SiD's New Global Parameters

SiD Collaboration Phone Meeting
July 30, 2008
John Jaros

Road to Optimizing SiD's Global Parameters

- We've been at this in earnest since the SiD Workshop at SLAC in February
- The approach has been to use Mark Thomson's Pandora PFA to explore PFA performance as a function of R, Z, B, λ,

  first, simply using Mark's parameterizations

  then, to study a SiD look-alike in the LDC framework called SiDish. Marcel Stanitzki has done this work.

- All the ingredients were put together in Marty's RAL talk, and have been updated in Marty's Warsaw talk.
- Since Warsaw, Marcel has explored Z dependence and the tradeoff of λ and nlayers in the hcal

The Answer

- The new baseline is very similar to the original SiD. It is slightly longer,a somewhat deeper HCAL with a few more layers

	SiD	SiD'
R	1.25m	1.25m
Z	1.70m	2.10m
B	5T	5T
λ	4.0	4.5
#layers	34	40
Cost*	620M$	670M$

The cost numbers are US style, with labor, contingency, indirects and escalation. Inflation rate is 3.5% and construction start is 2012. These numbers are optimistic

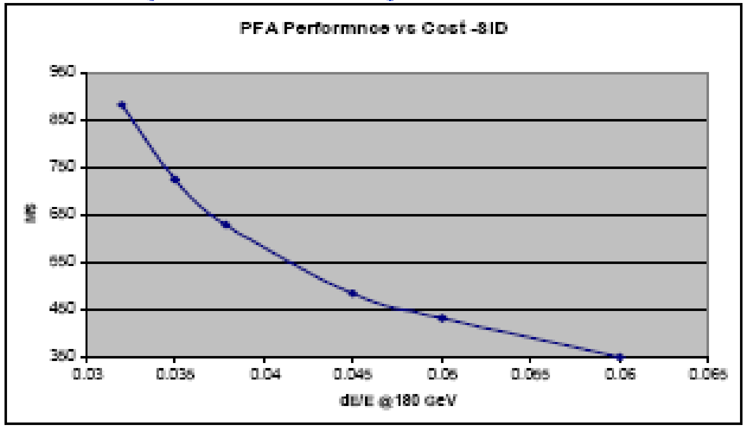
Review: Method proposed at SiD RAL Meeting

- Assume Mark Thomson's ILD Parameterization of $\Delta E_{jet}/E_{jet}$:

$$\alpha = 0.42\left(\frac{B}{4}\right)^{-0.31}\left(\frac{R}{1.78}\right)^{-0.61}(1+21.6e^{-\frac{N}{7.1}})$$

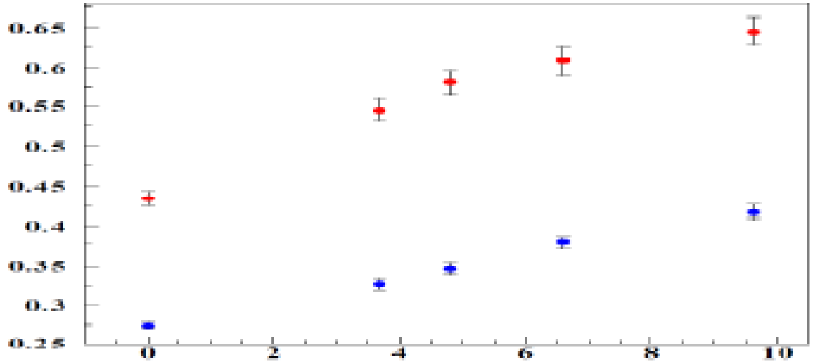
E_{jet}=180Ge

- Using SiD Cost Model, find R, B, and λ (= 4.3N/40) which minimize cost for a given $\Delta E_{jet}/E_{jet}$.



- Use Tim Barklow's study of ZHH, which gives $\Delta g/g$ vs $\Delta E_{jet}/E_{jet}$.

$$\frac{\Delta g_{hhh}}{g_{hhh}}$$



$$\frac{\Delta E_{jet}}{E_{jet}} \equiv \frac{\alpha_{90}}{\sqrt{80}} \quad (\%)$$

Is Mark's Parameterization valid for SiD?

- Marcel Stanitzky has studied a SiD-like detector, SiDish, using Mark's Pandora PFA program.

  SiDish has dimensions and aspect ratio appropriate for SiD, but still has TPC tracking, the LDC Ecal, and Scintillator/Fe Hcal.

