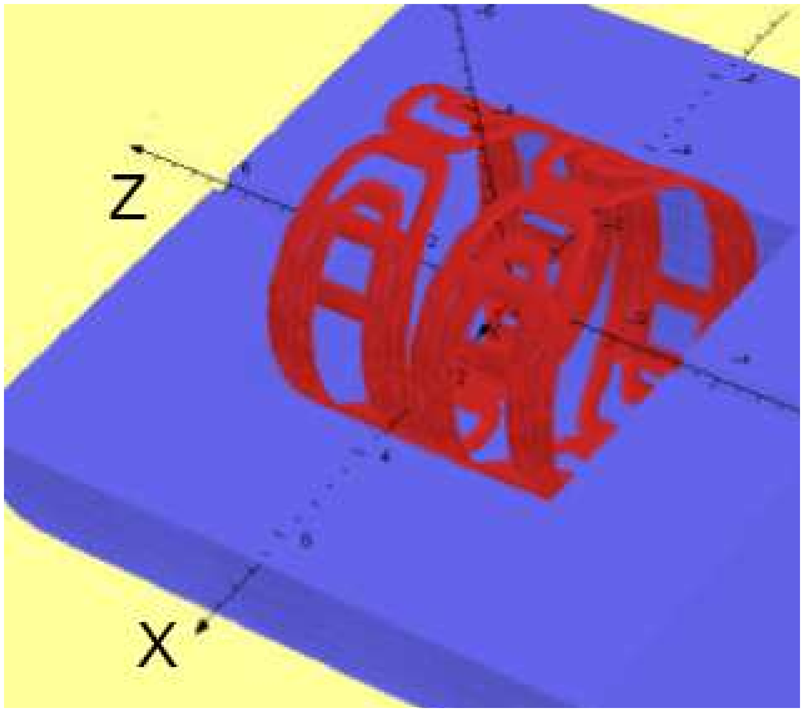


Detector Integrated Dipole (DID)
offers a good machine solution

align field along incoming beam direction

But likely causes difficulties for detector:

Non-uniform solenoid field
Background issues (redirecting pairs)



Concepts asked to evaluate if significant impact.
Tracking issues under study, LDC (Busser) indicates higher TPC backgrounds with current masking design. Significance not clear.

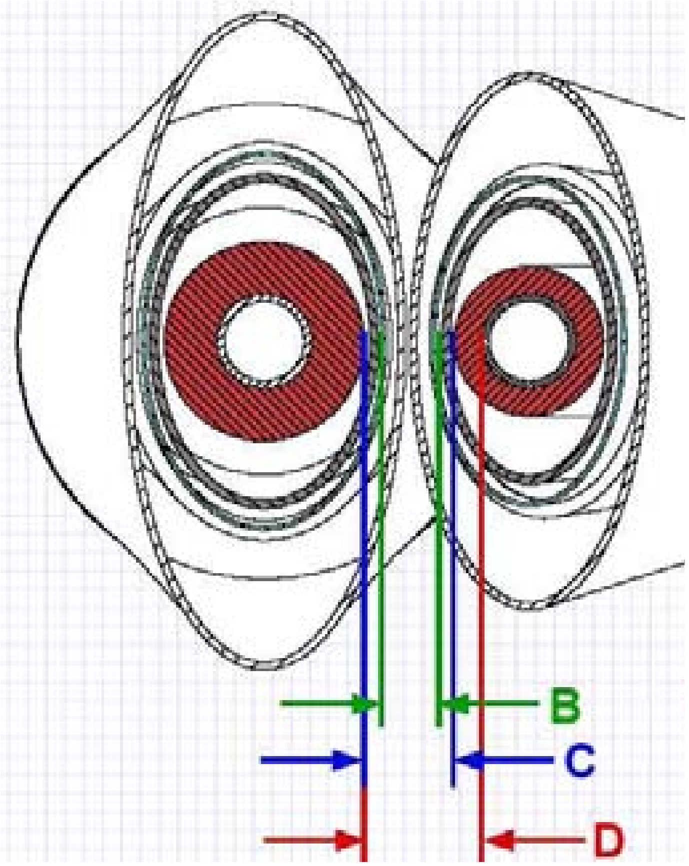
Advanced design for 20 mRad final doublet

Now thinking about reducing crossing angle by reducing material between coils

B. Parker, BNL

Scenario	d (mm)	Angle Range* (mr)	Issues	Confidence Level
A	70	20 - 15.5	Standard	Recommended
B	53	15 - 11.8	+ Cold Support	Probably OK
C	44	12.5 - 9.8	+ Stronger Comp'	Needs Study
D	38	10.8 - 8.4	+ Give Up Comp'	Highest Risk

Angle range is for 3.5 m < L < 4.5 m



Angles down to 10-12 mRad will be studied as alternates to baseline

Likely to improve 20 mRad issues, incompatible with γγ

Head-on Redux

Complicated magnets and potentially large losses in 2 mRad has prompted a renewed look at head-on options:

RF kicker (Y. Iwashita) and SLC-style separator (L. Keller)

Needs large effort to become realistic alternative

Backgrounds

see also T. Maruyama talk
August 17th

Background Sources

IP Backgrounds (Good backgrounds)

- Disrupted primary beam - extraction line losses
- Beamstrahlung (BSL) photons
- e^+e^- pairs from BSL γs
- pair backsplash from final doublet
- Hadrons from BSL or $\gamma\gamma$
- Neutrons from e^+e^- pairs
- Radiative Bhabhas

These scale with Luminosity: transport away, shield detectors. More reliable simulations

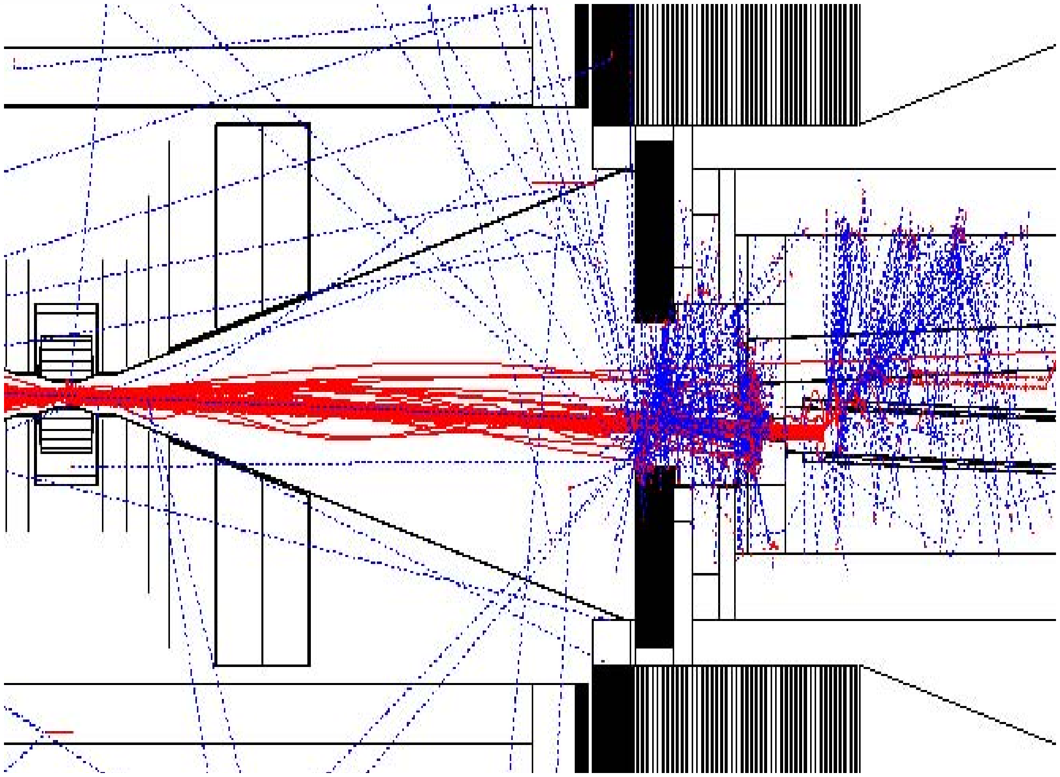
Machine Backgrounds (Bad backgrounds)

- Synchrotron radiation
- Neutron back-shine from dump
- Muon production
- Collimator scraping
- Beam Gas

These don't scale with Lumi: avoid near IP. Highly dependent upon assumptions

Tedious to evaluate all in detail, but clearly important for detector and IR conceptual designs!

