THE INTERNATIONAL LINEAR COLLIDER

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Outline

- Why the ILC?

- The Accelerator – tremendous progress towards TDR

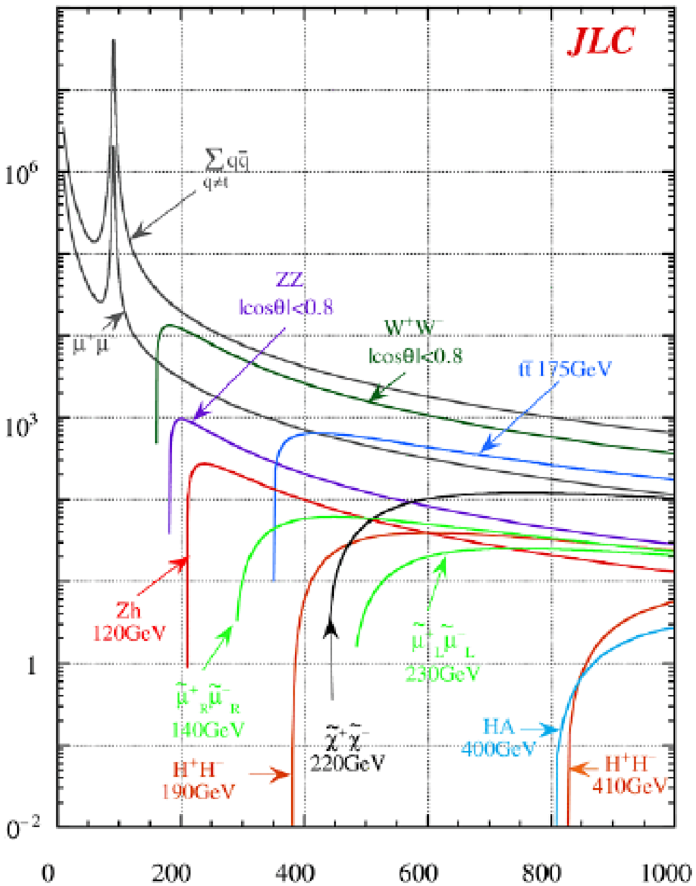
- The Detector Concepts – much R&D towards the DBD's

- The ILC Physics – an evolving picture!

Motivation: Why the ILC?

Exploit full range of physics with 500 GeV – 1 Tev
e^+e^- collisons: "The Electroweak Scale"

Cross-section in fb.

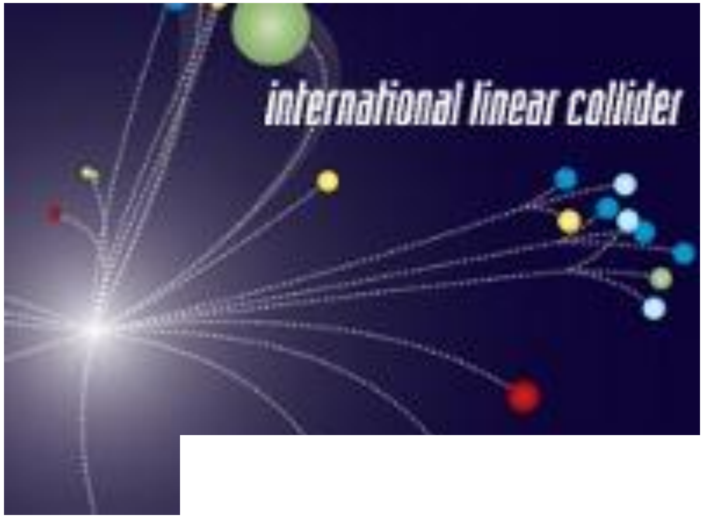


√s in Gev

<u>Michael Peskin – Nov. 2010</u>

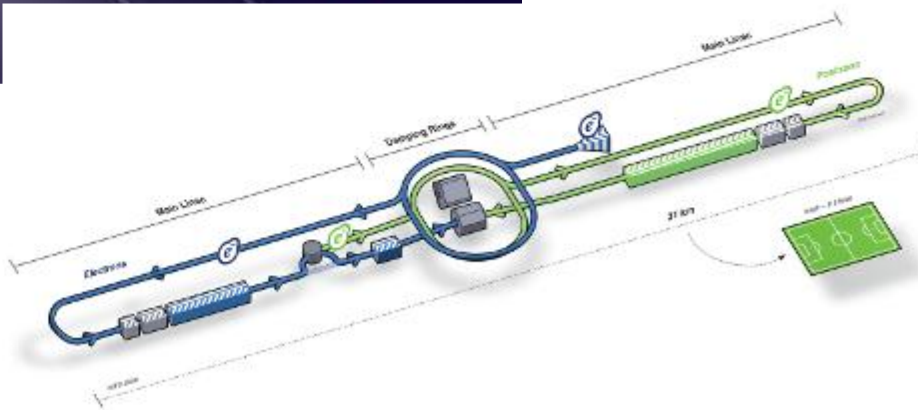
1. Precision measurements of $e^+e^- \to f\overline{f}$
   relevant to Z' models, extra dimensions, compositeness
2. Precision measurements of $e^+e^- \to W^+W^-$
   relevant to strongly interacting Higgs sectors
3. Precision measurements of m_t and $e^+e^- \to t\overline{t}$
   relevant to precision electroweak and/or
   strongly interacting sectors with Higgs and top
4. Precision measurements of the Higgs boson couplings
   testing whether this particle actually gives 100% of the
   mass of all quarks, leptons, and bosons
5. And, for any new particles discovered or suggested by LHC
   their detailed characterization and measurement of
   quantum numbers -- and relevance to cosmic dark matter

…so the ILC accelerator and detector groups have been working to meet these potential physics opportunities.



2004 -> decision to use superconducting RF

2005 -> Global Design Effort (GDE) started

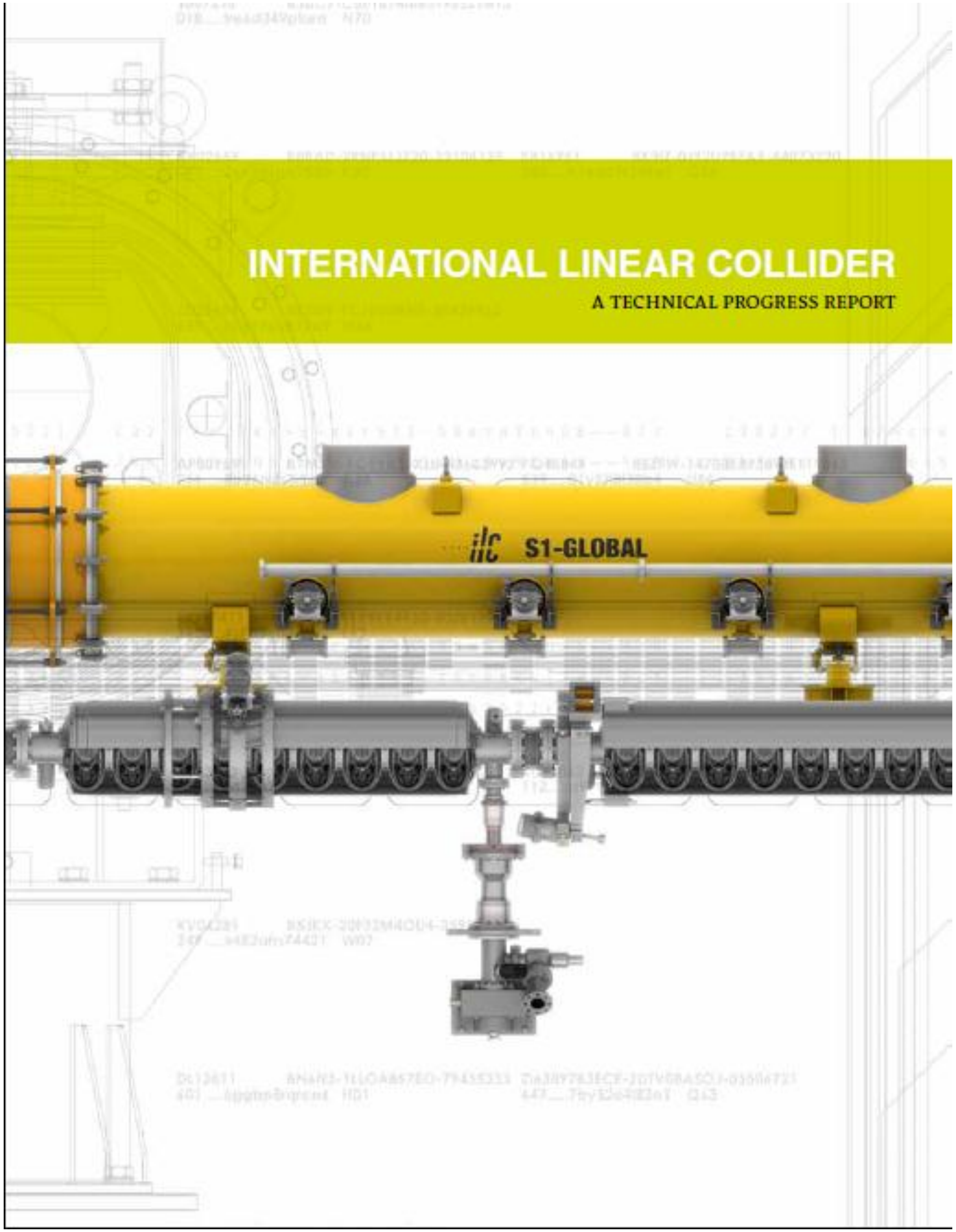


Focus on recent developments…

The ILC Interim Report

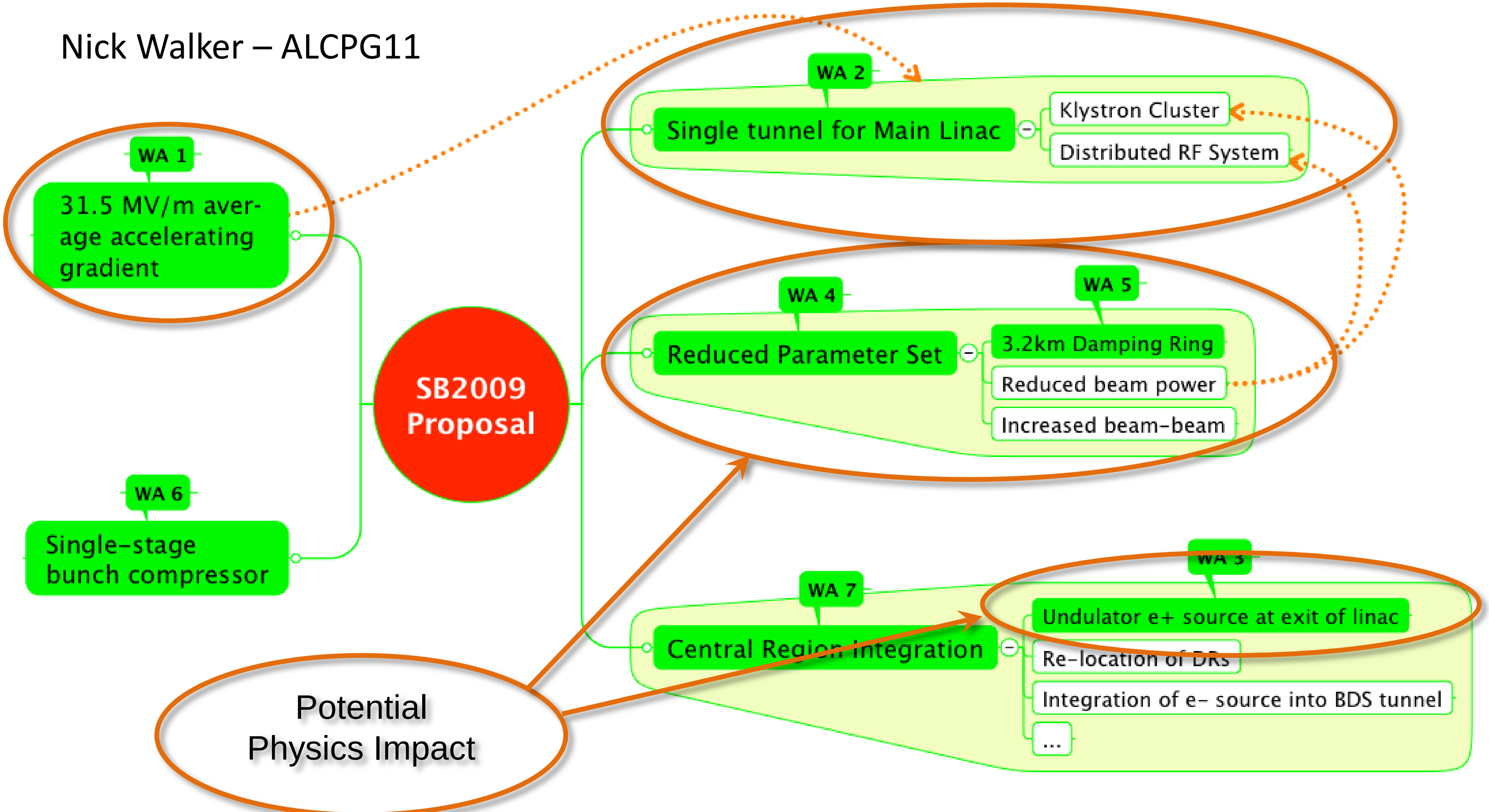
Documents the evolution of the ILC design from the Reference Design Report (RDR – 2007) to the modified baseline design for the TDR (2012).

Motivations: risk-mitigation, cost reduction (off setting potential future cost increases).



The SB2009 Proposal and Areas of Potential Physics Impact

Nick Walker – ALCPG11



The physics impact of the design changes were discussed during **two BAW (Baseline Assessment Workshops)** attended by accelerator designers and detector concept reps.

SB2009 Working Group – chaired by Jim Brau – iterated on GDE proposals during 2010 – modified ILC parameters -> discussed at BAW 1 & 2

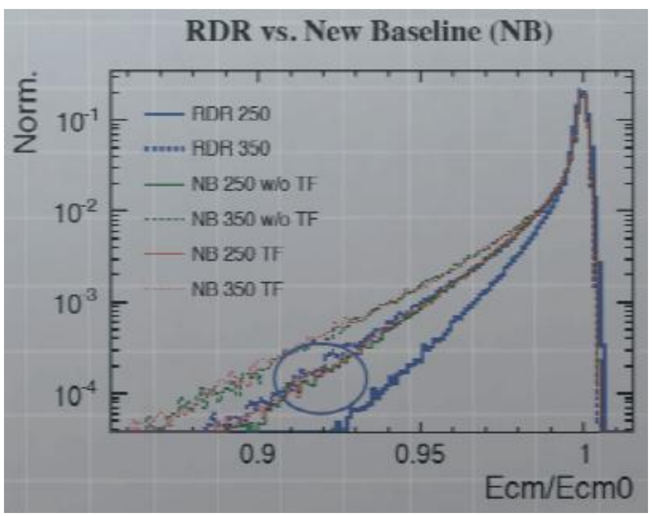
BAW-1: (KEK) ML Accelerator Gradient - Summary of Discussions and Proposal

As a result of the workshop discussions, we propose keeping our best effort to realize a ML accelerator operational gradient of ≥ 31.5 MV/m with Q0 ≥ 1E10, on average, with a gradient spread of not larger than ±20%. Plus adopt single tunnel main linac.