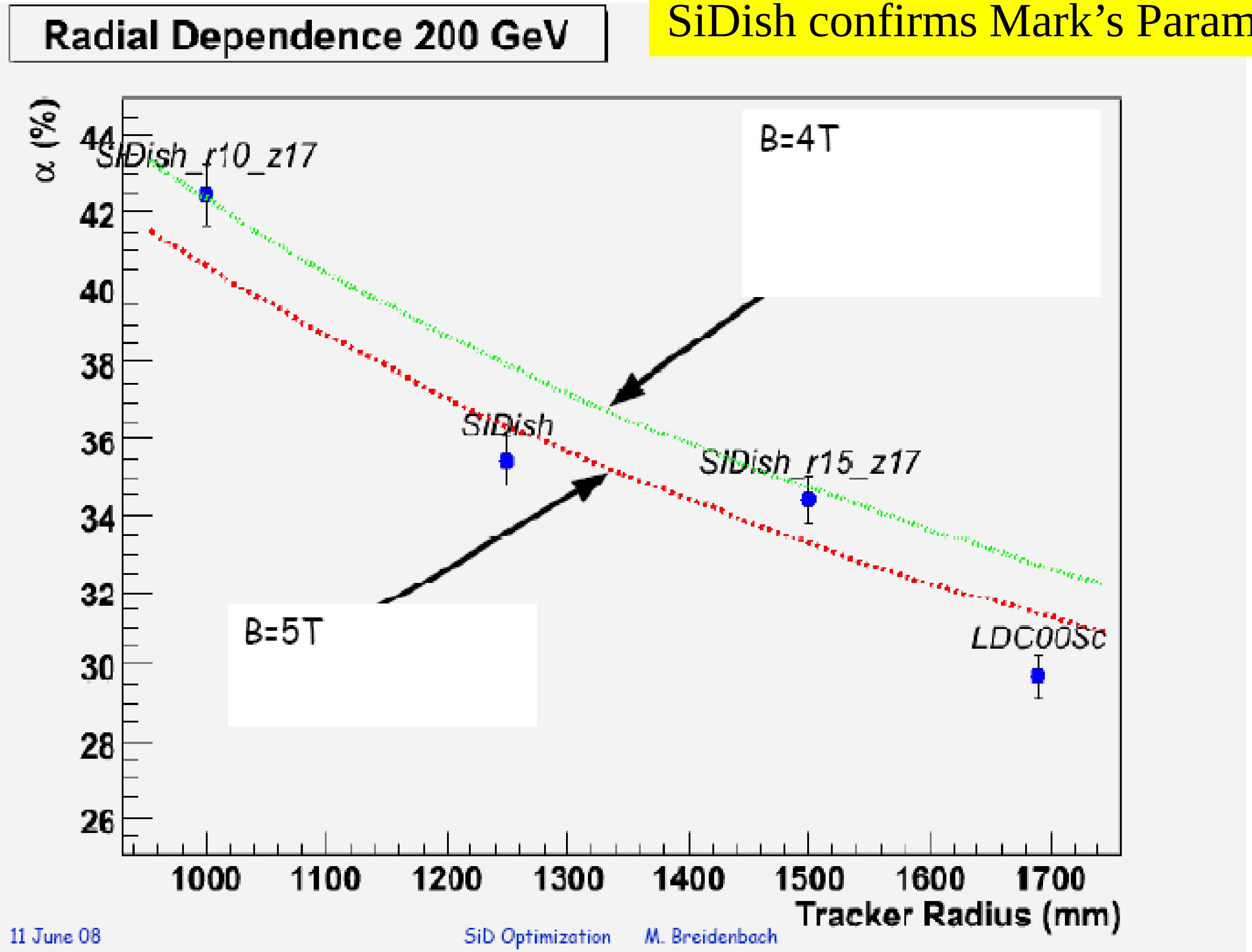
  - Tracker radius=1.25m
  - Tracker Z=1.7 m
  - ECAL SiW 20+10 layers, 1x1 cm tiles
  - HCAL Fe-Scint 40 layers 3x3 cm tiles
  - Same Calorimeter layout as LDC00Sc (besides ECAL 30+10->20+10)
  - 5 T Field

- Does the performance of SiDish agree with Mark's parameterization?

- How well does the performance of SiDish reflect what the performance of SiD will be?

Using Mark's scaling Law

SiDish confirms Mark's Parameterization



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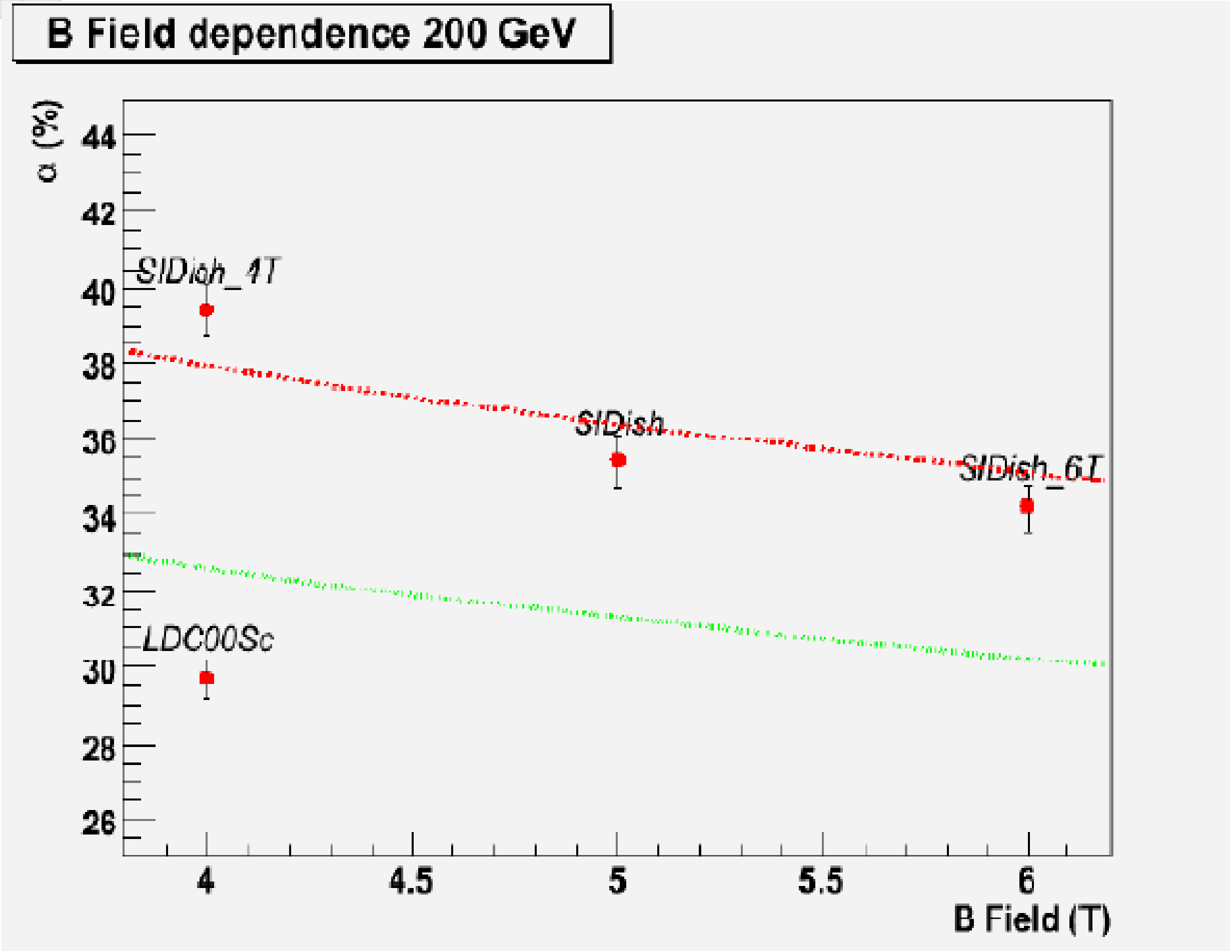


B Field dependence 200 GeV
α (%)
44
42
40
38
36
34
32
30
28
26
SIDish_4T
SIDish
SIDish_6T
LDC00Sc
4
4.5
5
5.5
6
B Field (T)

SiD = SiDish HCal issues?