New LDC Pair Simulations



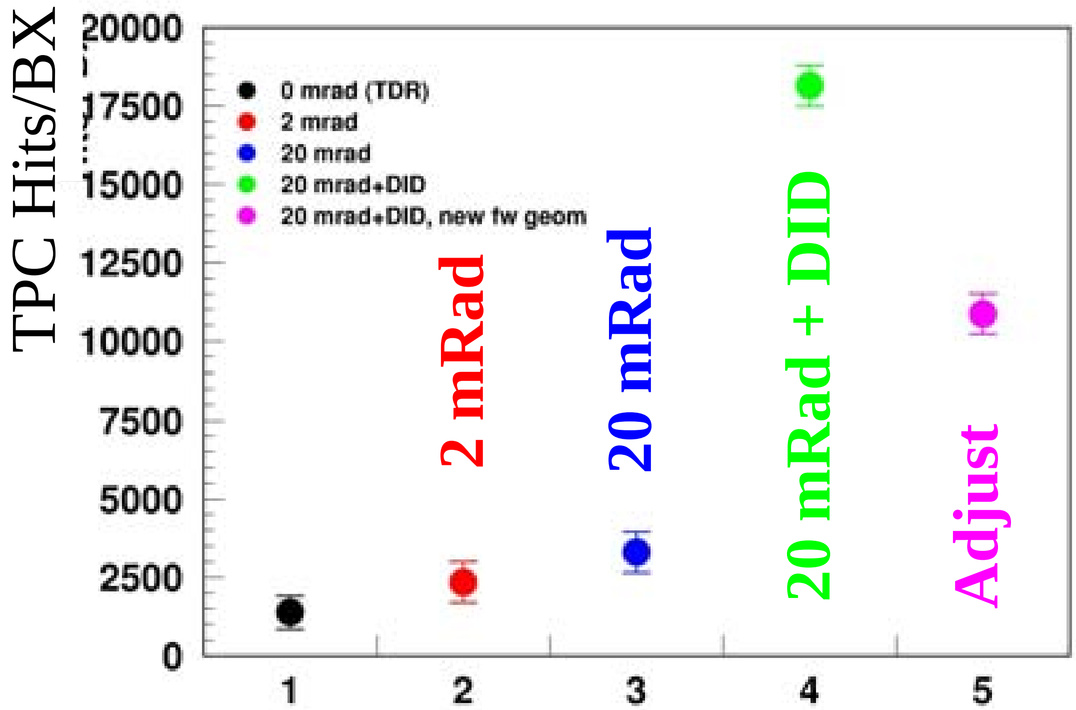
LDC Studies (K. Busser)

Investigate pair backgrounds in VXD and TPC for crossing angle options w/ realistic DID field

Initial Conclusions

- Realistic DID field changes pair hit pattern
- Pairs (and junk) from in-coming hole channeled into vertex detector L1
- Pairs hitting LumiCal edge scatter photons to TPC
- Opening LumiCal reduces effect somewhat

Details of fields and geometry very important...



TPC backgrounds worse in 20 mRad + DID, but is this significant?

Background Tolerance Estimates

Full simulations and physics studies are slow.
What can be understood from "rule of thumb" background tolerances?
W. Kozanecki (Saclay), et. al.

Different tolerances: damage, pile-up, pattern recognition, physics performance

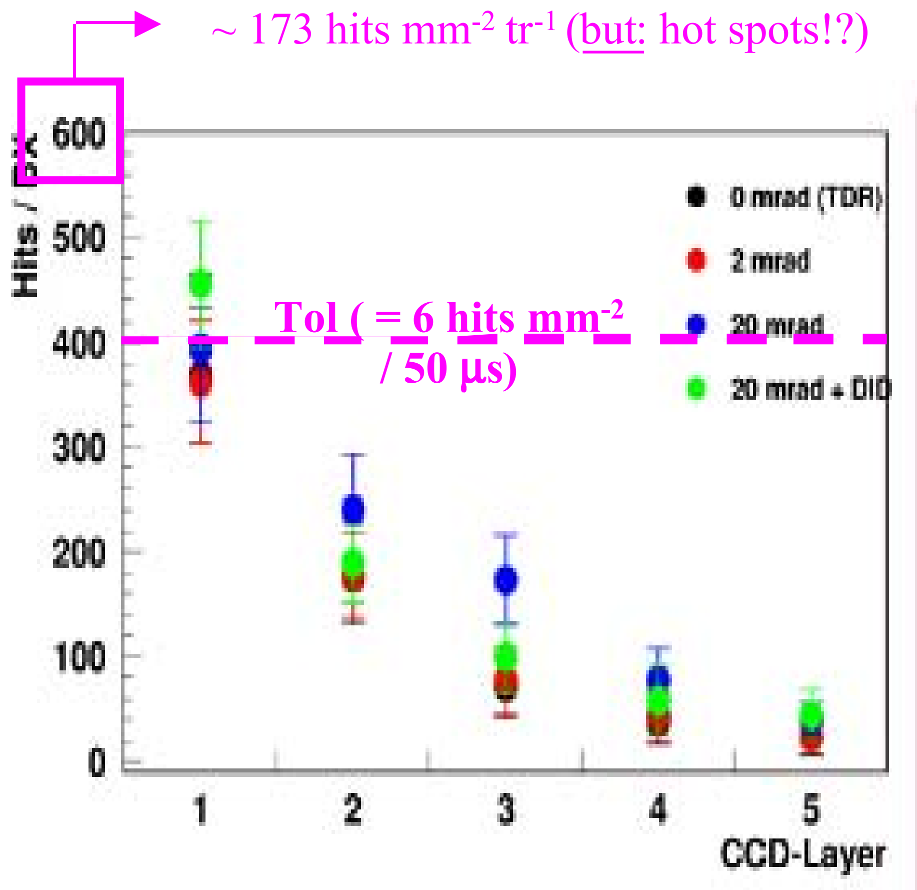
Working assumption: 1% occupancy in tracking detectors.
Conservative, but need realistic x10 safety factor.

Example from Witold's Talk

LDC Vertex occupancy vs. layer
comparing DID/crossing angle (pairs)

Data from K. Busser
Interpretation (tolerance) by Witold

See talk Wed. Aug. 24th
for many more plots like this



More Background Tolerance

General conclusions (Witold)

- 1% occupancy/readout window threshold useful for comparisions
- VXD (SiD, LDC) at or below 1%, GLD well below 1%
- TPC well below 1%*
- SiD tracker pileup appears to be 5-10 greater than stated tolerance
- High luminosity and low power parameters cause trouble

*Warning: Correlated hits (i.e.: tracks) and hot-spots may drastically change these conclusions. True impact/tolerance can only be evaluated by detector experts with detailed studies in concept groups.