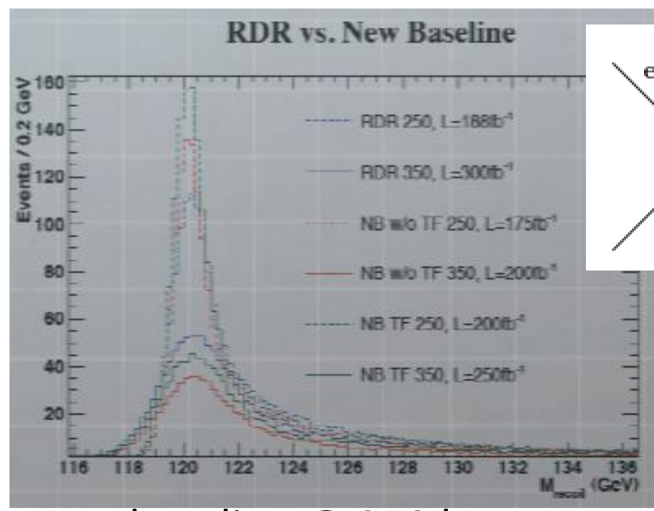
BAW-2: (SLAC) Reduced beam-power parameter set and the location and layout of the positron source.

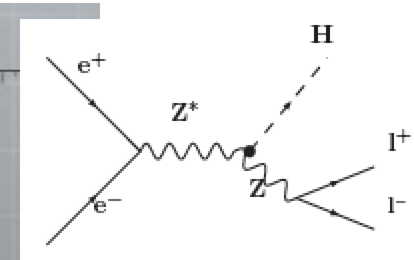
Move of the positron source systems from mid-linac (RDR design) to the end of the linac, overlapping and sharing tunnels with part of the beam delivery system.

Physics impact of new parameter set – examples (Higgs)



New baseline supplies significantly more integrated luminosity at low E





New baseline @ 250 has narrower peak than RDR @ 250 : smaller beam energy spread

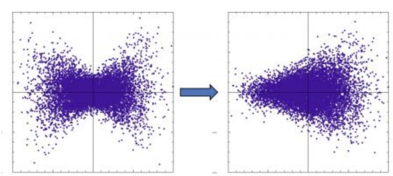
Hengne Li / LPCS

Key concern with SB2009: Energy Scans – more luminosity needed at low E.

Now addressed by new parameter set:

ILC Parameters

Adjustment of the longitudinal position of the focal point (optical waist) of individual longitudinal segments of the bunch effectively compensates the luminosity diluting effects of the hourglass effect.



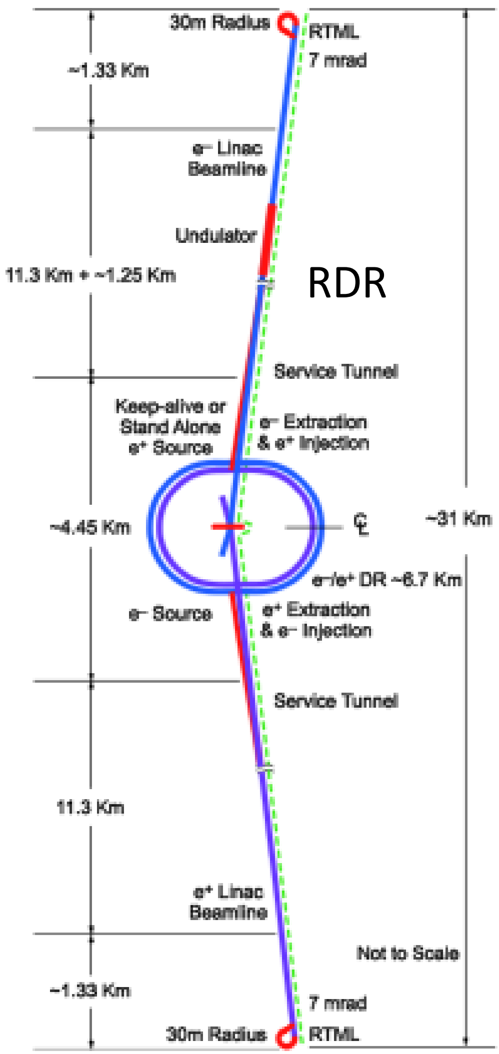
Centre-of-mass energy	E_{cm}	GeV	200	230	250	350	500	upgrade 1,000
Collision rate	f_{rep}	Hz	5	5	5	5	5	4
Electron linac rate	f_{linac}	Hz	10	10	10	5	5	4
Number of bunches	n_b		1,312	1,312	1,312	1,312	1,312	2,625
Electron bunch population	N_-	$x10^{10}$	2	2	2	2	2	2
Positron bunch population	N_+	$x10^{10}$	2	2	2	2	2	2
Main linac average gradient	G_{av}	MV/m	12.6	14.5	15.8	22.1	31.5	>31.5
RMS bunch length	σ_z	Mm	0.3	0.3	0.3	0.3	0.3	0.3
Electron RMS energy spread	$\Delta p/p$	%	0.22	0.22	0.22	0.22	0.21	0.11
Positron RMS energy spread	$\Delta p/p$	%	0.17	0.15	0.14	0.1	0.07	0.04
Electron polarisation	P_-	%	80	80	80	80	80	80
Positron polarisation	P_+	%	31	31	31	29	22	22
IP RMS horizontal beam size	σ_x^*	nm	904	843	700	662	474	554
IP RMS vertical beam size	σ_y^*	nm	9.3	8.6	8.3	7	5.9	3.3
Luminosity	L	$\times 10^{34}\ cm^{-2}s^{-2}$	**0.47**	**0.54**	**0.71**	**0.86**	**1.49**	**2.7**
Fraction of luminosity in top 1%	$L_{0.01}/L$		92.20%	89.80%	84.10%	79.30%	62.50%	63.50%
Average energy loss	δE_{BS}		0.61%	0.78%	1.23%	1.75%	4.30%	4.86%
IP RMS vertical beam size	σ_y^*	nm	6	5.6	5.3	4.5	3.8	2.7
Luminosity	L	$\times 10^{34}\ cm^{-2}s^{-2}$	**0.64**	**0.73**	**0.97**	**1.17**	**2.05**	**3.39**
Fraction of luminosity in top 1%	$L_{0.01}/L$		91.60%	89.00%	83.00%	77.90%	60.80%	62.30%
Average energy loss	δE_{BS}		0.61%	0.79%	1.26%	1.78%	4.33%	4.85%

Using Travelling Focus (last four rows)

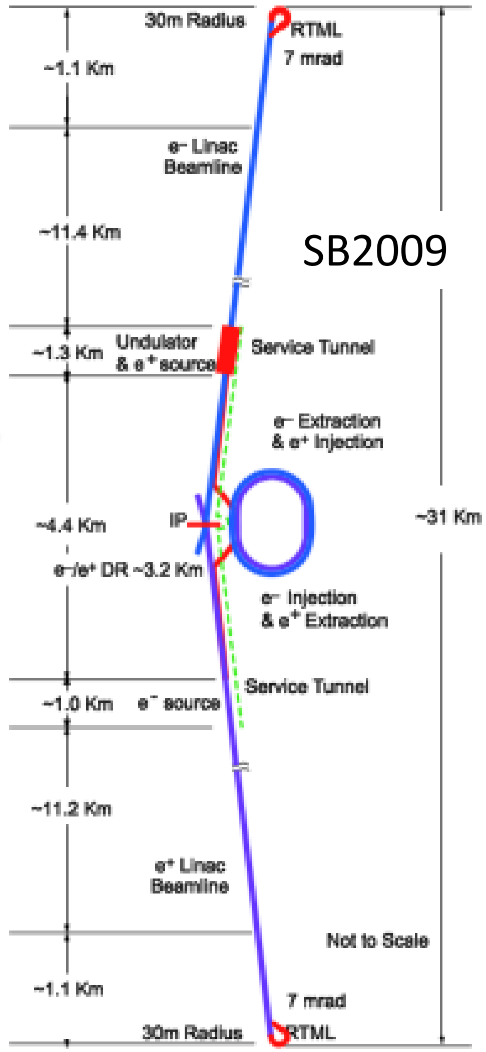
RDR Luminosity @ 500 GeV was 2 x 10^{34} $cm^{-2}s^{-1}$

Evolution of the ILC Accelerator Design

2007 RDR



2011 TDR



Principal changes

- Single tunnel solution for main linac + new RF generation and distribution schemes

- #bunches/pulse reduced from 2625 to 1312 to save cost (reduced RF power, smaller damping rings). Luminosity won back by traveling focus.

- Move positron source undulator to central region.

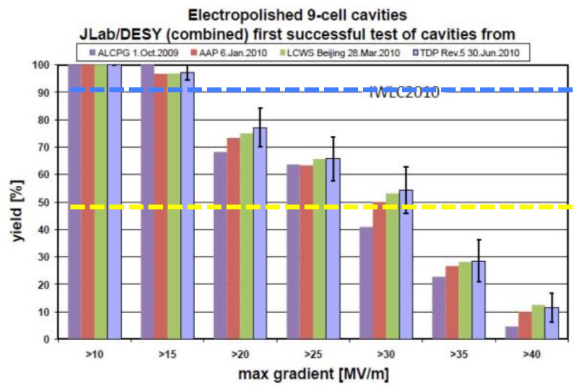
Retain flexibility to adapt design to new (LHC) results

Superconducting RF

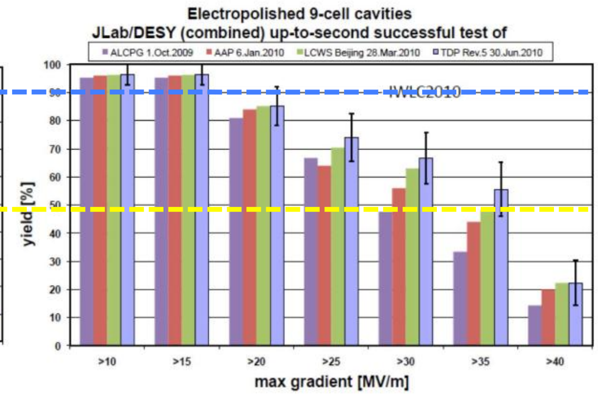
Goals for Technical Design Phase:

35 MV/m or higher with 90% production yield

TDP-1:



1st pass



2st pass

TDP-2 further cavity processing optimization:

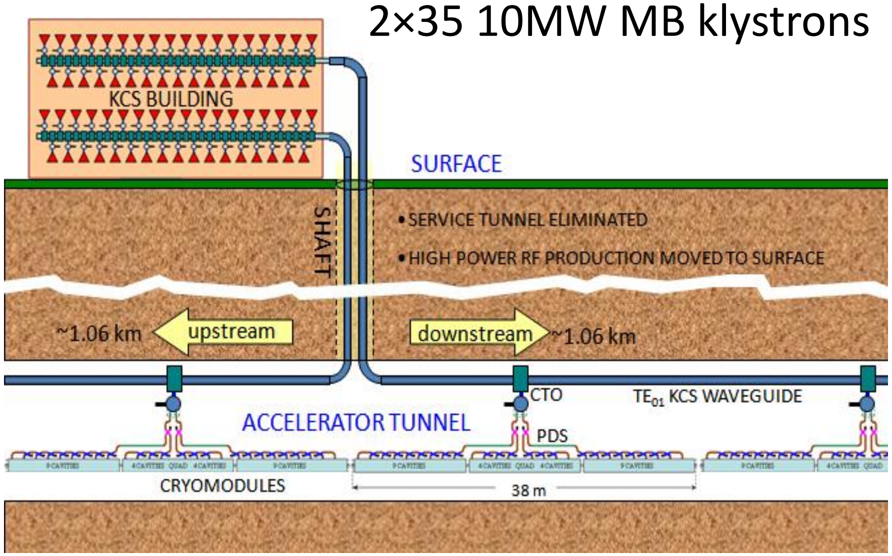
Joint effort	Progress
Research Instruments-JLab	Achieved 90% yield at ≥35 MV/m and Q_0 ≥8x10[9]
Research Instruments-Fermilab/ANL/JLab	Achieved ≥35 MV/m and Q_0≥8x10[9]
Research Instruments-Fermilab/ANL	Achieved 34.5 MV/m with tumbled cavity

Yield demonstrated on limited sample!