No, but we can estimate how large the differences are.

- SiD's Fe/RPC's might under-perform SiDish's Fe/scintillator. The RPC response is not yet optimized, and the pixel sizes are different). Both Mark and Marcel see small effects in present Pandora:

Scintillator

RPC

Detector	91 GeV		200 GeV	
	α %	Error	α %	Error
LDC00Sc	24.6	0.3	29.7	0.5
LDC00	27.0	0.5	31.7	0.6
SIDish	27.9	0.4	35.4	0.7
SIDish_rpc	31.7	0.5	38.9	0.7

ΔE/E might be as much as 10% worse
Or it might be better. Needs optimized PFA.

SiD = SiDish EMCal Issues?

- The SiDish ecal is a 20+10 version of the LDC ecal, total 20 X_0, with 1.4 mm and 4.2 mm W radiator thicknesses.
  SiD's EMcal is also 20 + 10, but with 2.5mm and 5.0mm radiator thicknesses, totaling 29 X_0.

Detector Tag	Radiator Thickness	Layers	X_0	uds (91 Gev) α %	uds (91 Gev) Error	uds (200 GeV) α %	uds (200 GeV) Error
SIDish	1.4/4.2 mm	20+10	20	27.9	0.4	35.4	0.7
SIDish_ecal40	1.4/4.2mm	30+10	24	27.1	0.5	33.9	0.6
SIDish_ecal_eq37	1.41 mm	37	15	28.1	0.4	37.6	0.6
SIDish_ecal25_50	2.5/5.0 mm	20+10	29	27.3	0.4	35.1	0.6

SiDish and SiD Ecals roughly equivalent for PFA,
For the cases studied. No use was made of the smaller SiD pixels. SiDish and not SiDish_ecal_25_50 was used in subsequent studies..

SiD = SiDish Tracking Issues?

- Mark Thomson, in his talk at the SiD RAL meeting, stressed the importance of TPC pattern recognition to recognize V0's, decays, interactions, and loopers.
- He indicated ~ 3% (absolute) improvement in the jet energy resolution parameter α, corresponding to ~ 10% improvement in $\Delta E/E$ after a lot of homework.
- Two differences between LDC and SiD could be significant for Pandora:
  - Amount of material in the tracking volume (which needs more study)
  - Differences in pattern recognition capability.

$\Delta E/E$ could be worse by 10% (upper limit)

New Input for PFA Optimization

- Tim Barklow has redone his fast MC study of measuring the triple higgs coupling, assuming a more realistic jet energy resolution distribution, and assuming the jet energy resolution $\Delta E/E$ is constant vs energy, not ~ $\alpha/\sqrt{E}$. He's added an analysis of the error in the chargino mass vs $\Delta E/E$ too.

- Use Mark's parameterization for α appropriate for 100 GeV jets, to select R, Z, and lambda for a given resolution:.

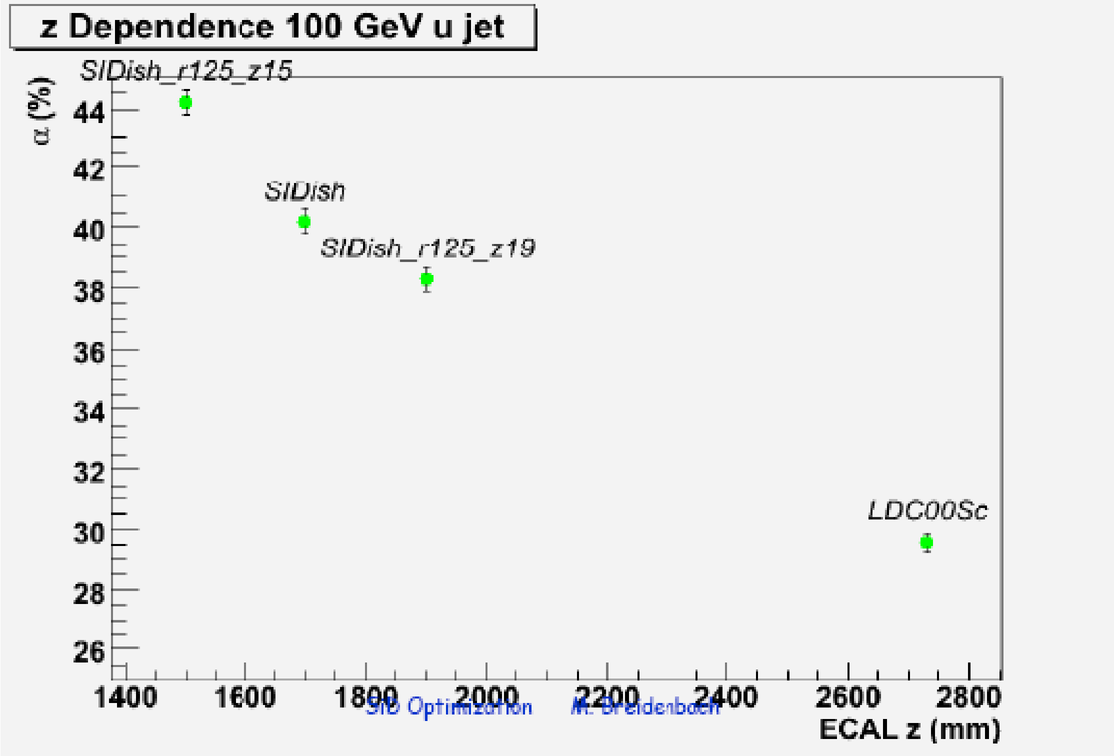
$$\alpha = 0.315 \left(\frac{B}{4}\right)^{-0.19} \left(\frac{R}{1.68}\right)^{-0.49} (1 + 6.3e^{-\frac{N}{8.0}})$$

- Use Marcel's study of SiDish performance vs Z_{ecal} for forward jets, to select Z_{ecal} so as to match jet energy resolution in the endcap with that in the barrel (at 100 GeV)

Jet Energy Resolution vs Z for Forward Jets (cos θ = 0.92)

M. Stanitzki

Detector Tag	u (50 GeV) α %	u (50 GeV) Error	u (100 GeV) α %	u (100 GeV) Error	u (250 GeV) α %	u (250 GeV) Error
SIDish	39.9	0.4	40.2	0.4	69.1	0.2
LDC00Sc	32.0	0.3	29.6	0.3	79.8	0.8
SIDish_r125_z15	43.4	0.4	44.2	0.5		
SIDish_r125_z19	38.9	0.4	38.3	0.4		