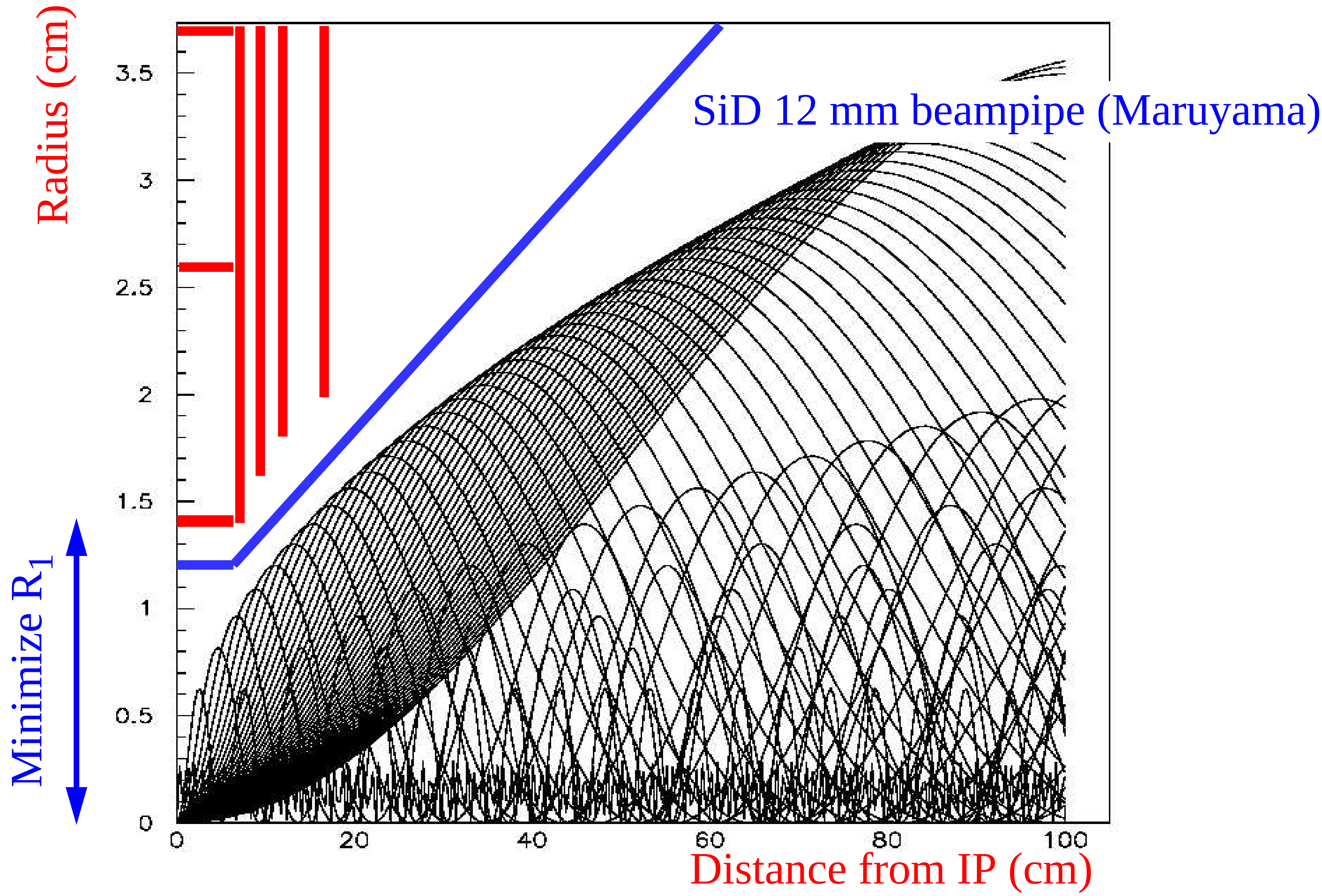
Background Comments

General limits useful to guide IR design, but also need the details.

Each detector concept group must “take ownership” of their background estimations and work with WG4 to more towards realistic IR designs. Work generally started in all concepts.

This is a lot of work, and adequate resources must be available in all concept groups to tackle all relevant background sources.

Vertex Tolerances



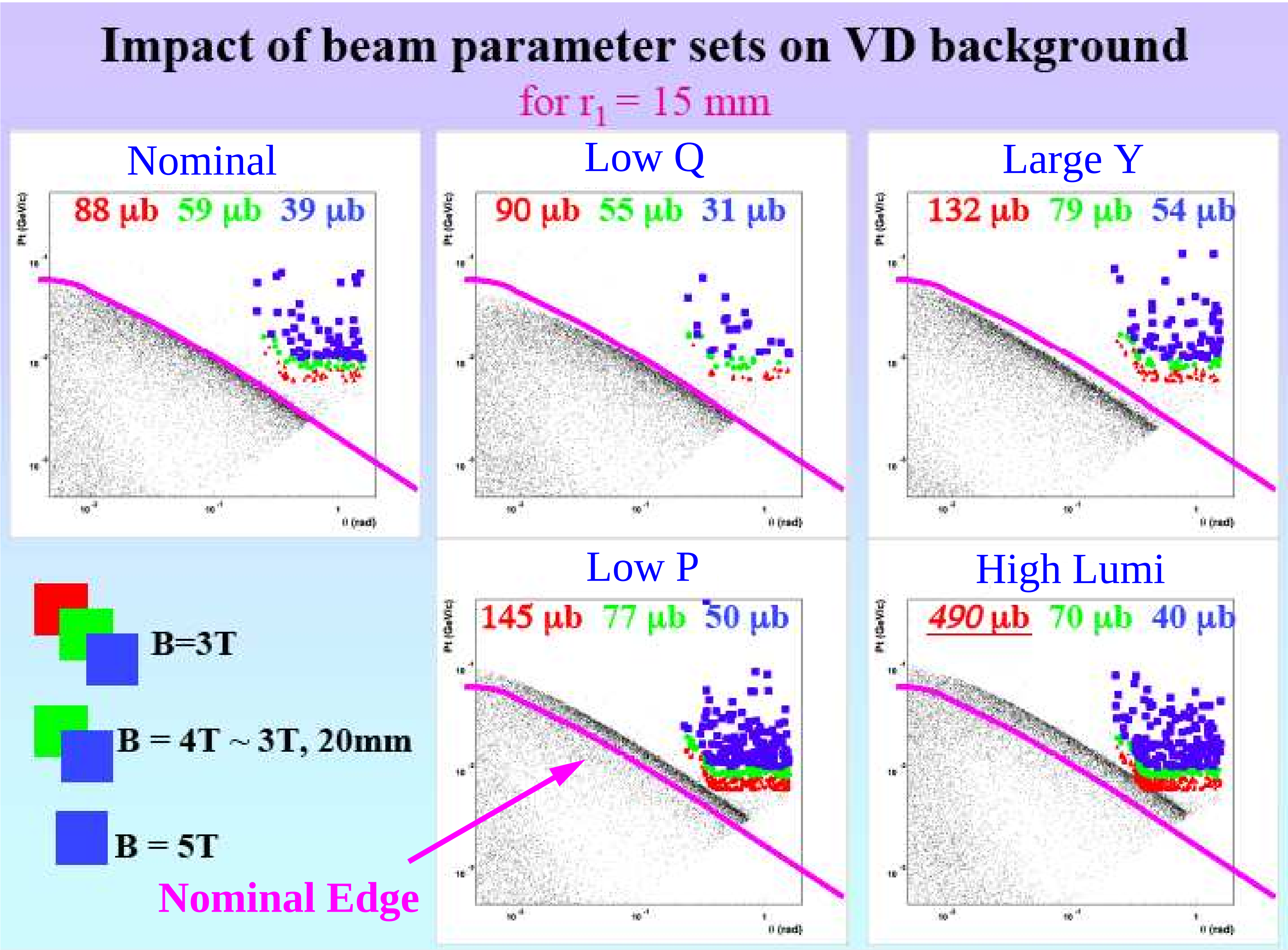
Direct pairs kept away from VXD by solenoid field, but tolerances are often tight (few mm)

May limit initial machine operations. Solenoid may not always run at nominal field. Detectors willing to sacrifice layer 1?