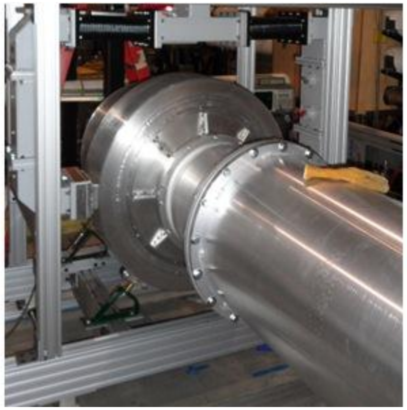
- Qualification of SCRF cavity vendors in each region
- Cryomodule production/beam testing
- 5 ILC cryomodules + 80 for XFEL to be built by 2014

High-Level RF Solutions (one Tunnel)

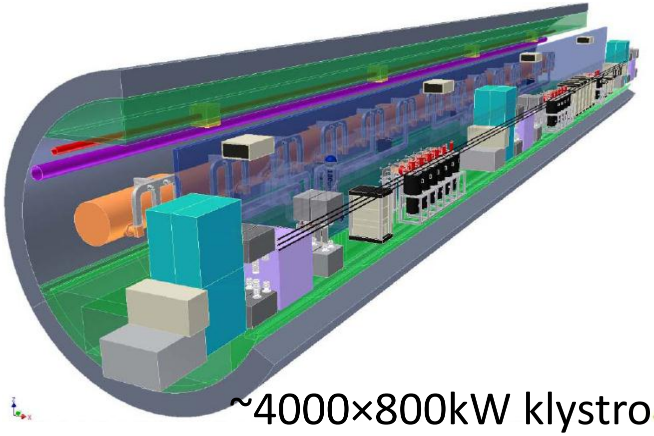
2×35 10MW MB klystrons



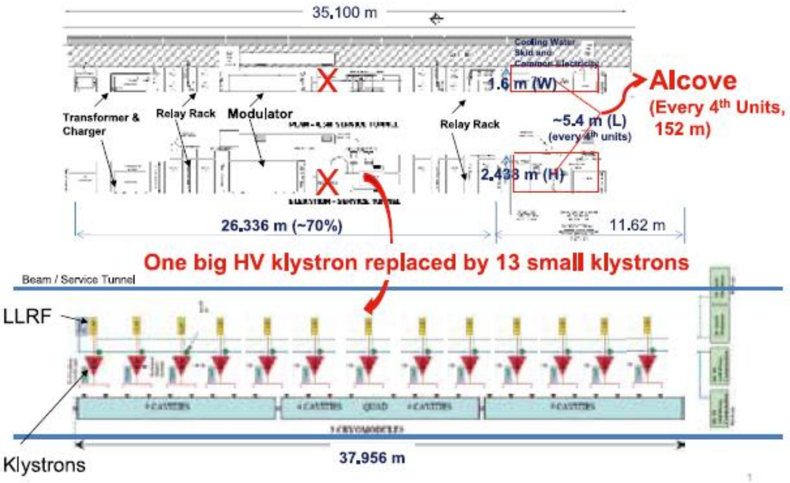
Klystron Cluster Scheme, KCS (SLAC)



Distributed RF Sources, DRFS (KEK demonstration)



~4000×800kW klystrons



Other major ILC Accelerator R&D efforts

- Systems Integration – string tests (DESY-TTF, FNAL-NML, KEK-STF)

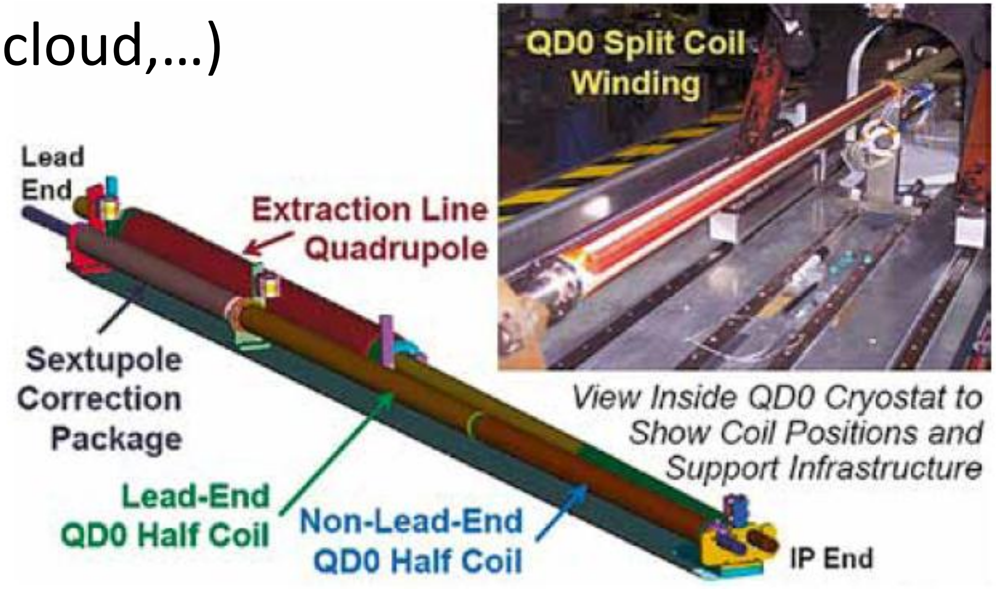
- Electron cloud control – emittance growth, beam instabilities.
  (low secondary emission coating (TIN), clearing electrodes)

- e+, e- sources

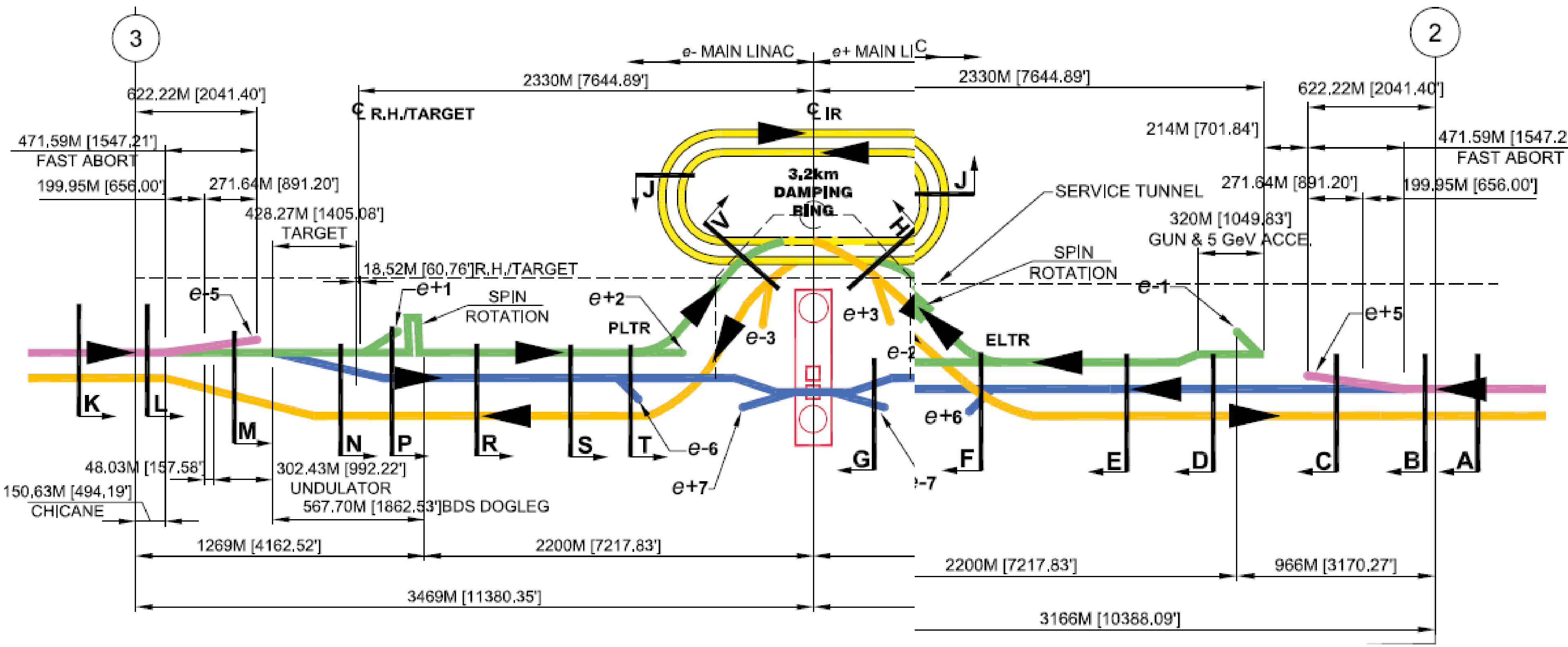
- Damping rings (relocation, e cloud,…)