New Input for Δg/g vs ΔE/E

T. Barklow

Analysis has now been redone with $\frac{\Delta E_{jet}}{E_{jet}}$ that reflects current PFA status

triple Higgs coupling error vs. genuine $\frac{\Delta E_{jet}}{E_{jet}}$ is plotted in BLACK

BR(H → bb)=0.678

$e^+e^- \to ZHH$

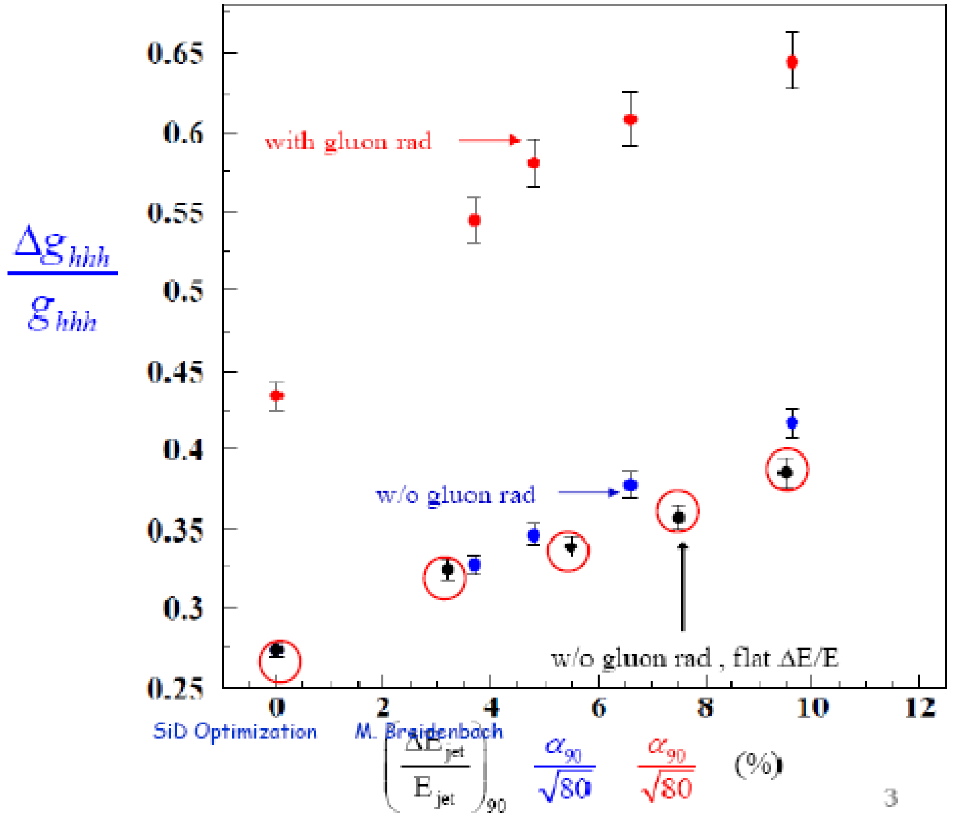
$\to qqb\bar{b}b\bar{b}$

$\sqrt{s} = 500\ GeV$

$L = 2000\ fb^{-1}$

$\Delta E_{jet}/E_{jet} = .06 \to .03$

equiv to $1.2\times$ Lumi



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T. Barklow

New Process: Chargino Mass vs ΔE/E

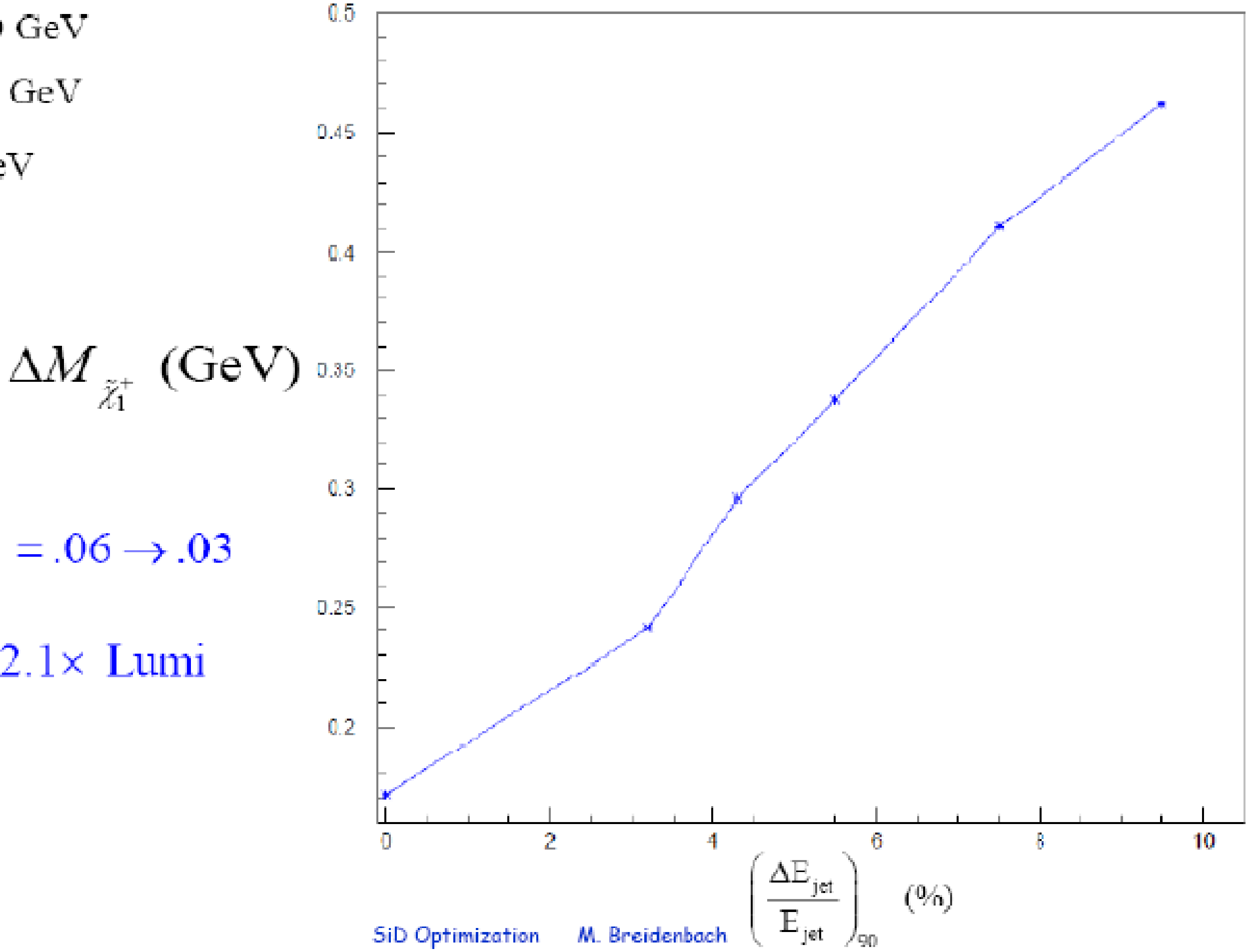
$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 qqqq$$