Variation with Parameter Sets

Transverse Momentum vs. Theta

C. Rimbault, LAL Orsay



High Lumi and Low Power problematic

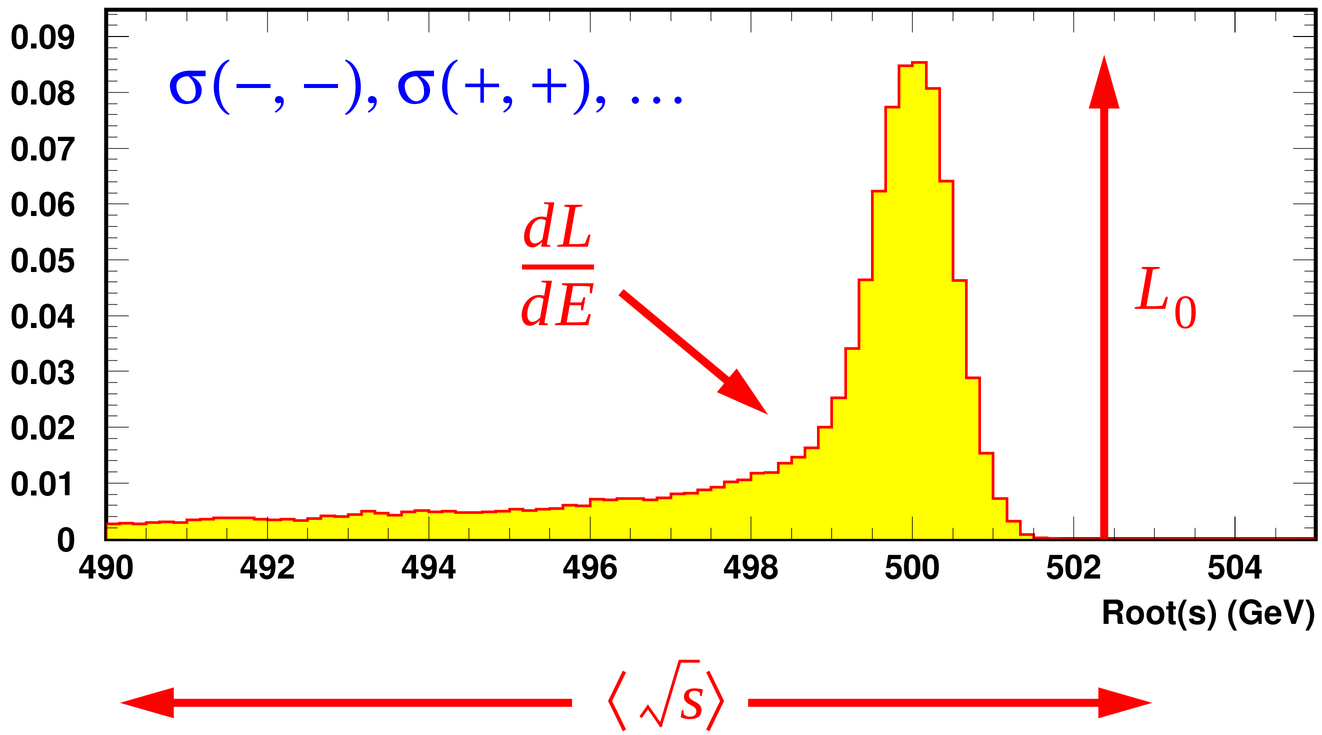
Unwise to push too hard here?

Beam Instrumentation and Forward Region

see also K. Mönig's talk

August 17th

IP Instrumentation



Fundamental IP Beam Instrumentation Goal

Spin-dependent absolute collision energy spectrum

Typical Components

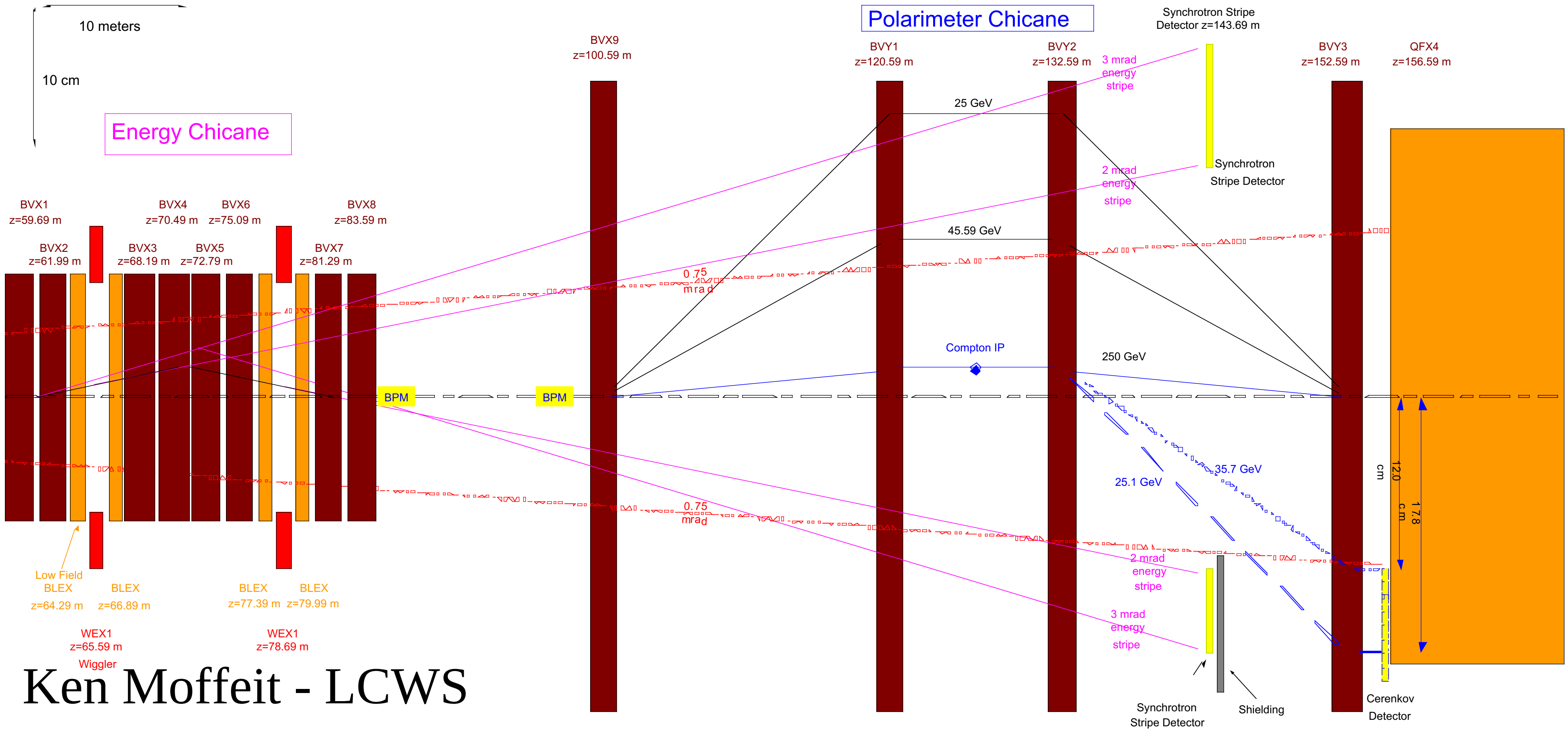
- Beam Energy
- Beam Energy Width
- Beam Polarization
- Absolute Luminosity
- Differential Luminosity Spectrum

Mixture of beam-based and physics-based measurements

Beam Instrumentation Design

Upstream and Downstream spectrometer and polarimeter designs now exist for both 2 mRad and 20 mRad schemes

20 mRad Extraction Line

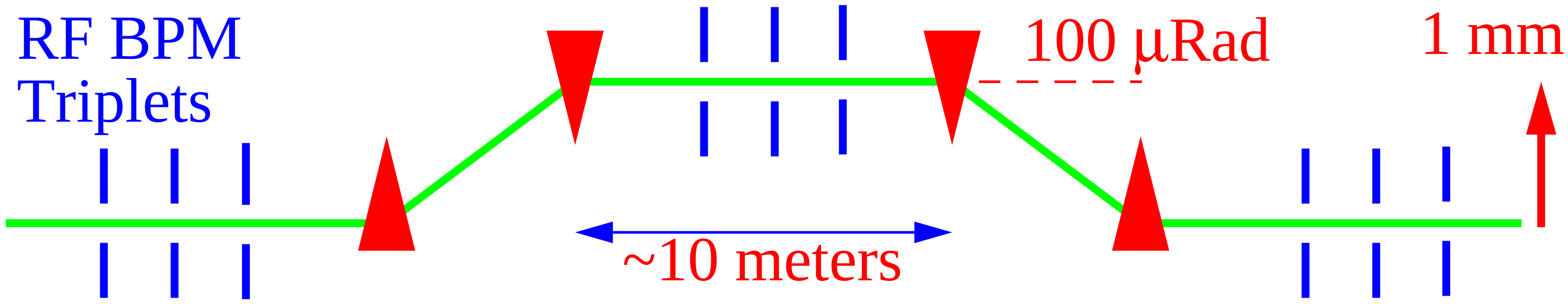


Ken Moffeit - LCWS

Upstream probably cleaner, measures incoming beam parameters
Downstream more challenging, but gives sensitivity to collision details