- Beam delivery system: interaction with detectors

- Conventional facilities

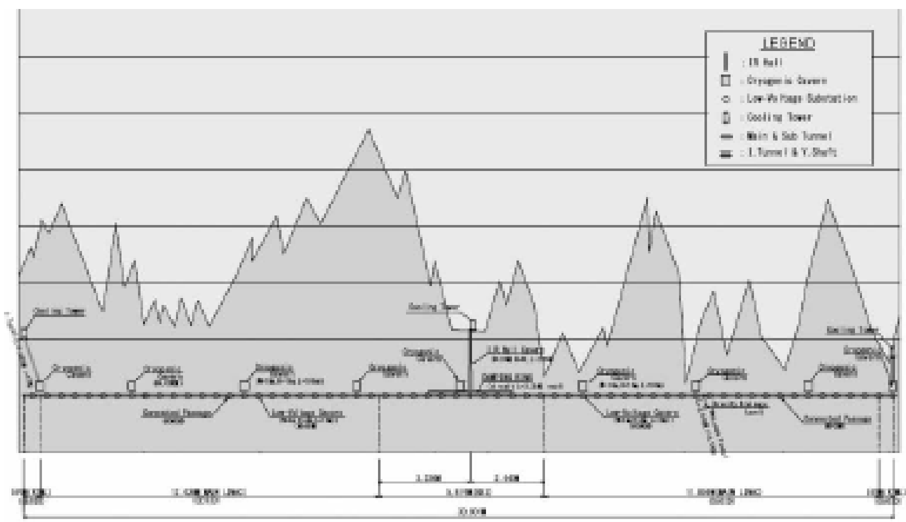


ILC Central Region

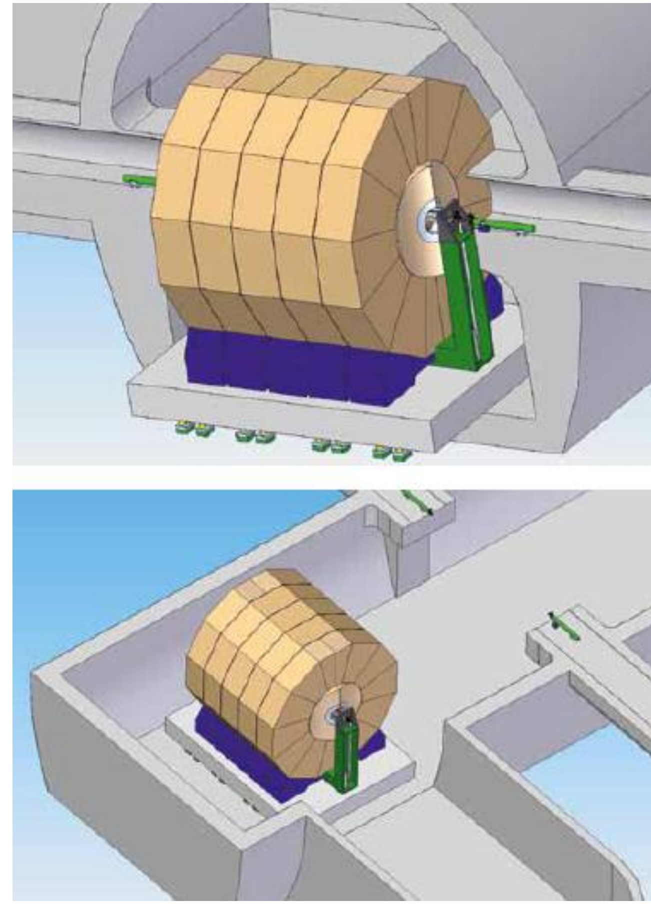


Conventional Facilities and Siting Studies

Central area/Detector Hall

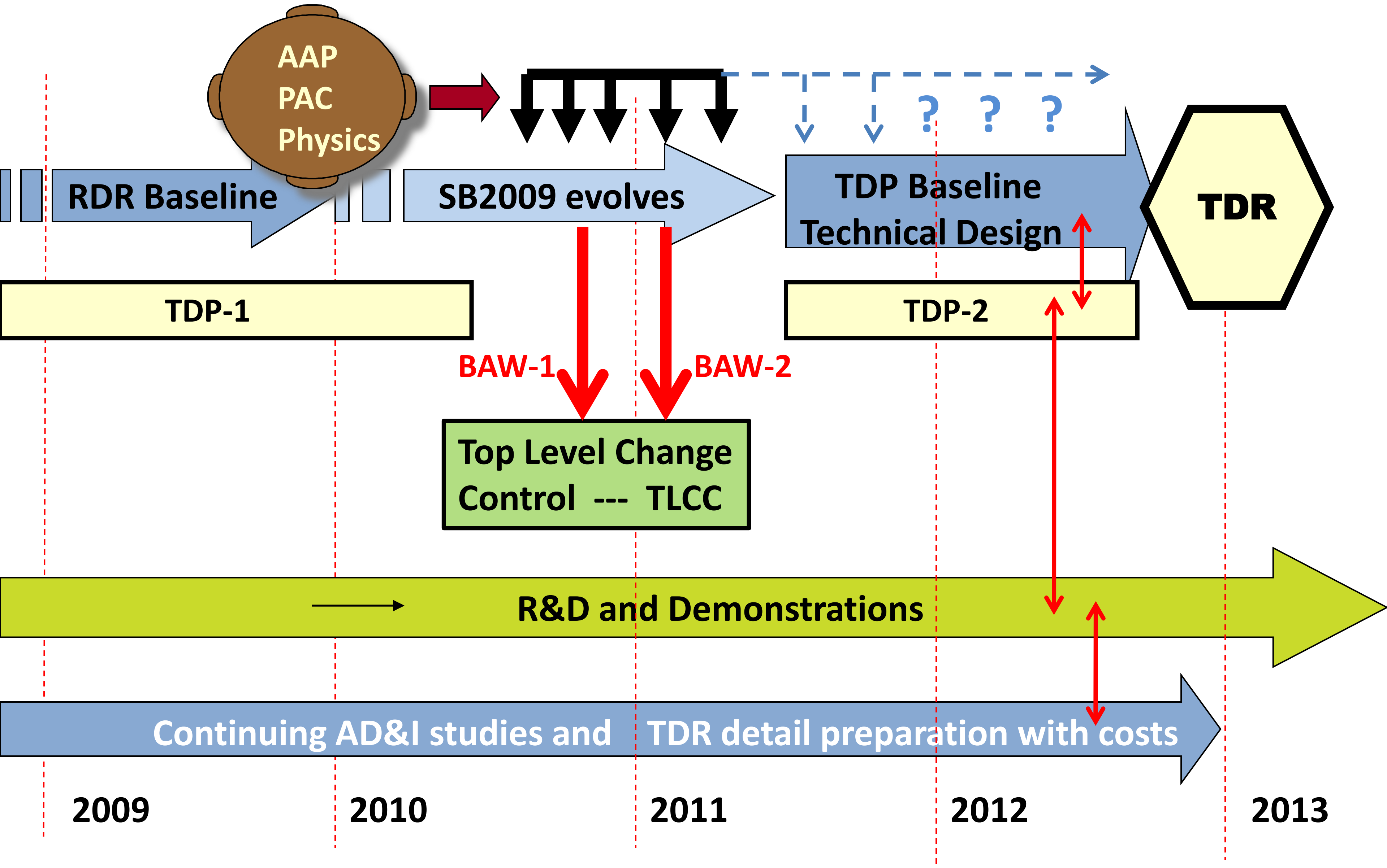


Japan – mountain region site



Example (ILD) on/off beam axis

Project Design Schedule



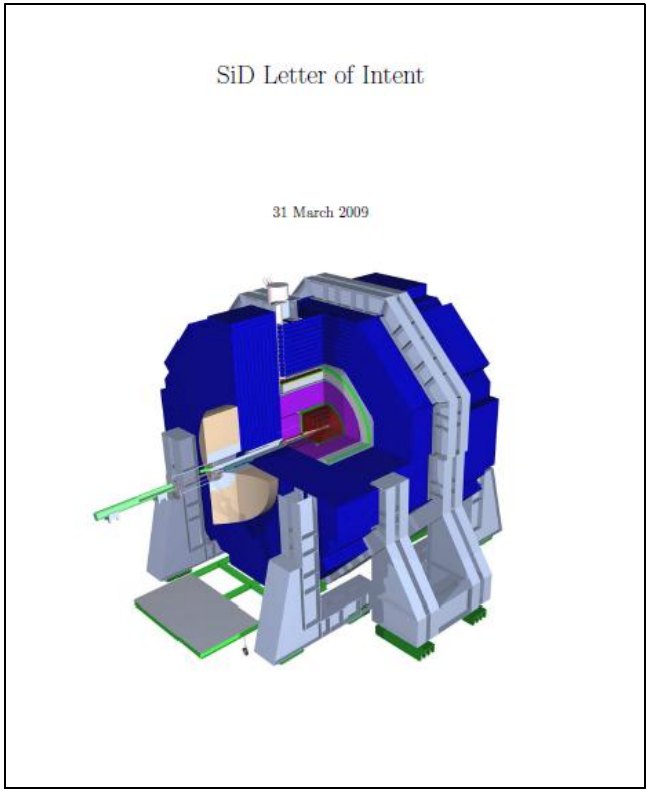
ILC Accelerator – 2013 and beyond

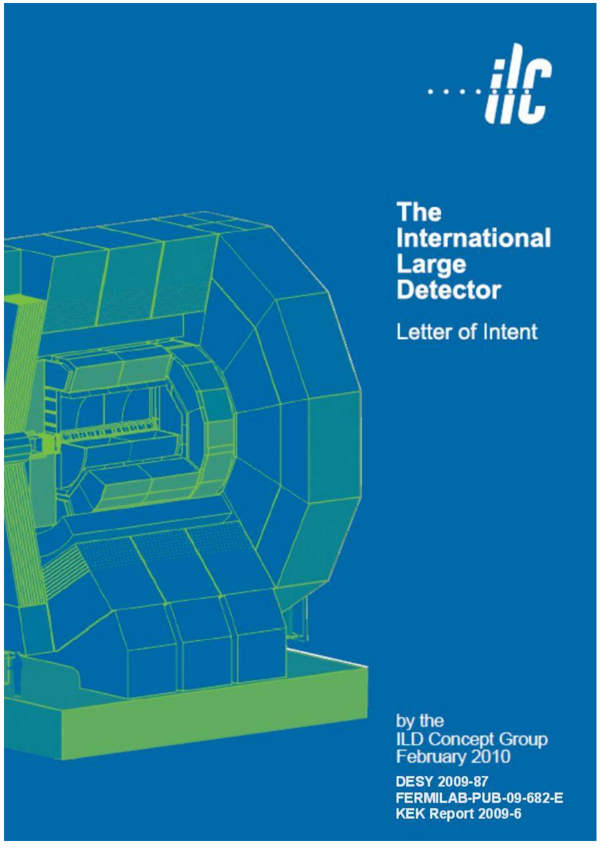
- GDE delivers TDR at the end of 2012
- Critical to maintain the focus and resources of GDE in the context of the new organization post 2012
- Ongoing discussions with ILCSC about new organization
- ILCSC meeting in Mumbai
- GDE/new organization overlap in 2013
- LCSGA (Linear Collider Steering Group of the Americas) in active discussion about future of American Regional Team
- Focus on mass production and costs
- Continued development of 1 TeV ILC design

- Must keep the effort going and be prepared to react to LHC physics results!

ILC Detector Concepts

Letters of Intent $\Rightarrow$ Validated Concepts (2009)





The focus is now on the Detailed Baseline Designs (DBD's) for late 2012

The ILD Detector Concept

ilcILD.org

- Designed for high precision measurements

- Combination of excellent calorimetry and tracking yields best possible overall event reconstruction.

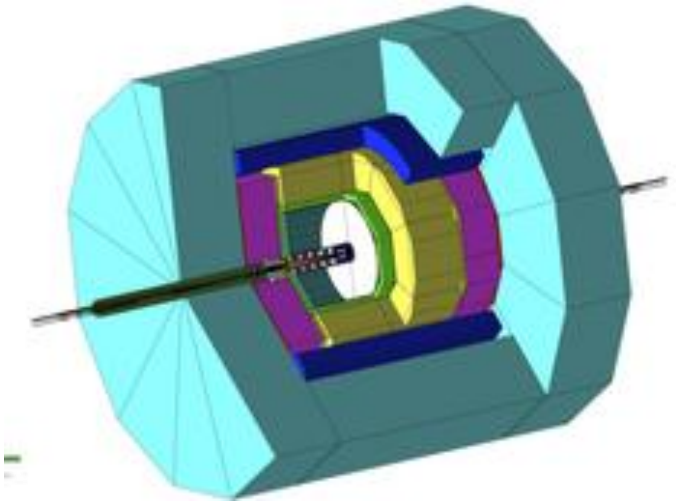
- Individual particle reconstruction in jets -> Particle Flow Calorimetry

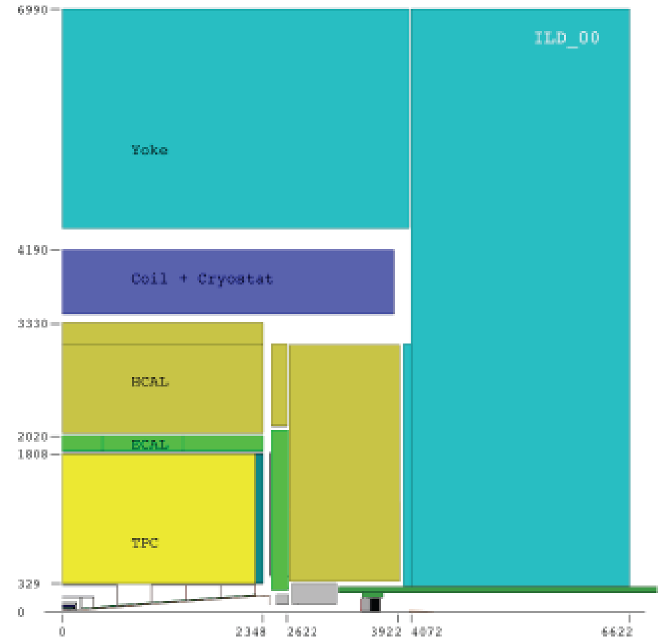
-TPC Central Tracker for redundancy (with VTX) and efficiency, excellent momentum resolution.

- Silicon pixel vertex detector – excellent b/c vertex tagging/Charge meas.

- Si-W Electromagnetic Calorimeter

- Scintillator-steel Hadron Calorimeter





The SiD Design

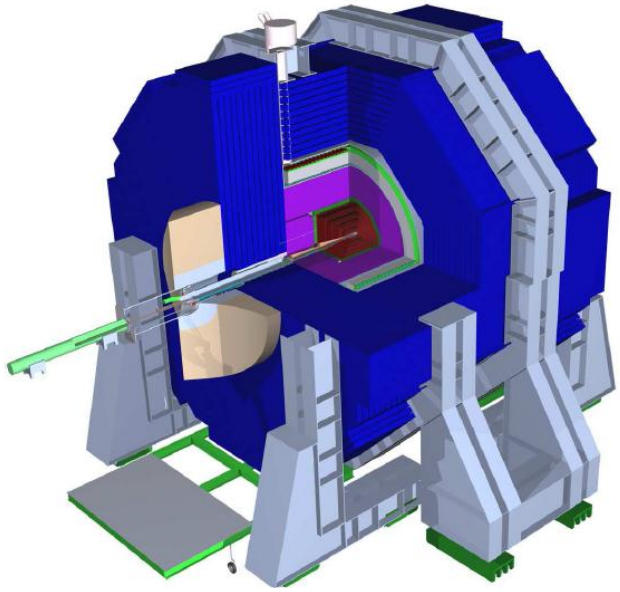
A compact, cost-conscious detector - precision measurements /wide range of new phenomena.

-> Compact design with 5T field.

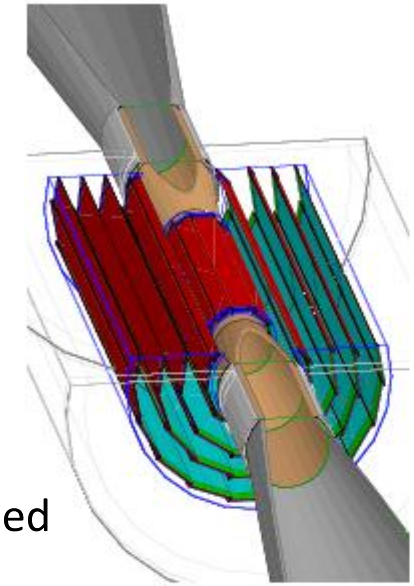
-> Robust silicon vertexing and tracking system – excellent momentum resolution, live for single bunch crossings, excellent b/c vertex tagging/charge meas.

-> Calorimetry optimized for jet energy resolution, Particle Flow approach, “tracking calorimeters”.

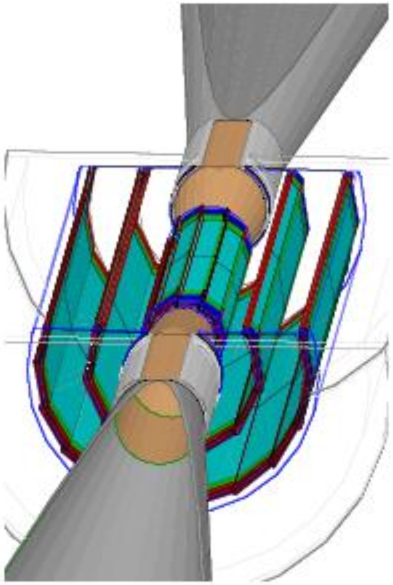
-> Iron flux return/muon identifier – component of SiD self-shielding.



Vertex Detectors



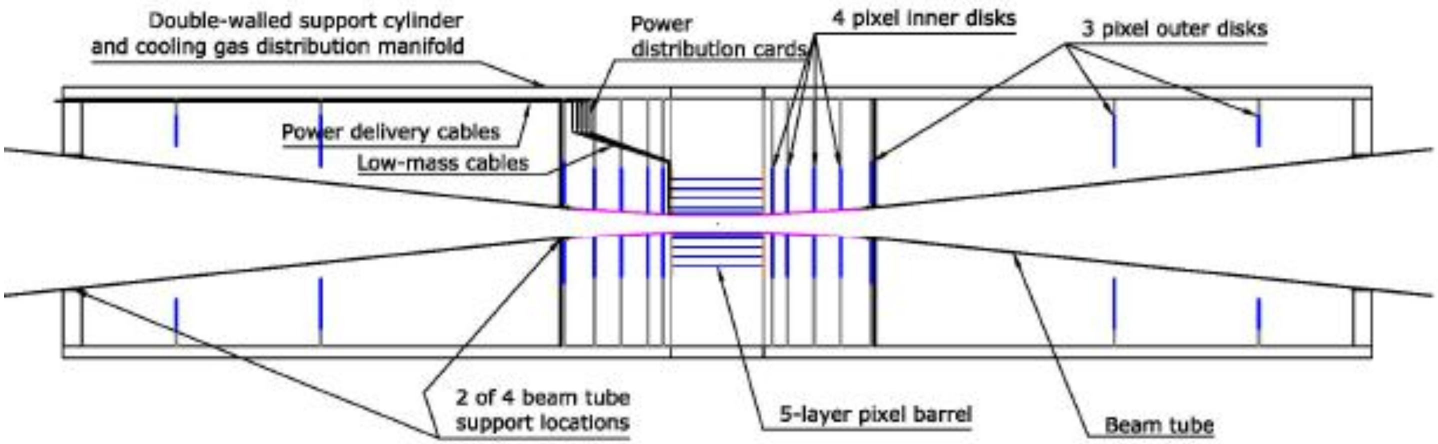
ILD



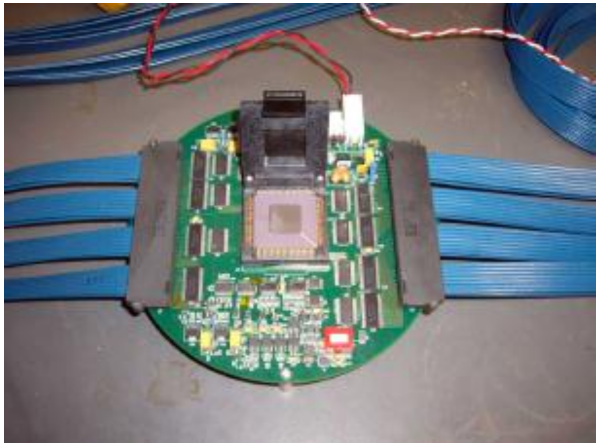
5 x single sided

3 x double sided

SiD

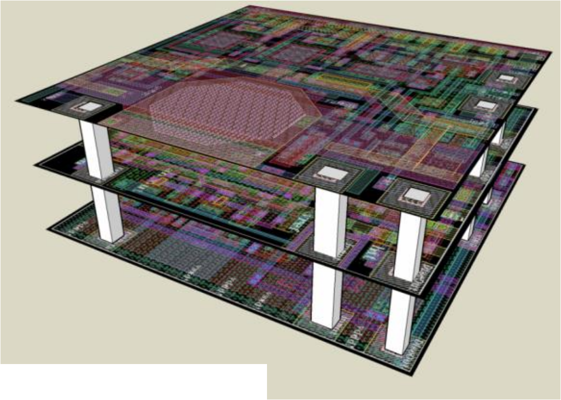


Vertex Detectors:
Technologies – but no prefered solution!