$M_{\tilde{\chi}_1^-} = 200.0$ GeV

$M_{\tilde{\chi}_1^0} = 106.2$ GeV

$\sqrt{s} = 500$ GeV

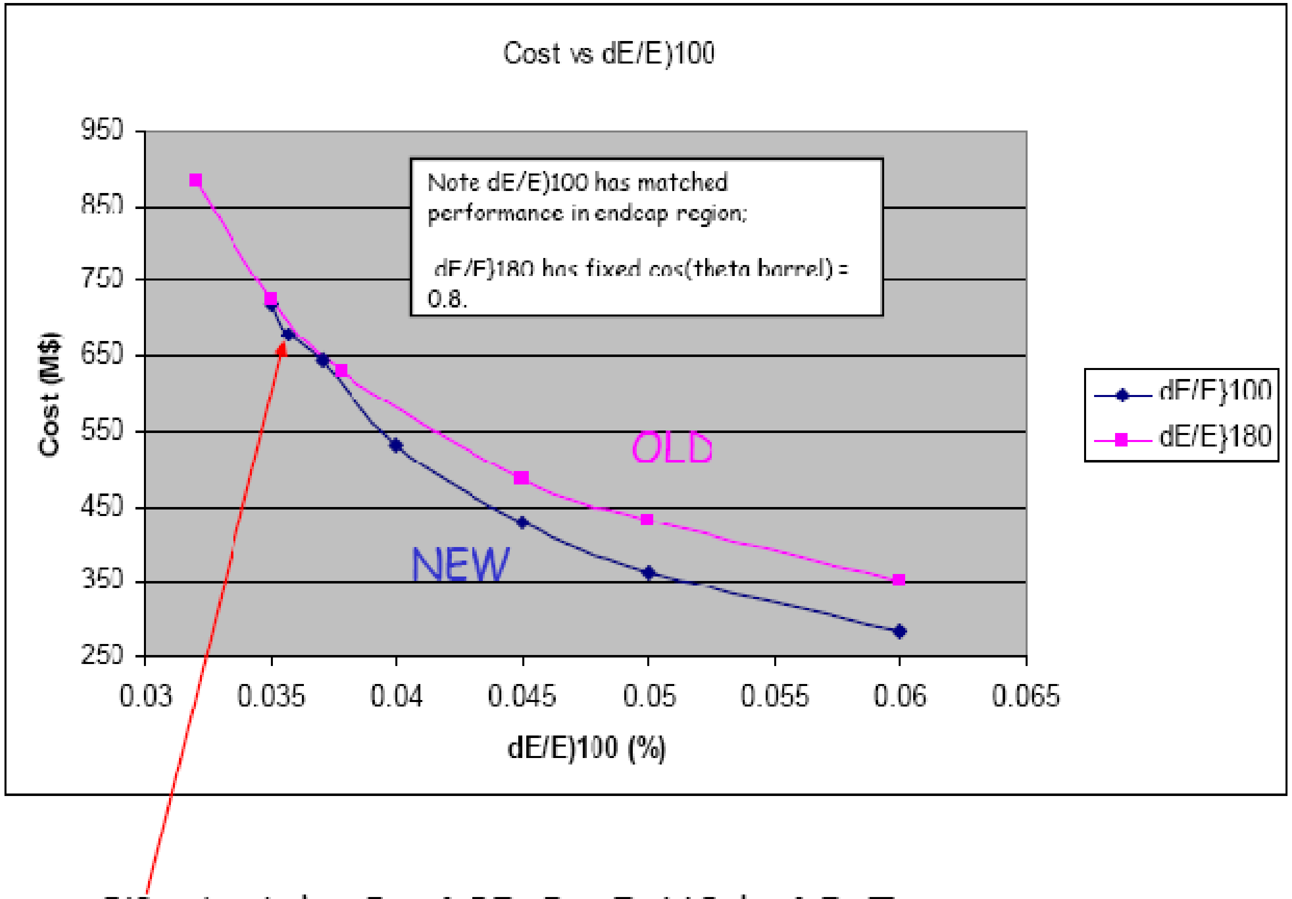
$L = 500\ fb^{-1}$



$$\left(\frac{\Delta E_{jet}}{E_{jet}}\right)_{90} = .06 \rightarrow .03$$

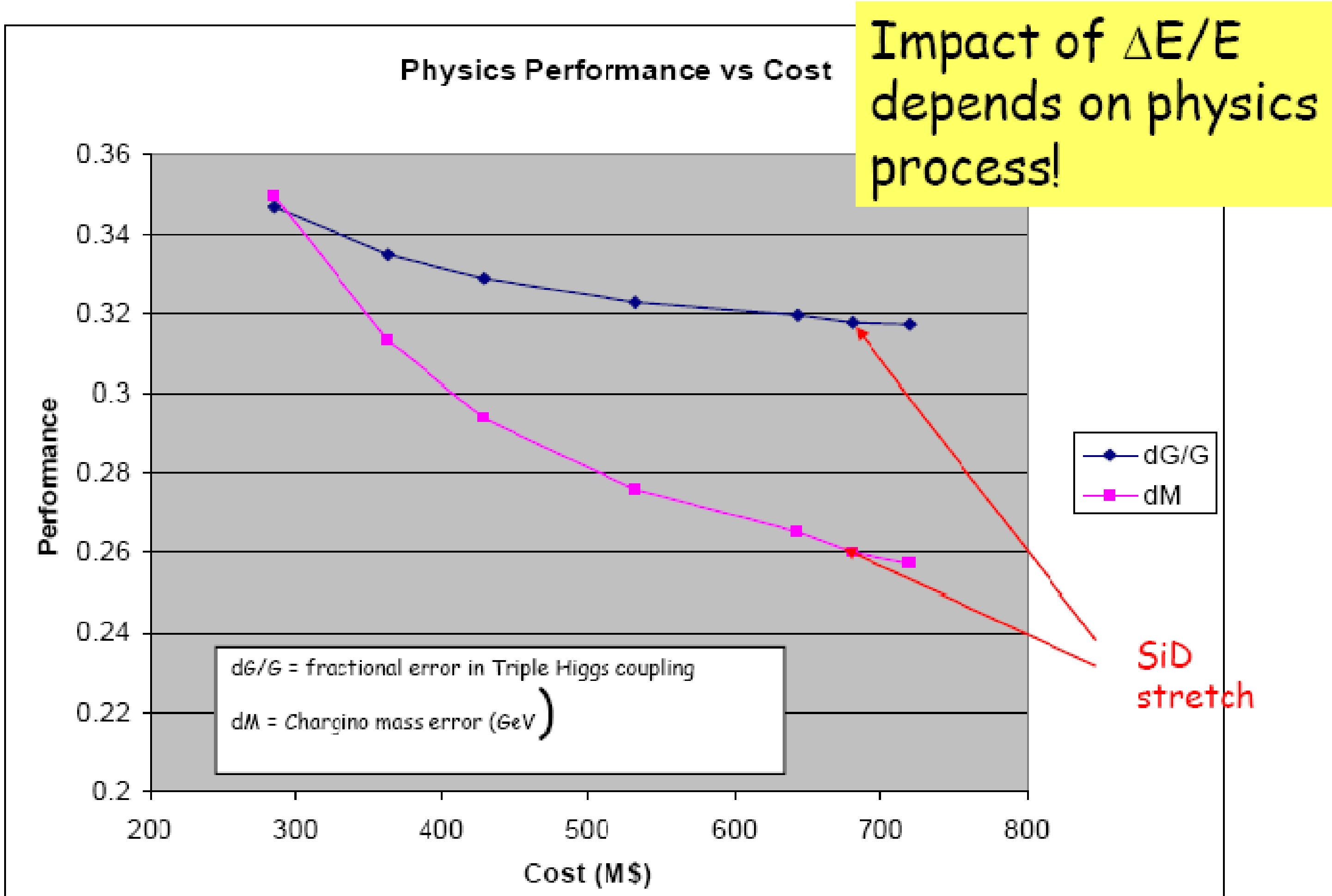
equiv to $2.1\times$ Lumi

Cost vs ΔE/E Old and New



SiD stretch - R = 1.25, B = 5, HCal =4.5, Z = 2.05

Bottom Line



Physics Performance vs Cost
Impact of ΔE/E depends on physics process!
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
Performance
200
300
400
500
600
700
800
Cost (M$)
dG/G
dM
dG/G = fractional error in Triple Higgs coupling