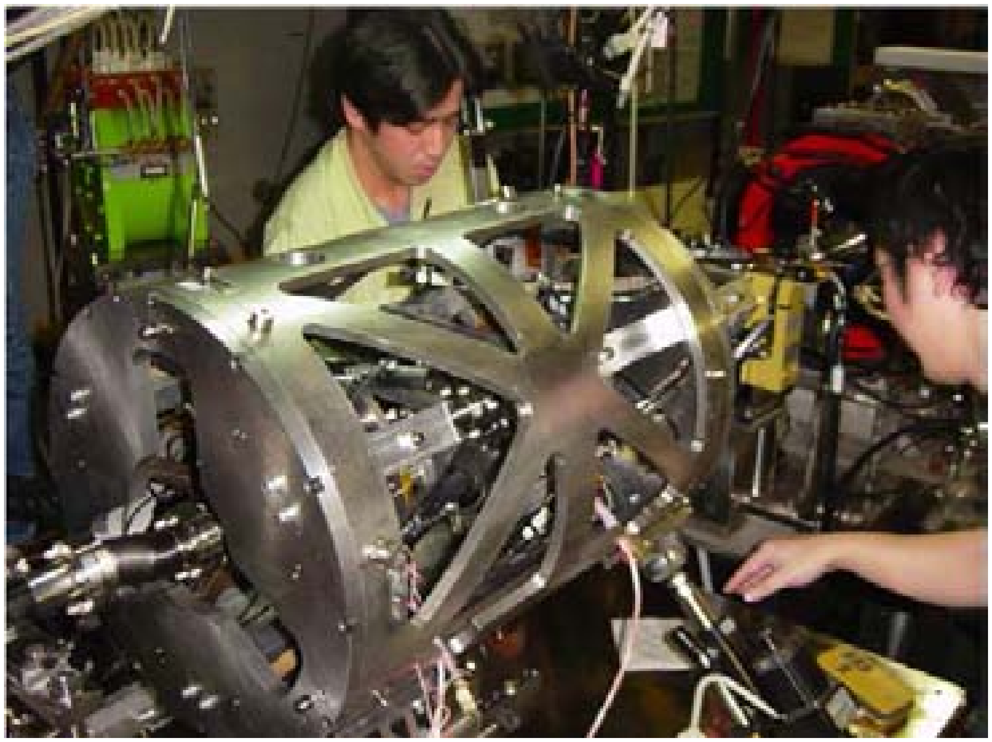
Both needed to reach ultimate accuracy of a precision machine
Complimentary systematics and control over collision uncertainties

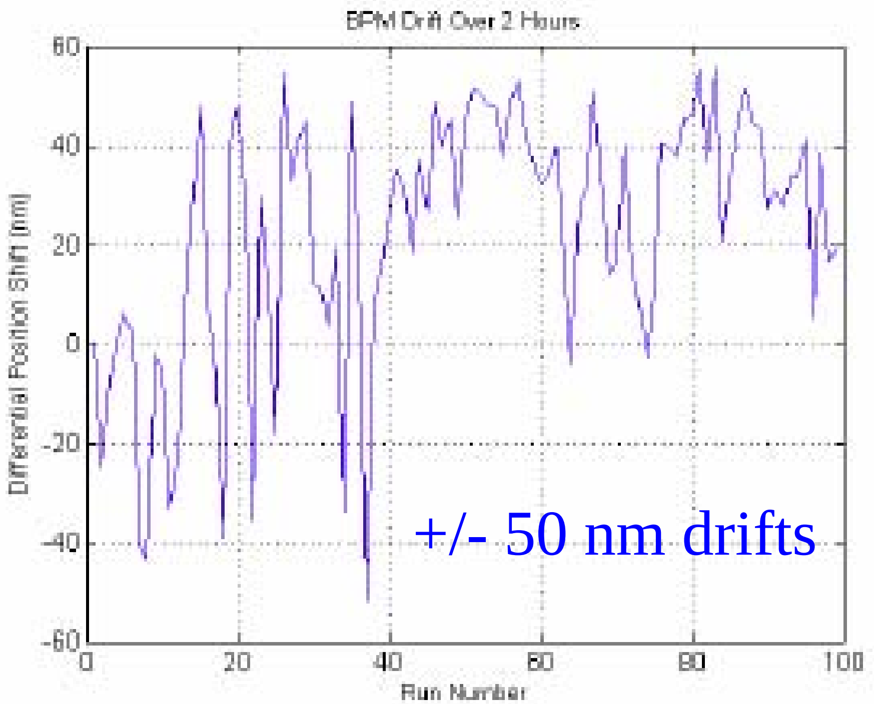
Beam Instrumentation R&D



Upstream spectrometer needs BPM resolution and stability
at sub-100 nm level for several hours

BPM Tests at ATF (nanoBPM program)

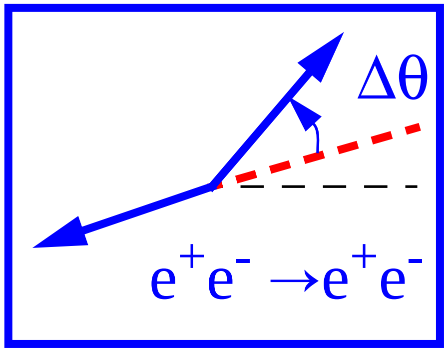




Many discussions this meeting on advancing spectrometer designs.
Tests starting in ESA this fall.

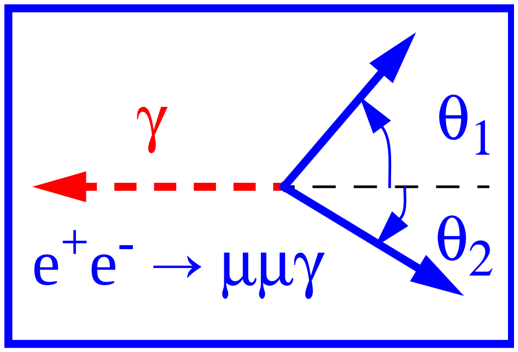
Bhabha acolinearity

- Best input for lumi spectrum shape
- Strong requirements on performance of forward tracking and calorimetry? θ ~ 200 mRad



$\mu^+\mu^-\gamma$ "Radiative Returns"

- Potentially best measure of $\langle \sqrt{s} \rangle$ correct for any collision bias
- Actually used at LEPII serious detector systematics