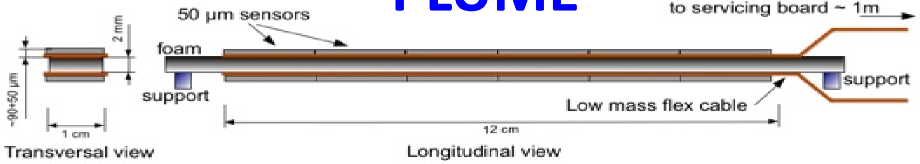
Examples

Chronopix

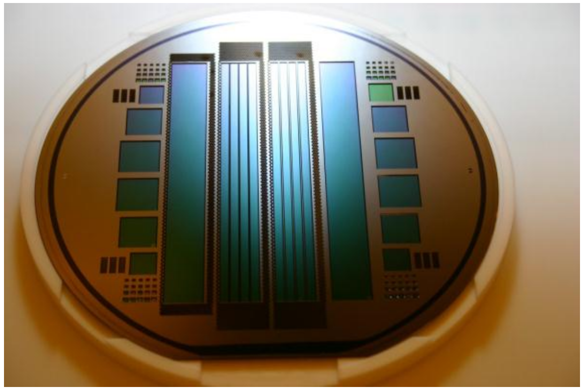


3-D

PLUME



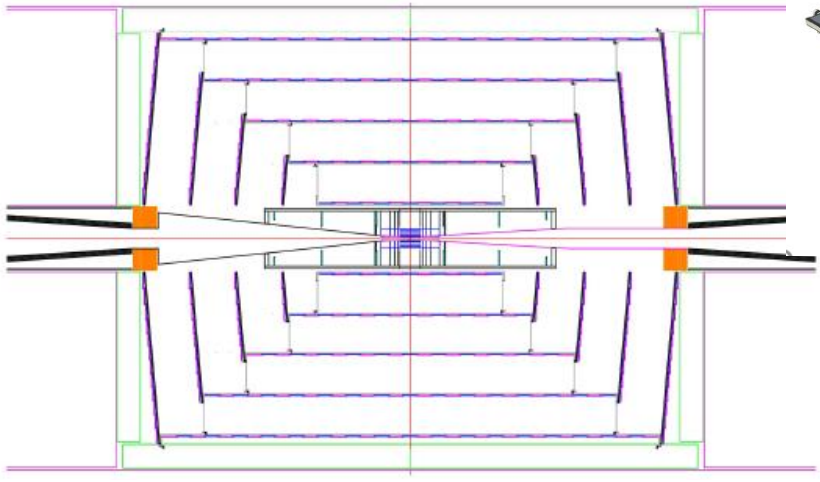
Fully equipped ladder with 50 μm sensors by 2012 ~ 0.3% X_0

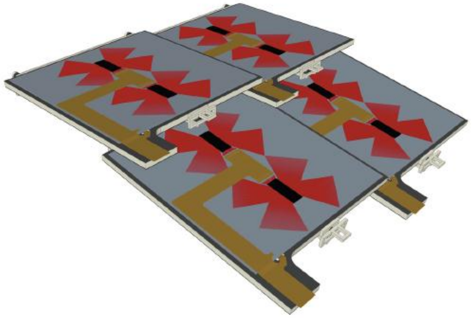


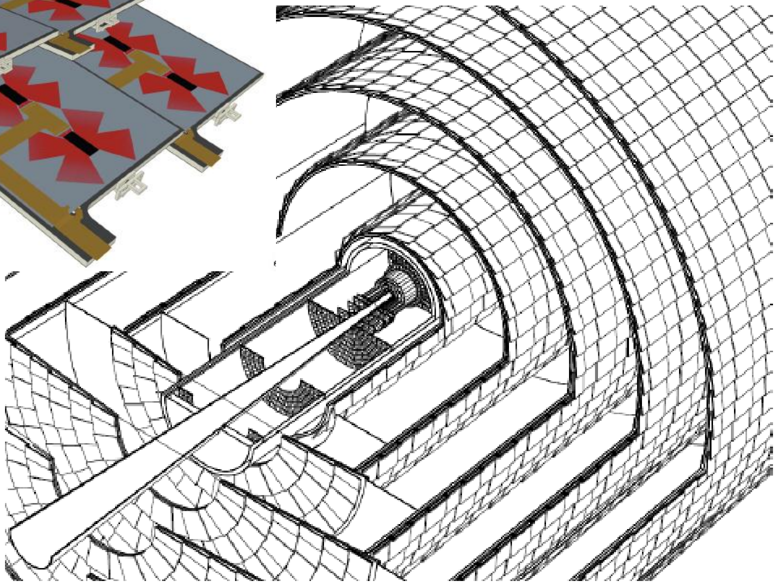
	ILC	*Belle 2*
occupancy	0.13 hits/μm²/s	0.4 hits/μm²/s
Frame time	25-100 μs	10 μs
Duty cycle	1/200	1
	Excellent spatial resolution (3- 5 μm) AND material budget (0.12 % X_0/layer)	Lowest possible material budget (0.15 % X_0/layer) Moderate pixel size (50 x 75 μm²)

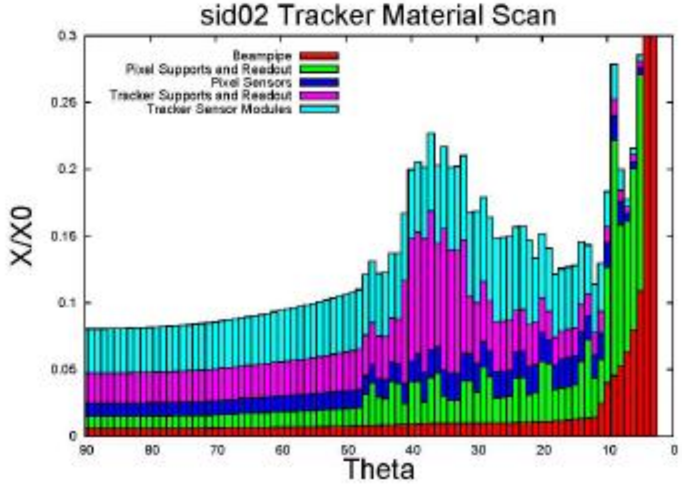
DEPFET

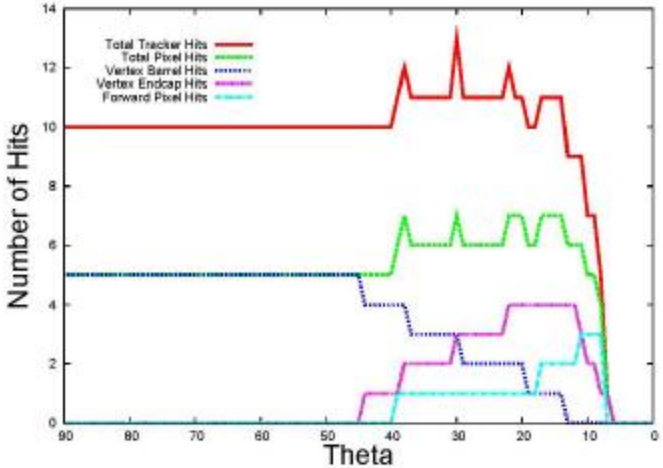
Silicon Tracking - SiD



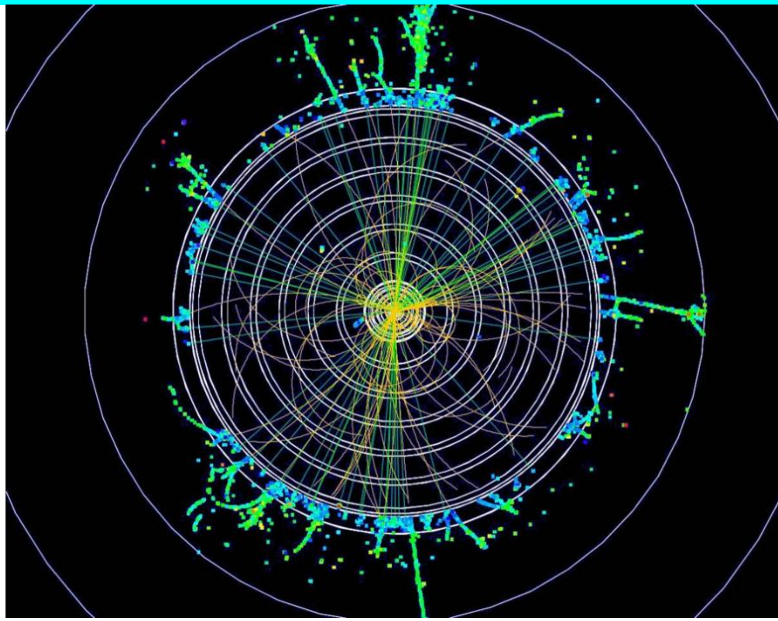








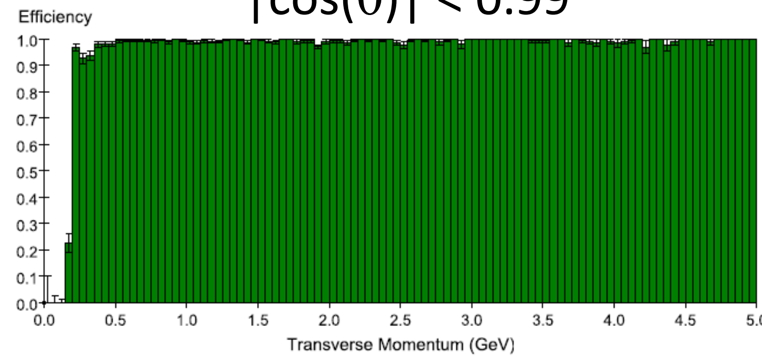
Silicon Tracking - SiD

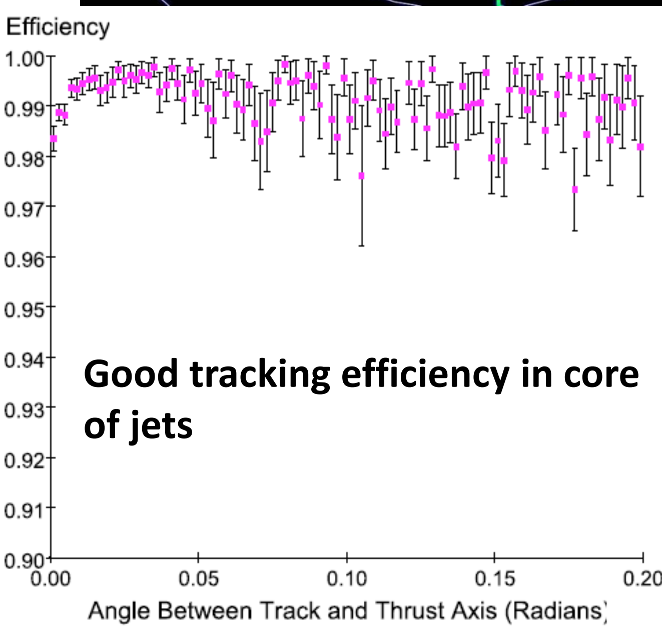


Generally find high tracking efficiency for tracks with:

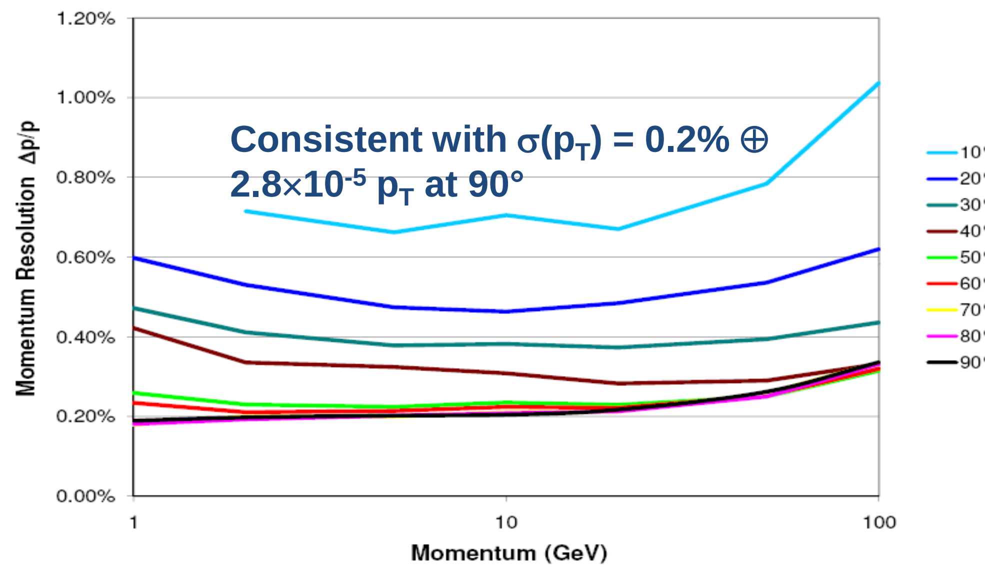
$p_T > 0.2$ GeV

$|\cos(\theta)| < 0.99$





Good tracking efficiency in core of jets



Consistent with $\sigma(p_T) = 0.2\% \oplus 2.8\times10^{-5}\, p_T$ at 90°

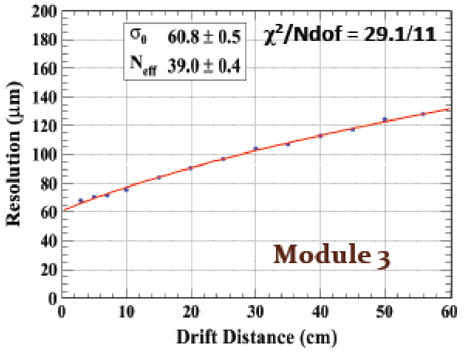
Residual issue; tracking across barrel/endcap overlap region.