dM = Chargino mass error (GeV)
SiD stretch

New since Warsaw

- Marty's Warsaw talk summarized status mid June.
- Marcel has studied z dependence at 91, 200, 500 GeV.

  Effects seen at 200 are also seen at other energies, and are expected naively.

  They indicate SiD should be longer than nominal 1.7 m (to endcap ECAL front face).

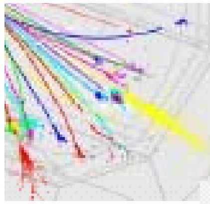
- Marcel has studied N and lambda dependence around the SiD nominal global params (5T, 1.25m) at 100 GeV jet energy.

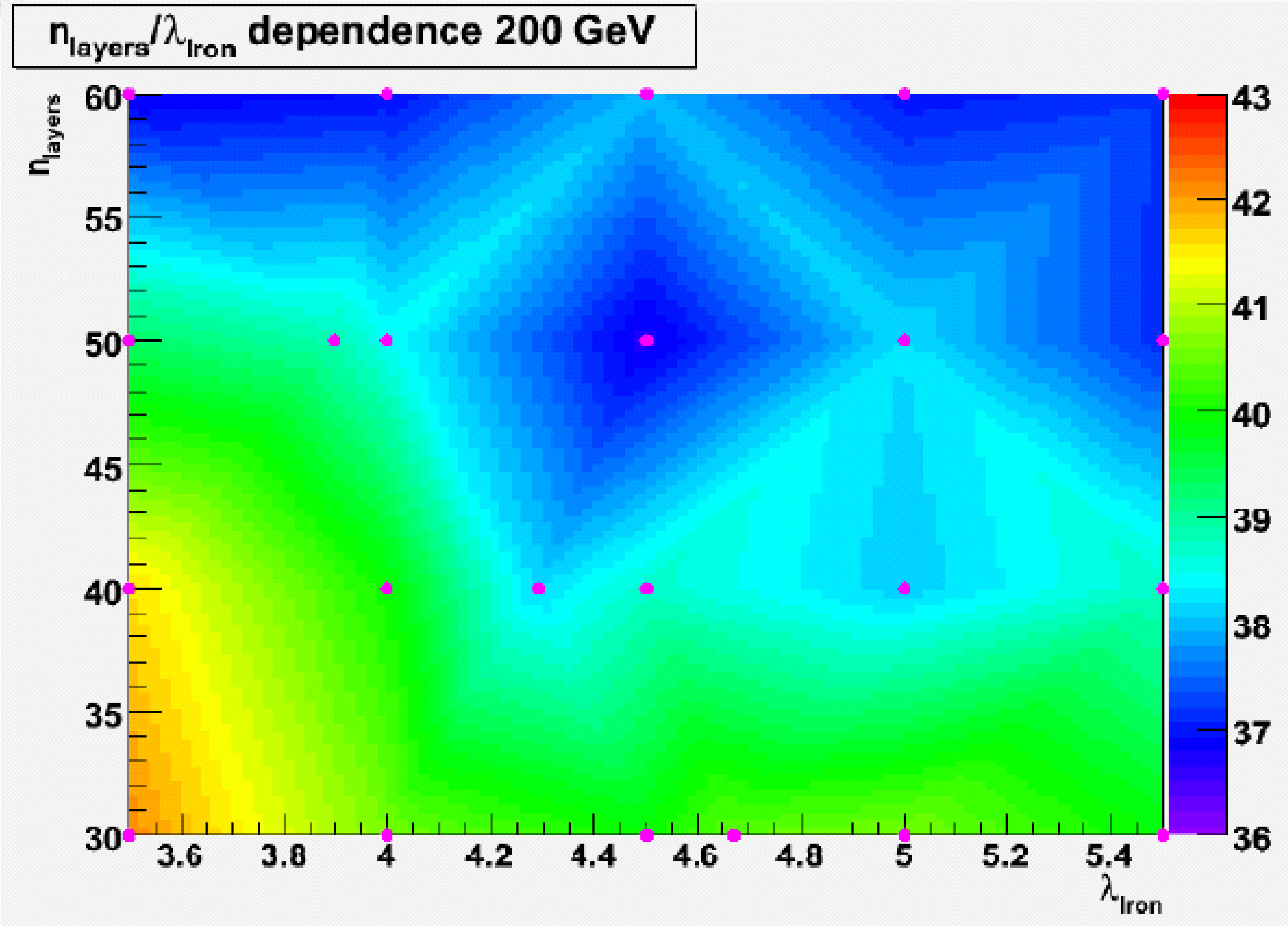
  Very little improvement beyond 4-4.5 lambda