Also t-channel WW for polarization monitoring

Stringent detector requirements

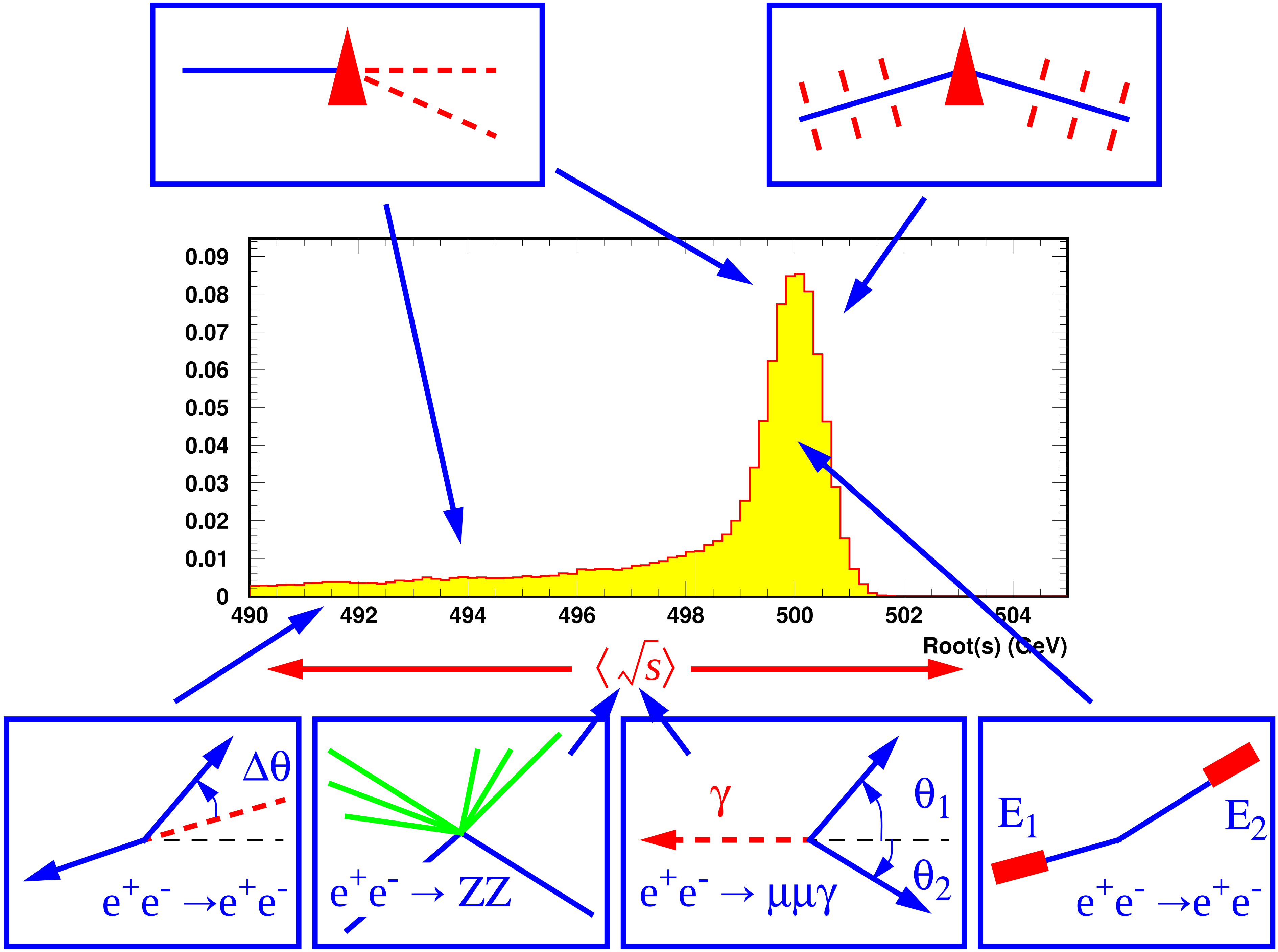
Need precise tracking to ~150 mRad

$\delta\Theta \approx 0.1\%$ per event (Γ_Z limit), absolute angle known to 10^{-4}

Forward tracking system must be given same care and effort as precision luminosity measurements. See K. Mönig LDC talk

Will likely determine ultimate precision on masses due to $\delta\langle \sqrt{s} \rangle$!
Need to do a good job here to reach δm ~ 50 MeV

Putting it all Together

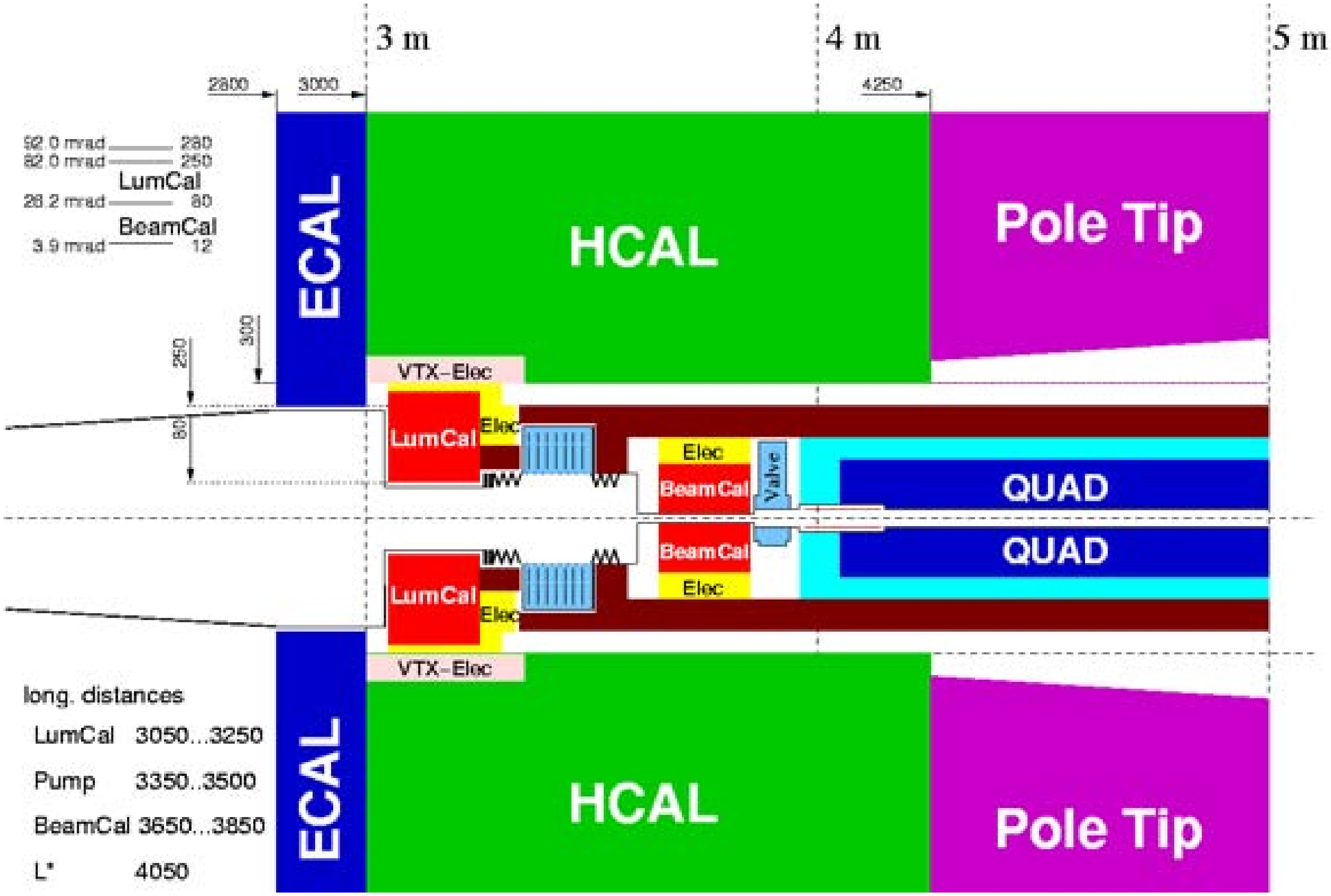


Need combined analysis putting together all pieces and extracting physics result

S. Boogert working on efficient MC generation from beam-beam simulations

Goal: close the loop and show required precision can be achieved

LDC Forward design (2 mRad, L* = 4.05 m)



Luminosity Monitor ~ 20-50 mRad - Outside pair backgrounds
Also shields pair backsplash from lower angles