Gaseous Tracking - ILD

- $\sigma(r, \varphi) \leq 100\ \mu m$
- $\sigma(z) \approx 500\ \mu m$
- 2 hit resolution
  - $\approx$ 2mm in (r,φ)
  - $\approx$ 6 mm in z
- dE/dx ~ 5%

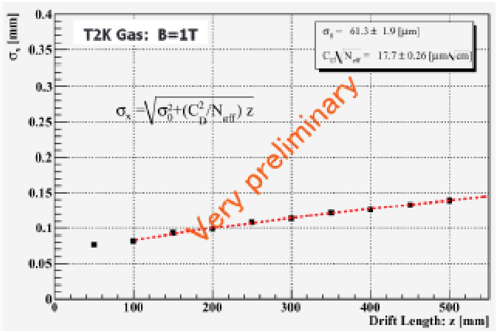
- **MicroMegas**

B=1 T $C_d = 94.2\ \mu m/\sqrt{cm}$ (Magboltz)

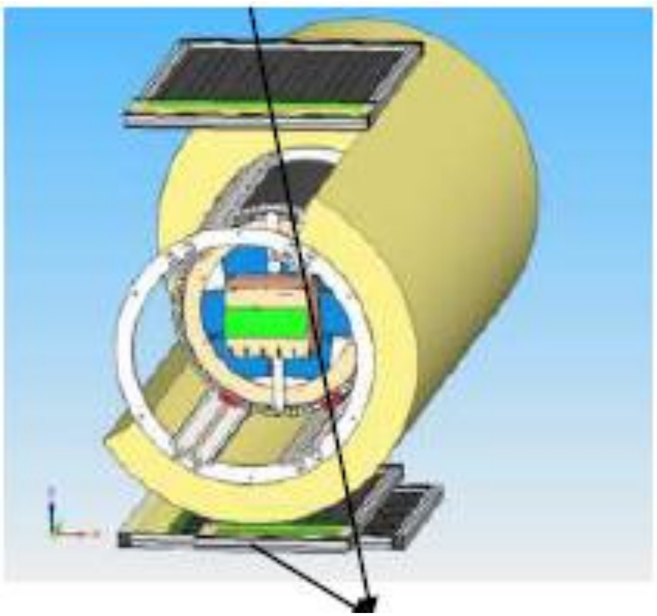


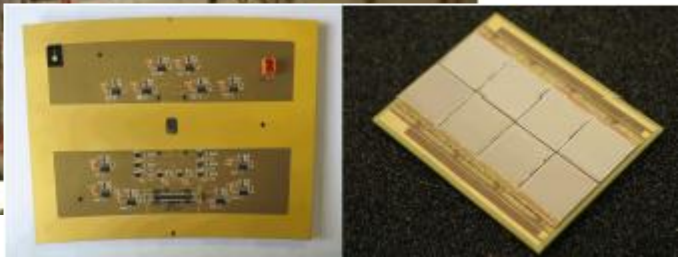
- **GEM**

B=1 T $\sigma_0 = 61.3 \pm 1.9\ \mu m$



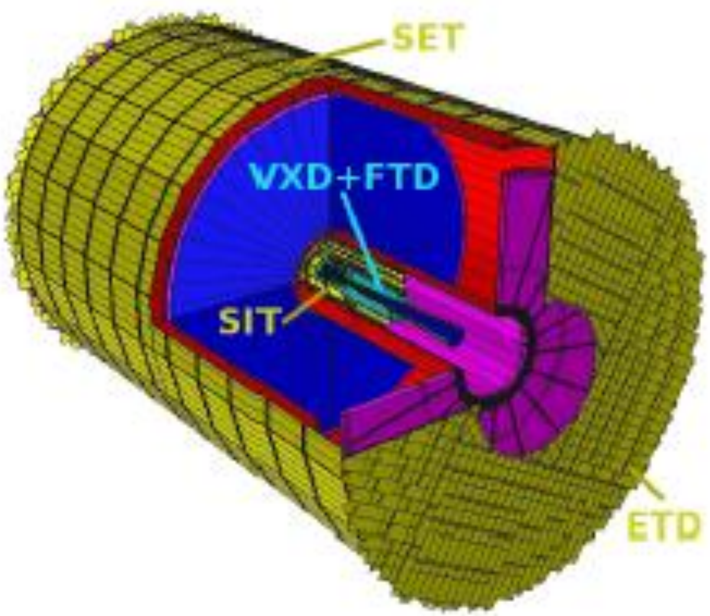
Resolution of 80 μm at 2m drift in B=3.5 T obtained!

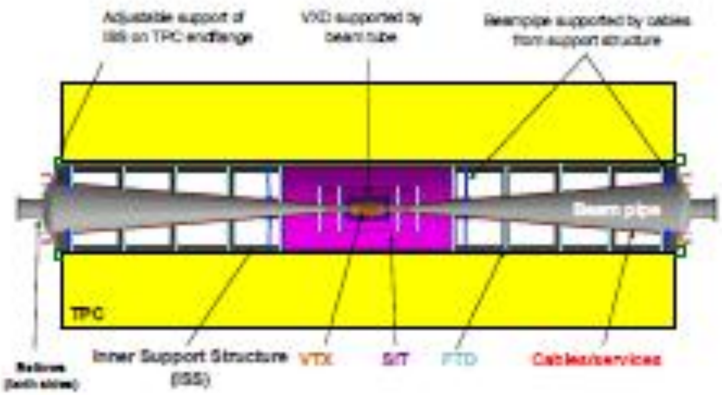


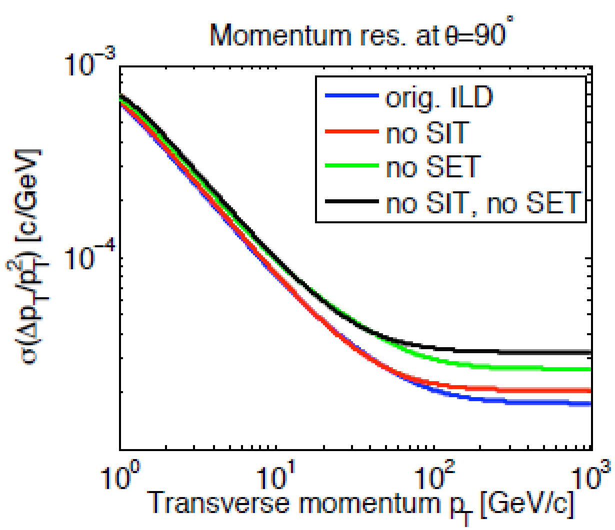


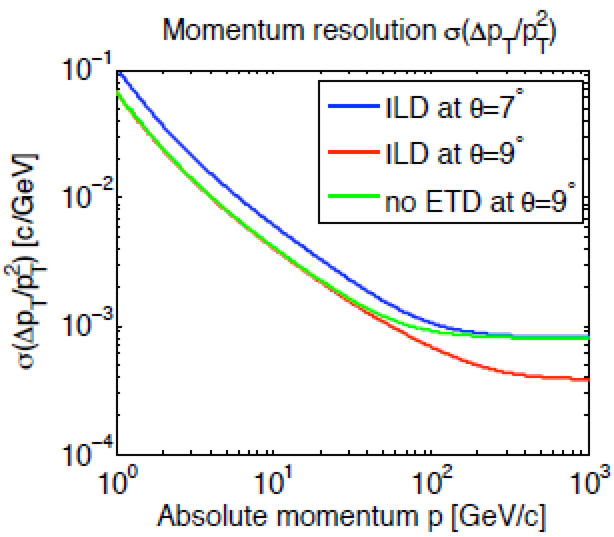
TimePix Readout

Silicon Tracking - ILD





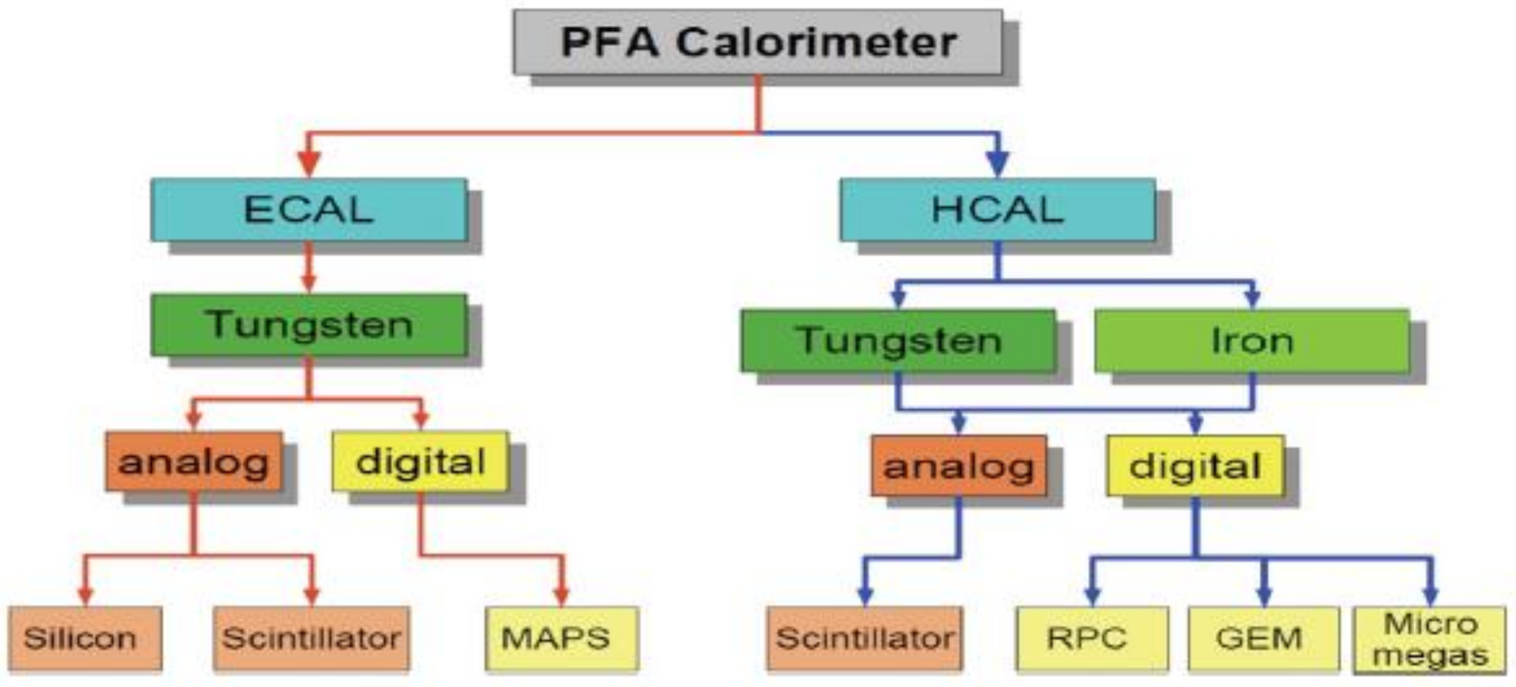




Calorimetry

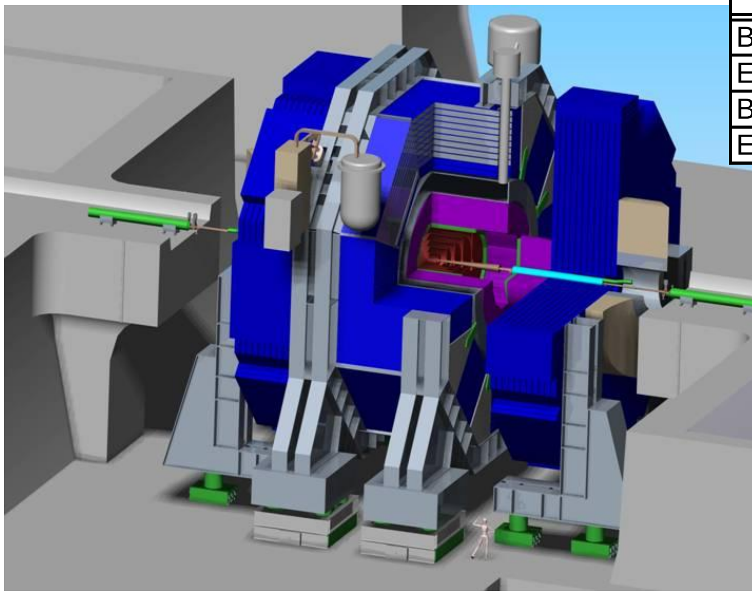
Both ILD and SiD have adopted the Particle Flow approach to calorimetry. Software development and hardware prototypes have shown that PFA can deliver the required precision measurements of jet energies for the ILC physics program.

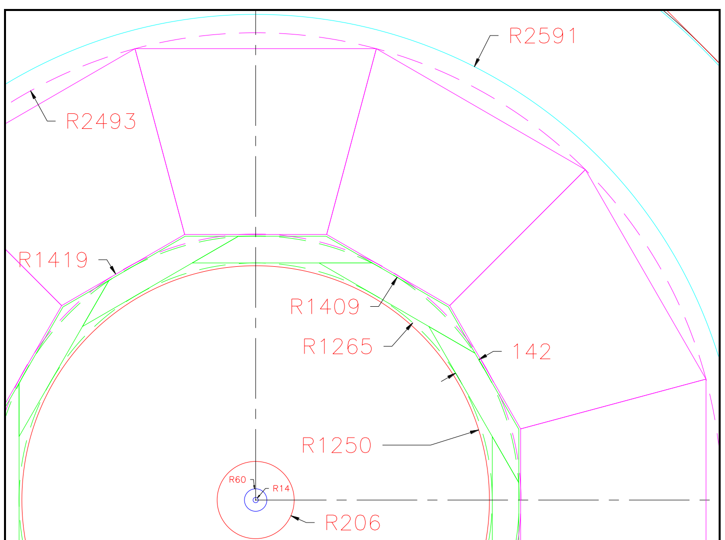
Many technology choices!

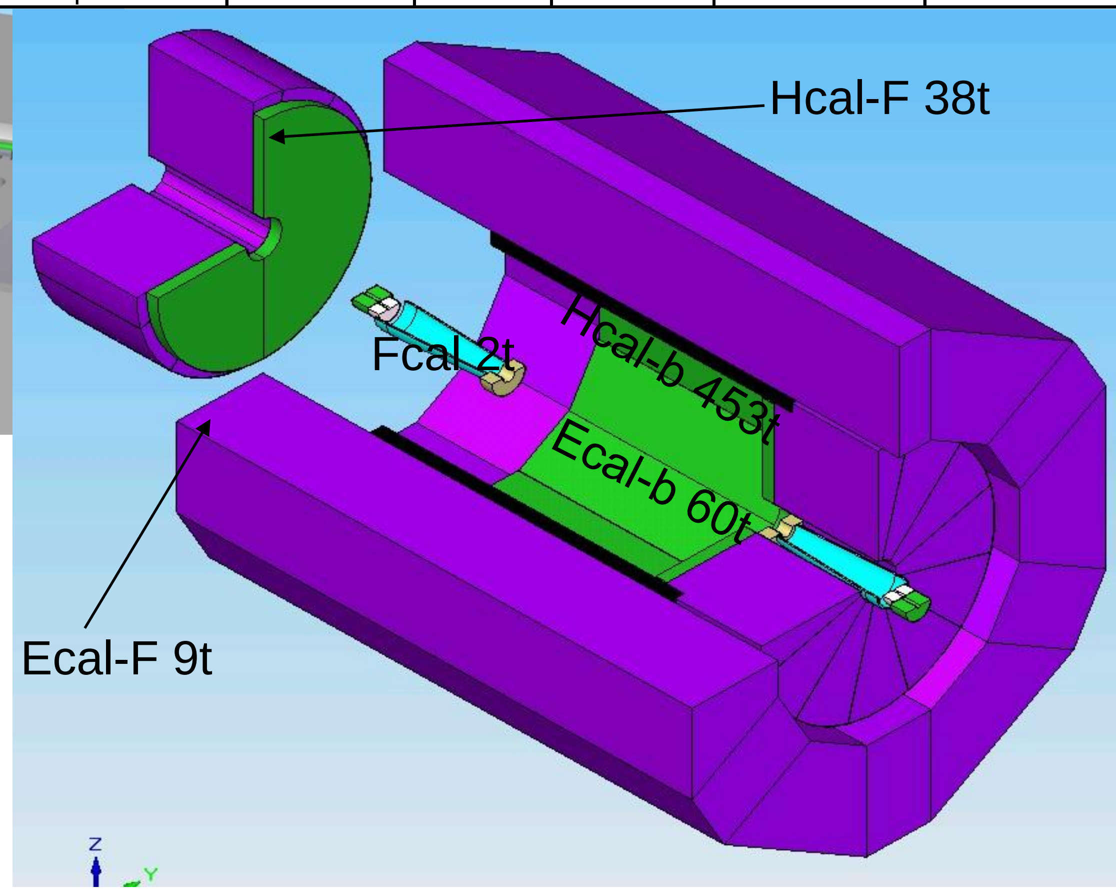


SiD Calorimeter System

	Technology	Xo / λ	Absorbers	Weight (tons)	Area (m^2)
Barrel Ecal	Silicon-W	26	Tungsten	60	80
Endcap Ecal	Silicon-W	26	Tungsten	2 x 9	2 x 143
Barrel Hcal	RPCs	4.5	Stainless	453	3000
Endcap Hcal	RPCs	4.5	Stainless	2 x 38	2 x 247