  Increasing N compensates for decreasing lambda. It turns out that these changes are roughly flat in cost, and the total thickness of the HCAL is about 1.2m for various combinations.

  Conclude that 4.5 lambda and 40 layers is reasonable.

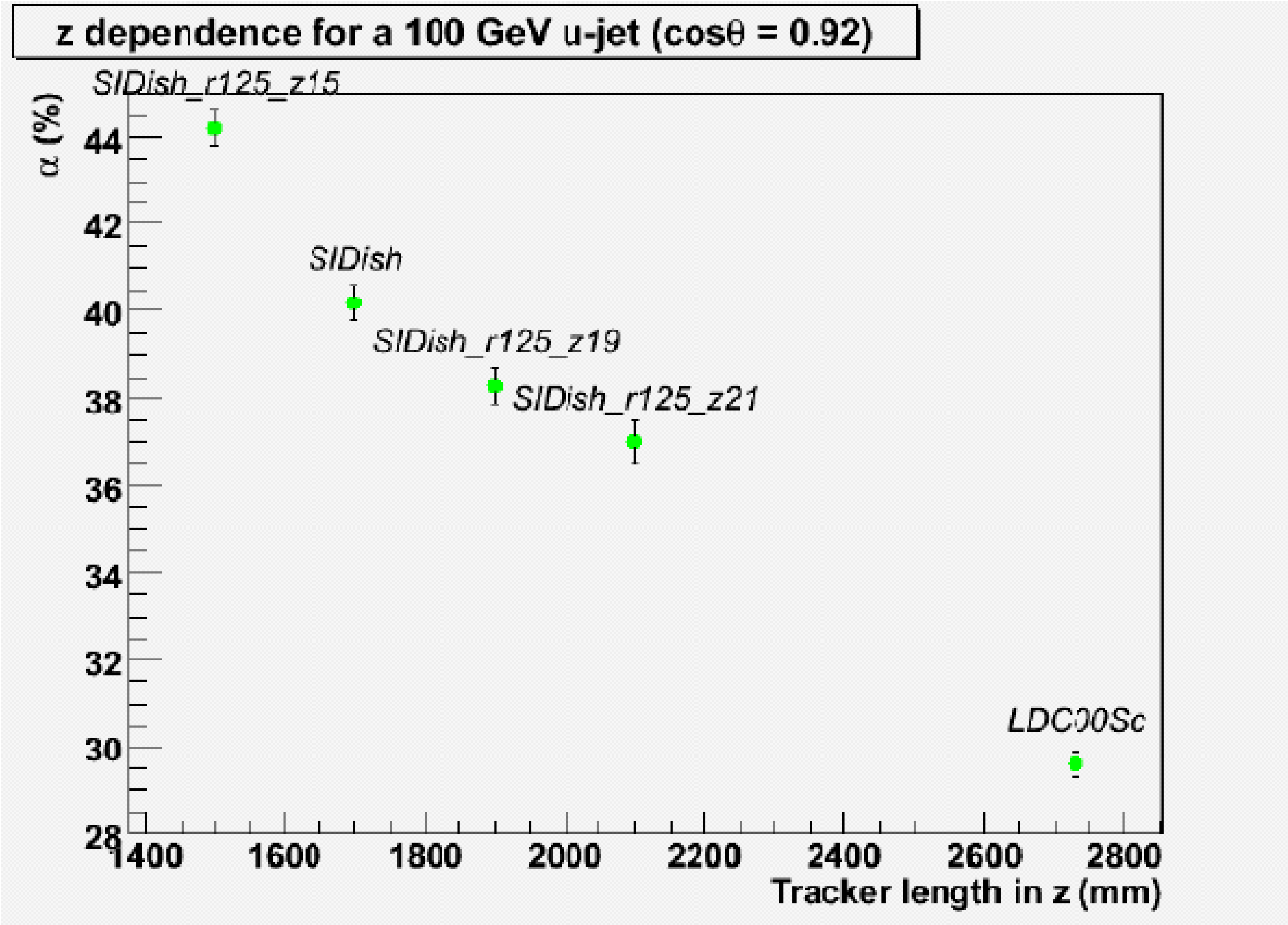
200 GeV

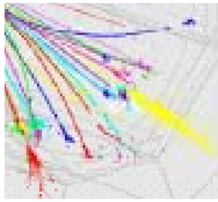




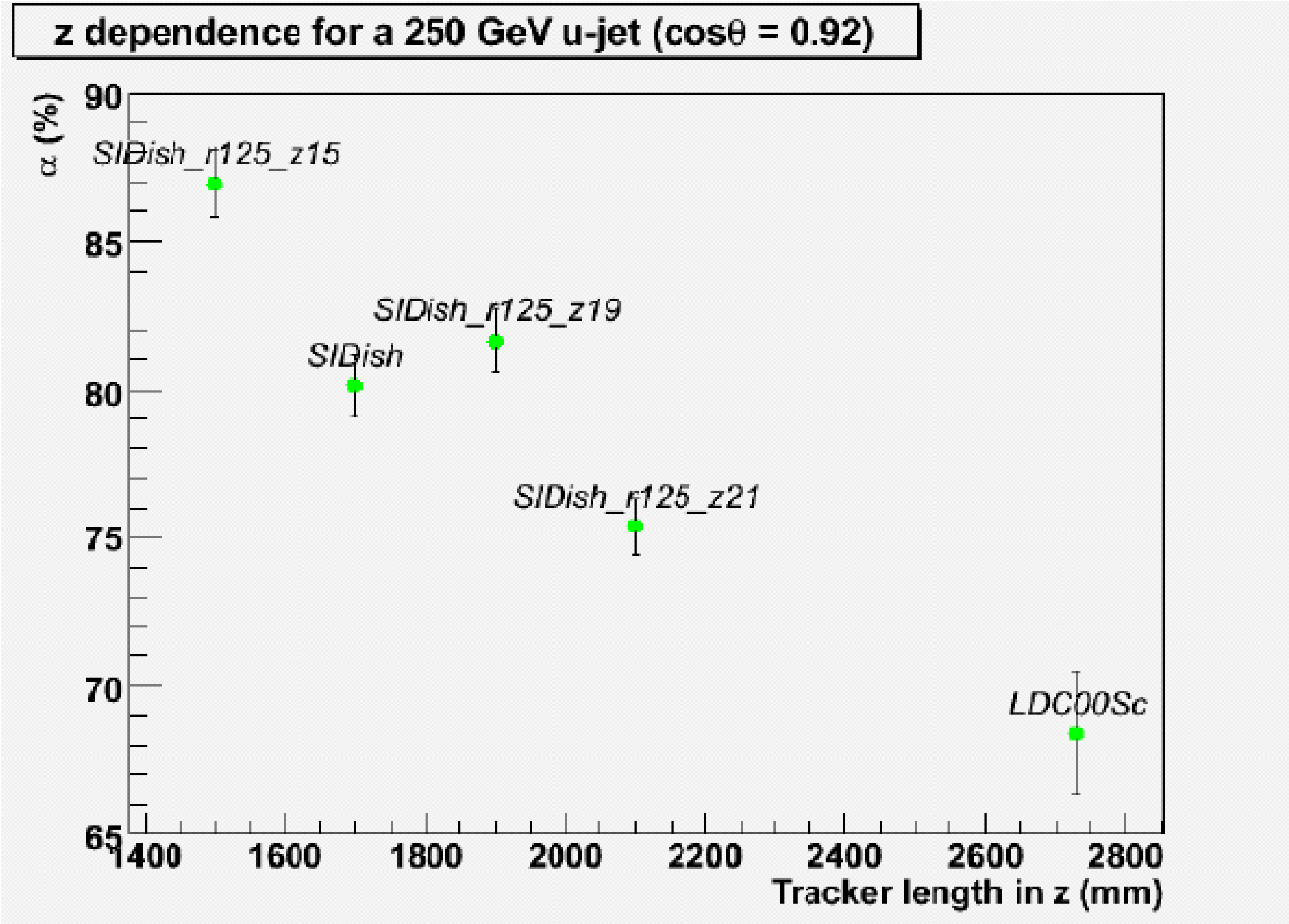
n_layers/λ_Iron dependence 200 GeV
n_layers
60
55
50
45
40
35
30
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
λ_Iron
43
42
41
40
39
38
37
36
α

z dependence 100 GeV





z dependence 250 GeV



Rationale for SiD' from Marty

An attempt has been made to provide an intellectually sound basis for SiD's parameter choices based on showing that the detector performance, defined as the errors in a significant set of physics measurements (for fixed luminosity), is below an inflection point in a plot of detector cost versus performance.

The most charitable evaluation of this effort that can be made is that it has started; and indications are that the baseline SiD is already on the wrong the side of the knee, but that its performance is more than adequate for the physics . There remain many caveats that have been discussed regarding both cost estimation, the maturity of the PFA, and the applicability of Pandora to the SiD design. Decisions are needed now to proceed with the LOI.

Radius

- Set Rtrkr = 1.25 m.

  There is no momentum measurement argument for larger, and the PFA indicates performance beyond cost optimal for the physics. The tracker group will resist going smaller, but this is what is likely to happen if we are forced to lower the detector cost.

B Field

- Set B = 5 T.

  This provides superb momentum resolution and background control for the VXD. More subtly, the PFA parameterization of Mark Thompson, which approximately saturates performance at 4.5 λ HCal, indicates cost optimal performance at 5 T. The recent results from M. Stanitzki, which vary lambda and number of layers around the SiD nominal global parameters, may indicate lower B could be optimal. But these results haven't explicitly included the effects of varying B or tracker radius, so may not be applicable, and in any case aren't yet conclusive. Finally, 5 T is as high as seems rational for a solenoid of this size.