- Pair Monitor ~ 5-20 mRad - Front surface, machine diagnostics

- γγ Tagger ~ 5-20 mRad - Cal. to veto γγ electrons as SUSY background

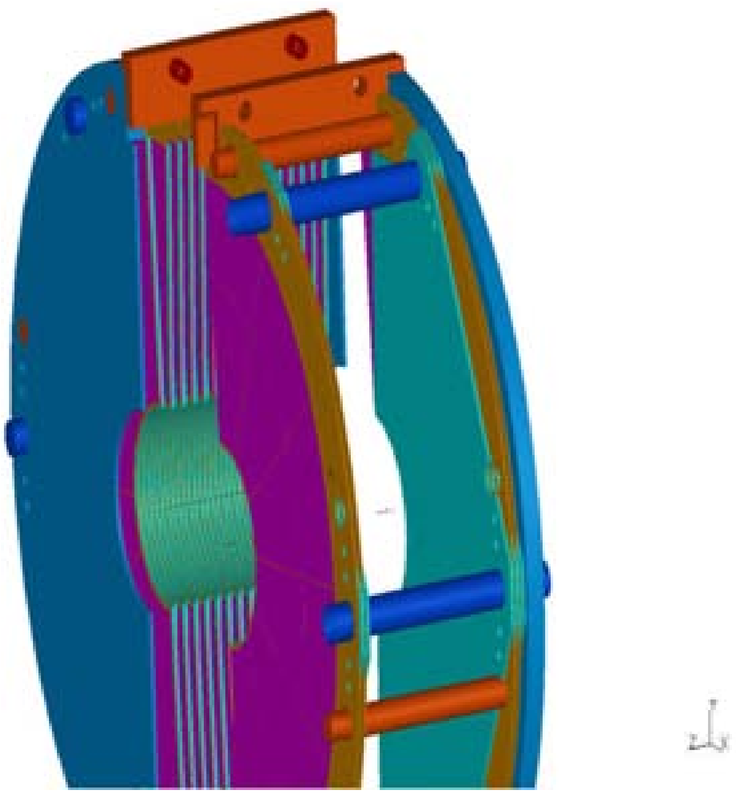
Could be all one, or several different detectors

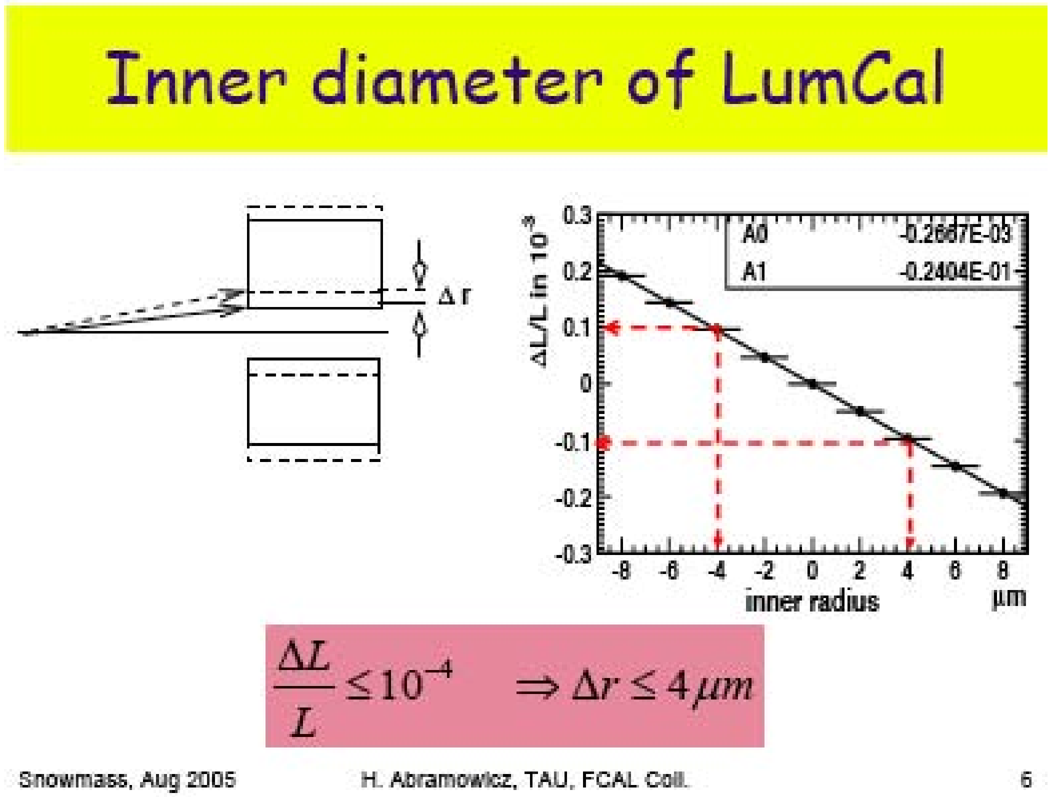
Precision Luminosity

Series of talks on precision luminosity - W. Lohmann et. al.

Ambitious goal of 10^{-4}

(below 10^{-3} probably OK)





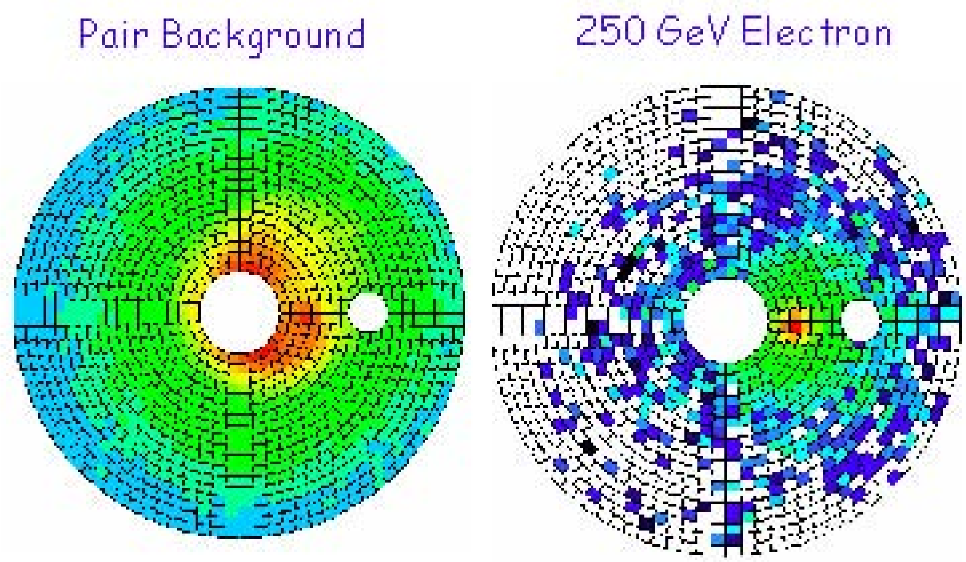
Extensive studies made for head-on
Rad-hard detectors considered

Initial studies for 20 mRad indicate
larger backgrounds - need increased inner radius.

Detailed evaluation of 20 mRad boost on detector geometry needed

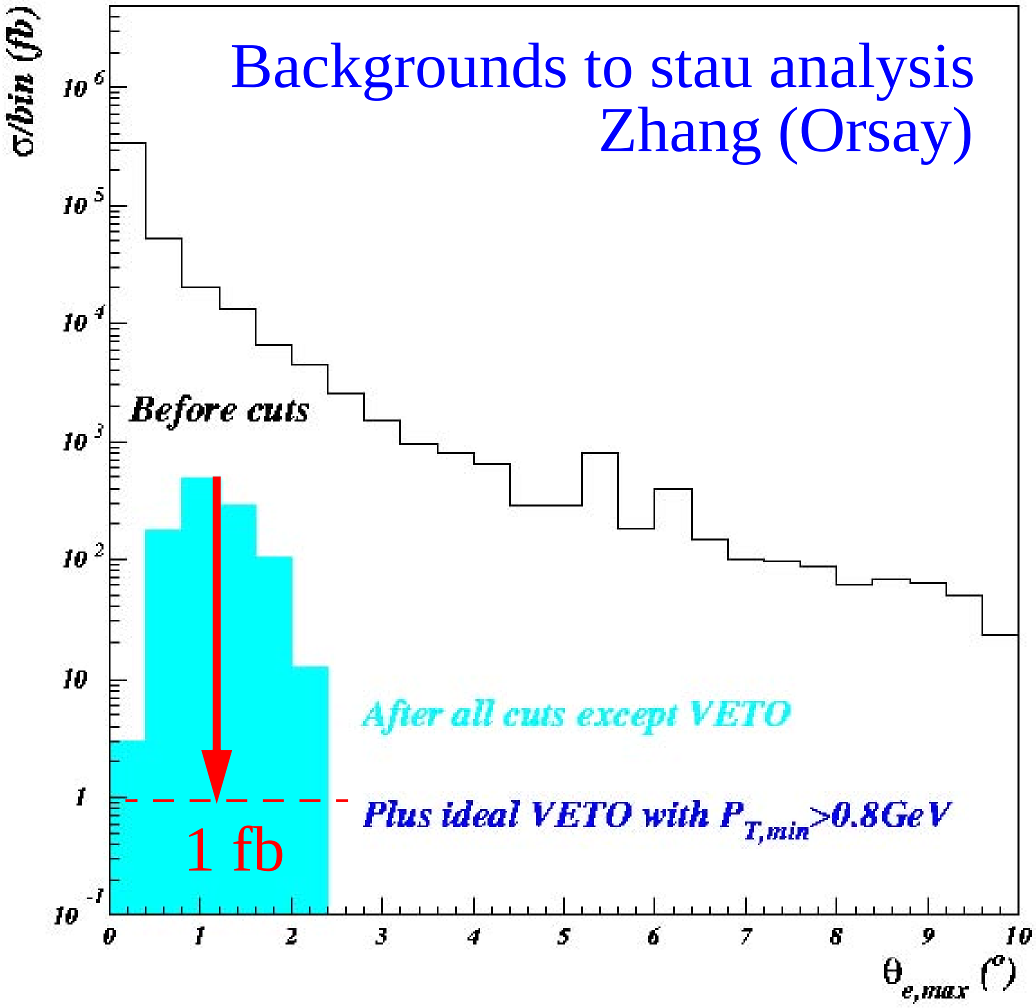
Ultimate OPAL precision based on phi symmetry - D. Strom
May be much more difficult in crossing angle