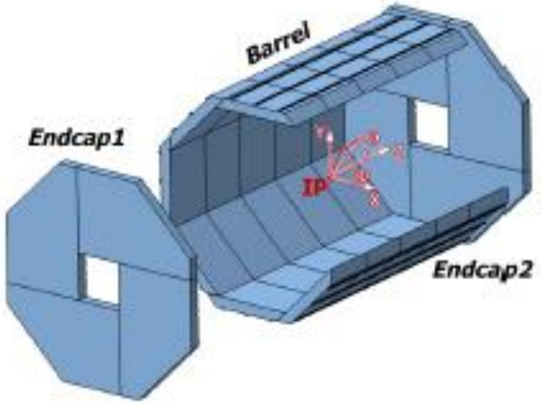


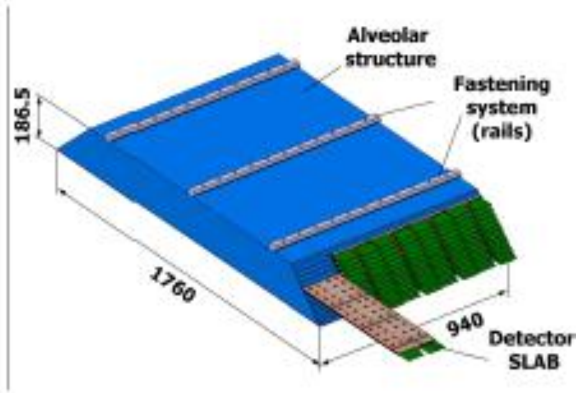


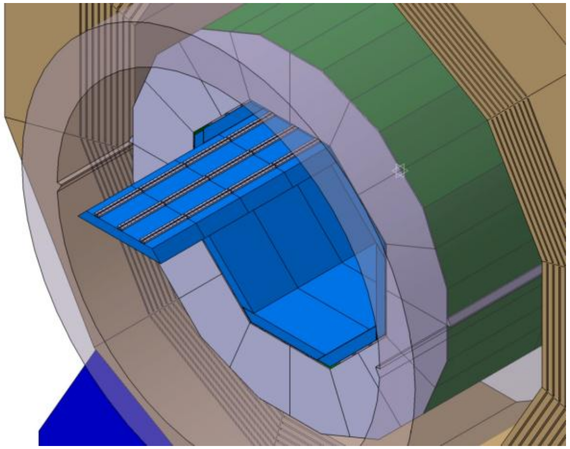
For FCal we follow the work of the FCal Collaboration.

ILD Calorimeter System

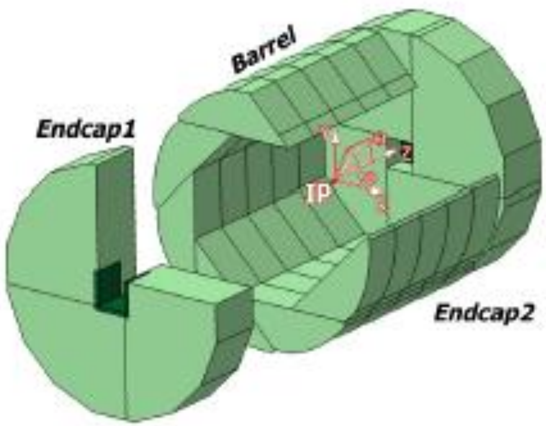
ECAL

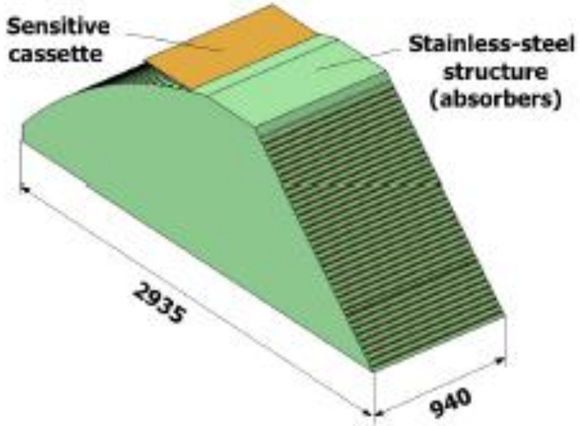






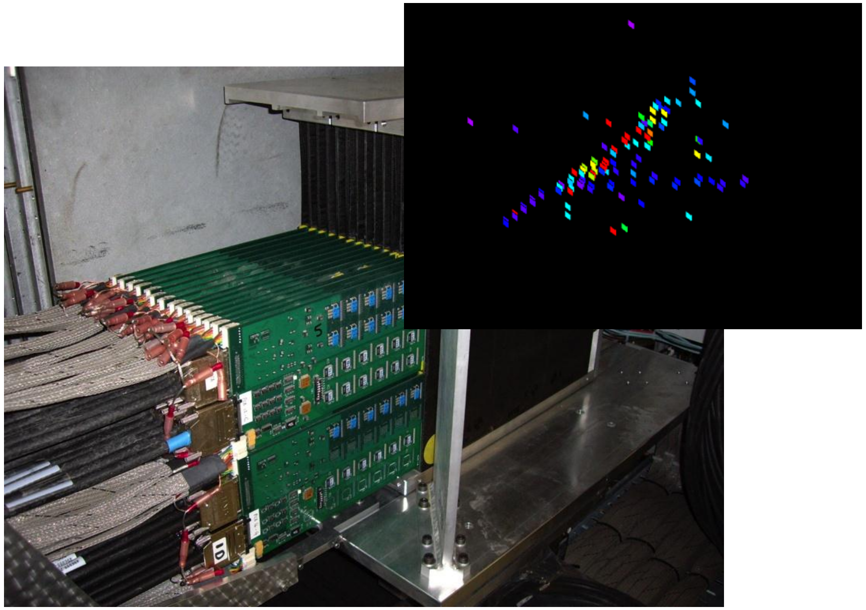
HCAL

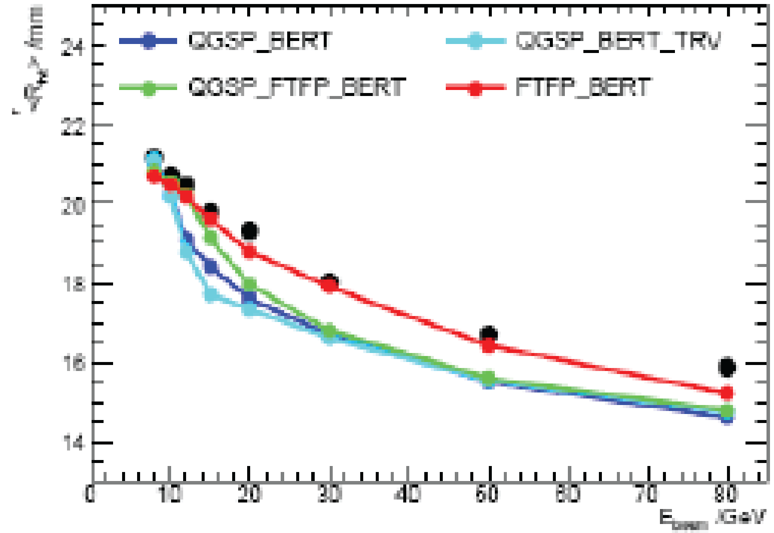




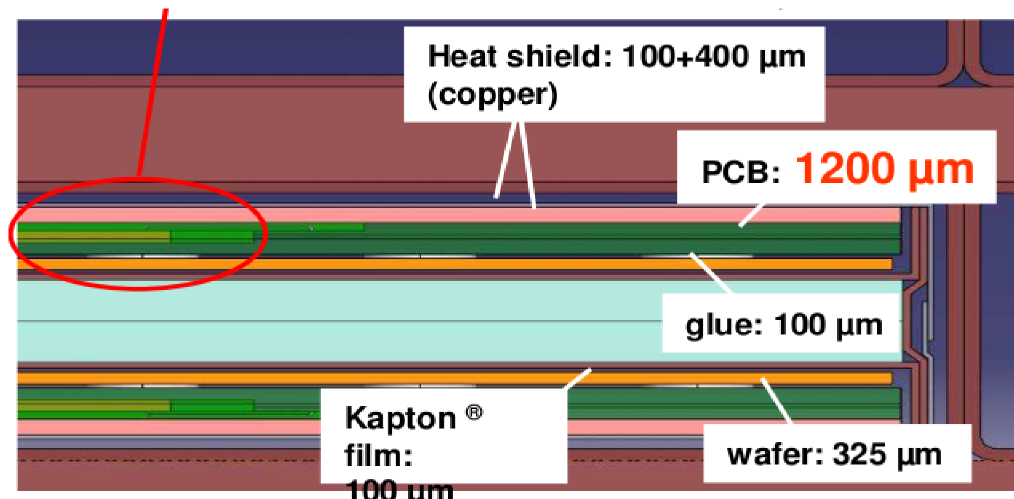
ILD Electromagnetic Calorimetry

CALICE Calorimeter for ILC

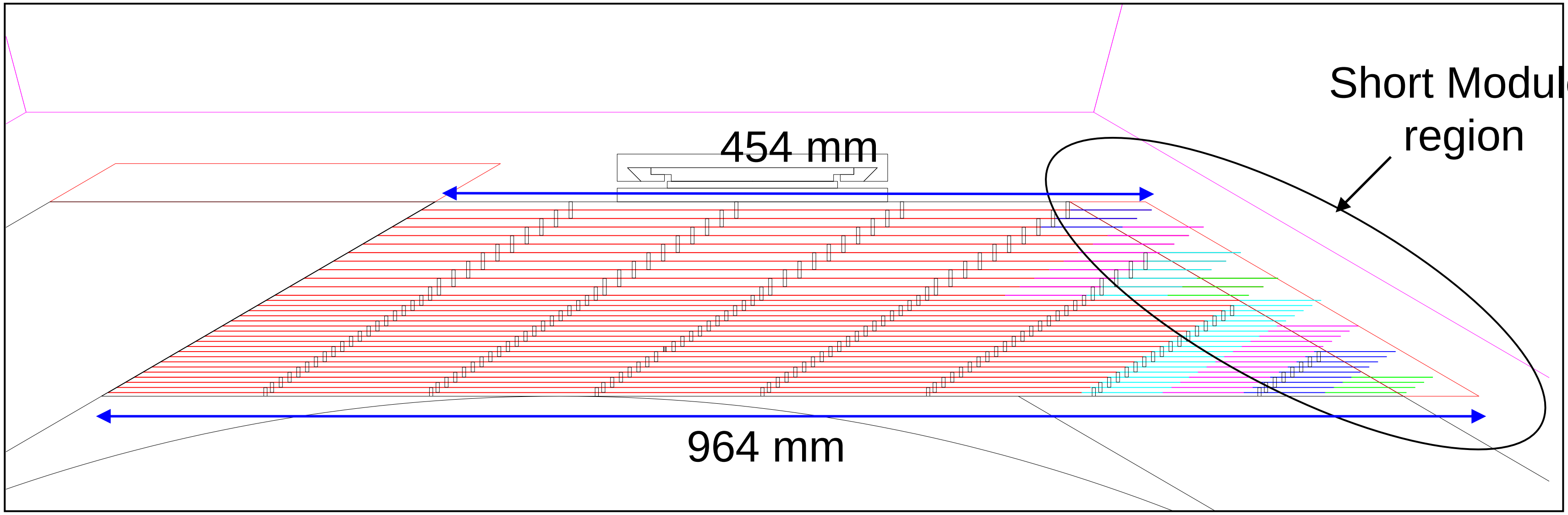


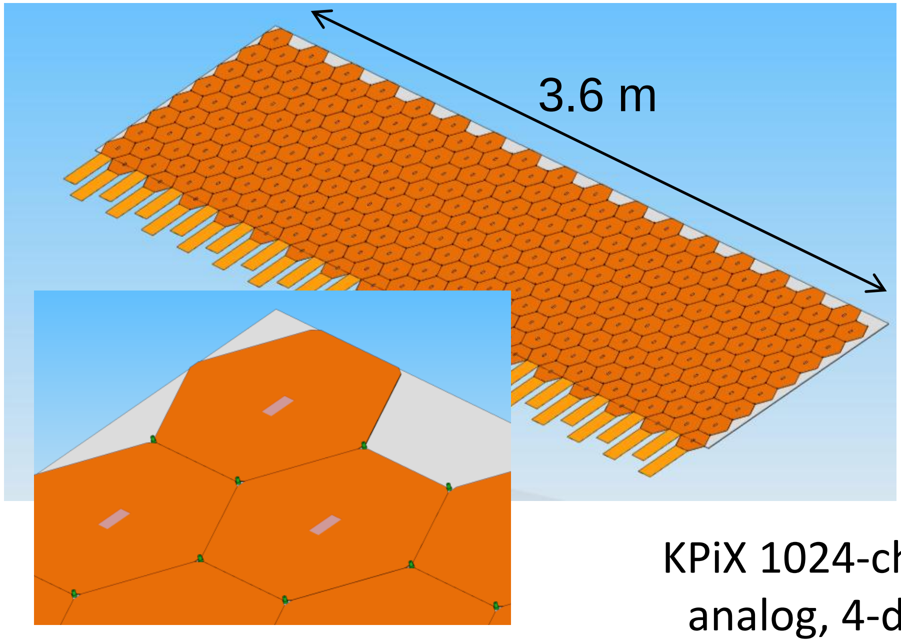


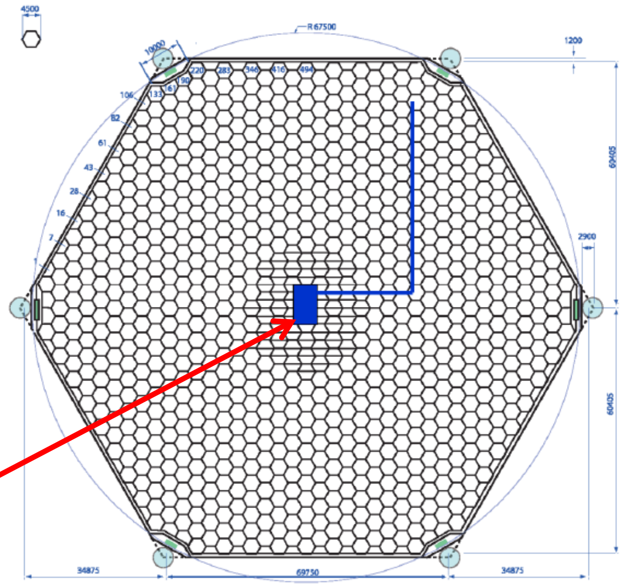
~2/3 ILD barrel module
under construction