Hcal

- Set HCal λ radiator = 4.5.
  Both the Thompson and Stanitski work favor 4.5 over 4.0, and the cost penalty is relatively modest. Let the radiator be stainless steel, although this choice over cartridge brass must be revisited.
- Set HCal Nlayers = 40.
  Stanitzki's results indicate a complete tradeoff between number of layers and thickness in this parameter neighborhood, and the detector cost is also a good balance between layers and total radiator thickness

Z (Endcap Ecal)

- Set the front face of the Endcap EMCal at Z = 2.1 m. Based on the Stanitzki work, this balances the PFA performance between the barrel and endcap. This is an increase in detector half-length of 40 cm. Preliminary engineering studies indicate:
  - L* can remain at 3.5 m, and the support situation for QD0 is slightly improved.
  - The arrangement of the forward calorimeters and masks is still satisfactory.
  - The increase in detector length is easily compensated by changes to Pacman, leaving the hall unchanged.
  - The mechanical concepts for the barrel EMCal and HCal are unaffected.
  - The barrel tracker concept should be ok, but will need work.
  - There is some question about the beampipe and support of the VXD that is not yet resolved.

Cost

- Thus the major remaining question is about the detector cost. In US accounting, the inflation rate and start date must be specified. The inflation rate used to date is 3.5% for both labor and M&S; this may be very optimistic, perhaps a factor of 2 for M&S. Previously, the start date has been 2012; this now seems irrational and 2016 is the new goal. The bottom line is $795M. As a fraction of the ILC cost, this is possibly ok. As an absolute number of dollars to be funded significantly by the US, it probably is not. As a fraction of a lower cost linear collider, it seems steep.