Far-Forward $\gamma\gamma$ Tagging



Electron hermeticity key for SUSY and other analyses

Challenge: Separate 250 GeV electron from 10s TeV pair backgrounds per crossing



Several studies done on performance for $\tilde{\mu}\tilde{\mu}$ and $\tilde{\tau}\tilde{\tau}$

Rely on huge suppression of $\gamma\gamma$ background

$\varepsilon \sim 99.9\%$ probably required!

Modest acceptance hole is OK if you know where it is - reduced efficiency

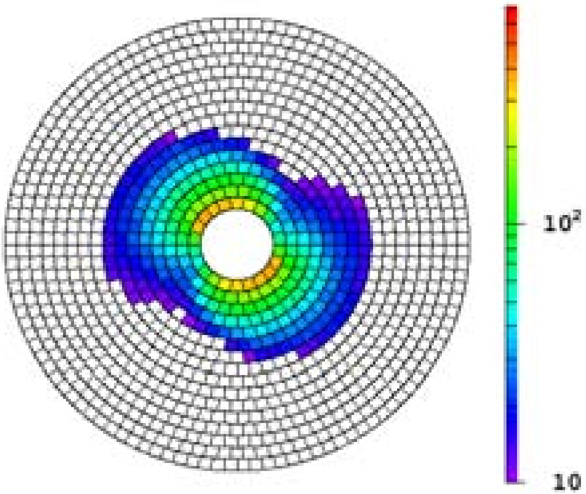
Larger hole leads to Bhabha backgrounds (1 Bhabha per 2 BX)

Pair background rates problematic

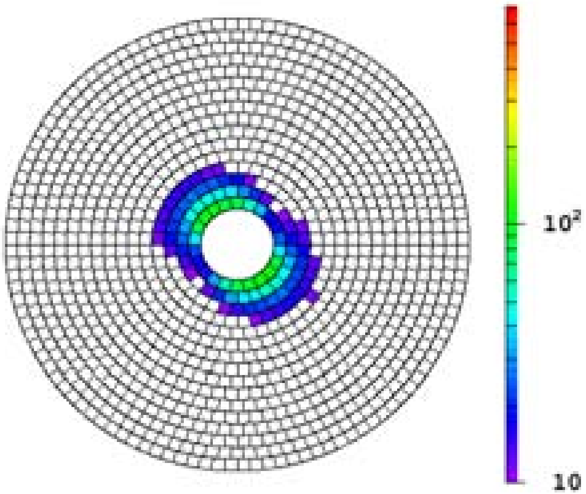
Forward Pair Distributions

Pair Energy in BeamCal (L* = 4m, B = 4T) - P. Bambade - Orsay

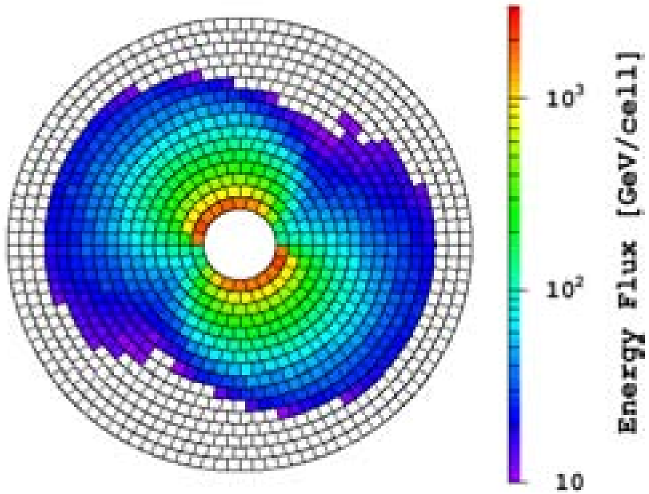
2 mRad Nominal



2 mRad Low Q



2 mRad High Lumi



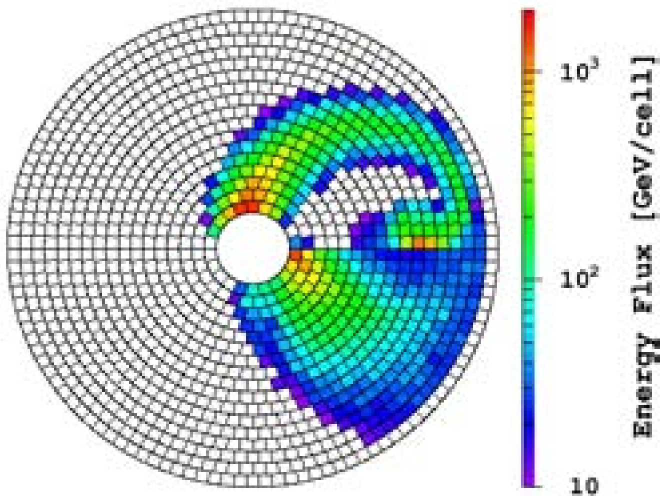
Larger energy deposition at larger angles impacts ultra-efficient electron ID

2 mRad qualitatively better

Can quantify 2 mRad - 20 mRad difference under certain assumptions/models

e.g.: Factor of 1.8 in ΔM ($\tilde{\tau} - \tilde{x}^0$) reach - Bambade

20 mRad + DID Nominal



Differences from machine parameter sets very significant

Low Q (or similar) would be most beneficial if physics demanded

Hard to judge how much weight this carries in global optimization

There is no MDI working group!

More of an avenue of communication between the accelerator, detector, and physics groups

Most closely tied to ILC WG4 - IR layout issues + community on detector/physics side

Global issues (e.g.: 1 or 2 IRs, parameters) also important

WWS Interim MDI Panel - through Snowmass

M. Woods, P. Bambade, T. Tauchi

Needs to be expanded/reformulated to include concept representatives, WG4, and guidance from GDE

MDI Communication Examples

- Urgent MDI questions for concepts
  - necessary to complete conceptual design
- Vertex session Tuesday with questions for WG4

Communication goes both ways...

Summary

- Wide range of topics covered at Snowmass under WG4, MDI, and IP Beam Instrumentation
- Key features of IR conceptual design in place
  Baseline crossing angles: 2 mRad and 20 mRad
  Intermediate 10-12 mRad to be pursued as alternate
- Detector backgrounds depend on details of detector technology and IR geometry

  Large effort from concepts needed here!

- Beam instrumentation design proceeding
  Detailed evaluation of performance starting
- Physics reference processes also needed
  Stringent detector requirements, part of benchmarks
- Studies of forward detector performance continuing

Working towards ever better understanding of
MDI optimization process