SiD Electromagnetic Calorimeter

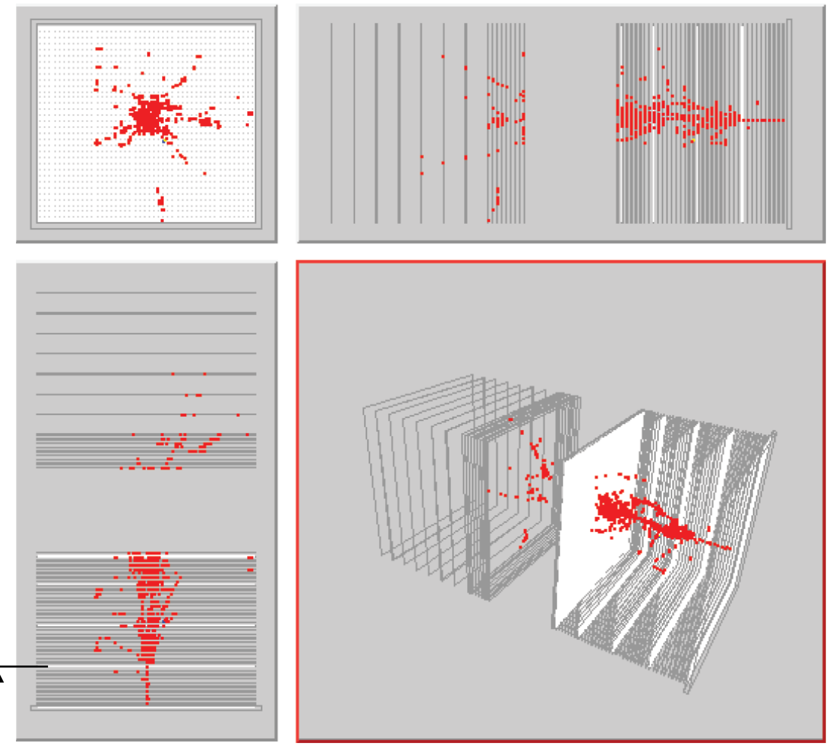


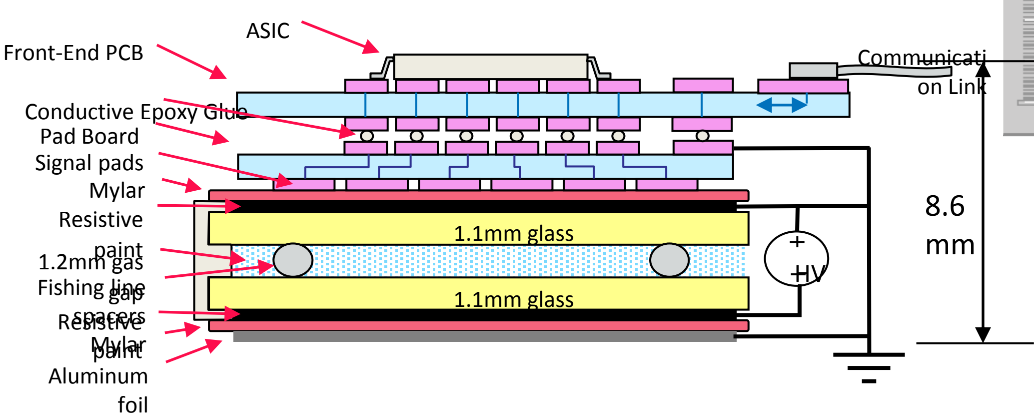




KPiX 1024-channel, full analog, 4-deep, chip

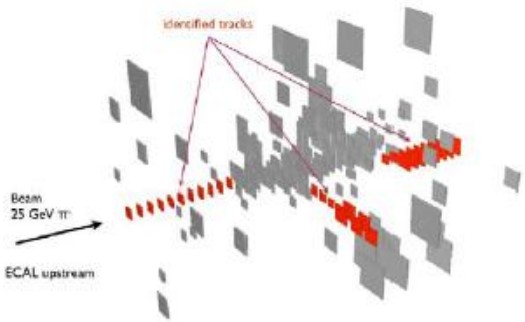
RPC DHCAL



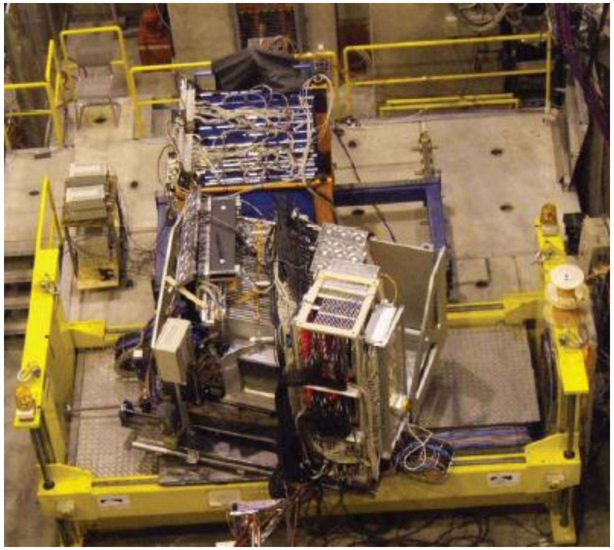


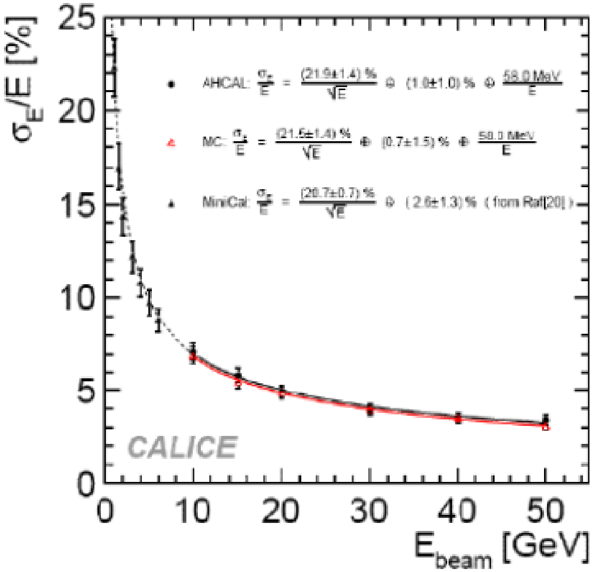
ASIC
Front-End PCB
Conductive Epoxy Glue
Pad Board
Signal pads
Mylar
Resistive paint
1.2mm gas gap
Fishing line spacers
Resistive paint
Mylar
Aluminum foil
Communication Link
1.1mm glass
1.1mm glass
+
-HV
8.6 mm

ANALOG HCAL

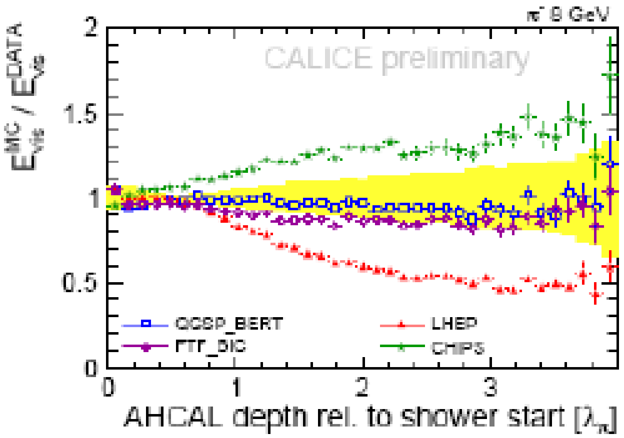


identified tracks
Beam
25 GeV π⁻
ECAL upstream

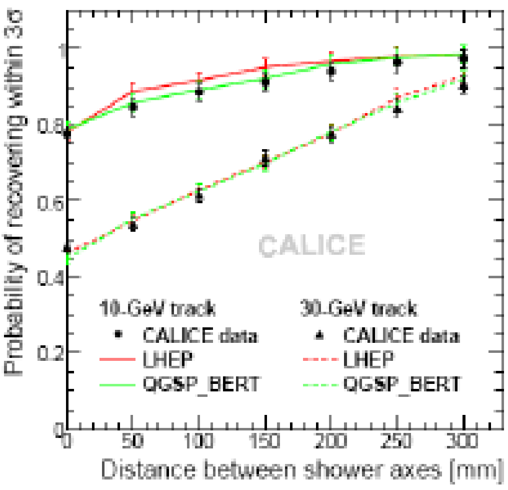




σ_E/E [%]
AHCAL: $\frac{\sigma_E}{E} = \frac{(21.9\pm1.4)\,\%}{\sqrt{E}} \oplus (1.0\pm1.0)\,\% \oplus \frac{58.0\,\text{MeV}}{E}$
MC: $\frac{\sigma_E}{E} = \frac{(21.5\pm1.4)\,\%}{\sqrt{E}} \oplus (0.7\pm1.5)\,\% \oplus \frac{58.0\,\text{MeV}}{E}$
MiniCal: $\frac{\sigma_E}{E} = \frac{(20.7\pm0.7)\,\%}{\sqrt{E}} \oplus (2.6\pm1.3)\,\%$ (from Ref[20])
CALICE
E_{beam} [GeV]



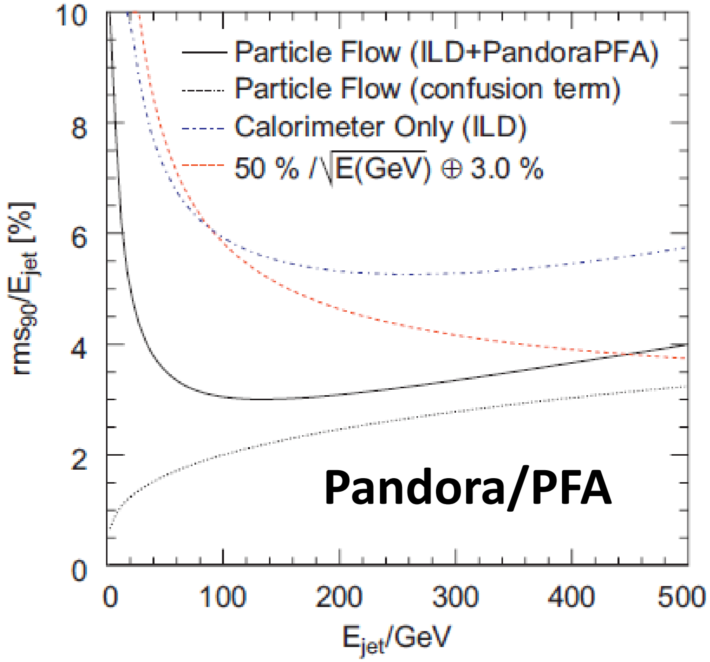
$E_{vis}^{MC} / E_{vis}^{DATA}$
π⁻ 8 GeV
CALICE preliminary
QGSP_BERT
FTF_BIC
LHEP
CHIPS
AHCAL depth rel. to shower start [λ_π]



Probability of recovering within 3σ
CALICE
10 GeV track
CALICE data
LHEP
QGSP_BERT
30 GeV track
CALICE data
LHEP
QGSP_BERT
Distance between shower axes [mm]

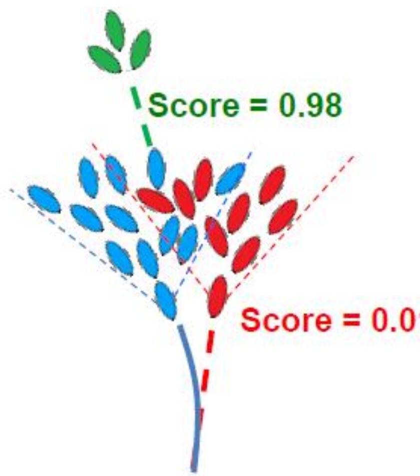
Calorimetry/PFA Performance

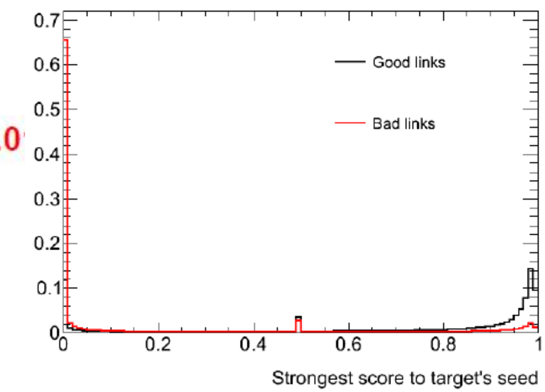
Mark Thomson UNIVERSITY OF CAMBRIDGE



SiD –Iowa PFA

Undergoing complete rework – results soon





Jet energy resolution for $Z \to uds$ events with $|\cos\theta_{q\bar{q}}| < 0.7$, expressed as: (i) the rms of the reconstructed di-jet energy distribution, E_{jj}; (ii) rms_{90} for E_{jj}; (iii) the effective constant α in $rms_{90}(E_{jj})/E_{jj} = \alpha(E_{jj})/\sqrt{E_{jj}(\text{GeV})}$; and (iv) the fractional jet energy resolution for a single jet where $rms_{90}(E_j) = rms_{90}(E_{jj})/\sqrt{2}$.

Jet energy (GeV)	rms (GeV)	$rms_{90}(E_{jj})$ (GeV)	$rms_{90}(E_{jj})/\sqrt{E_{jj}}$ (%)	$rms_{90}(E_j)/E_j$ (%)
45	3.4	2.4	25.2	(3.74 ± 0.05)
100	5.8	4.1	29.2	(2.92 ± 0.04)
180	11.6	7.6	40.3	(3.00 ± 0.04)
250	16.4	11.0	49.3	(3.11 ± 0.05)
375	29.1	19.2	81.4	(3.64 ± 0.05)
500	43.3	28.6	91.6	(4.09 ± 0.07)

Detectors – Detailed Baseline Designs

Goal: Deliver the DBD's for SiD and ILD with the accelerator TDR at the end of 2012.

DBD should "make a compelling case that detectors capable of fully exploiting the physics potential of the ILC are feasible, cost effective, and based on demonstrated detector technologies."
(S. Yamada, ILC Research Director)

The DBD's will present integrated detector designs that:

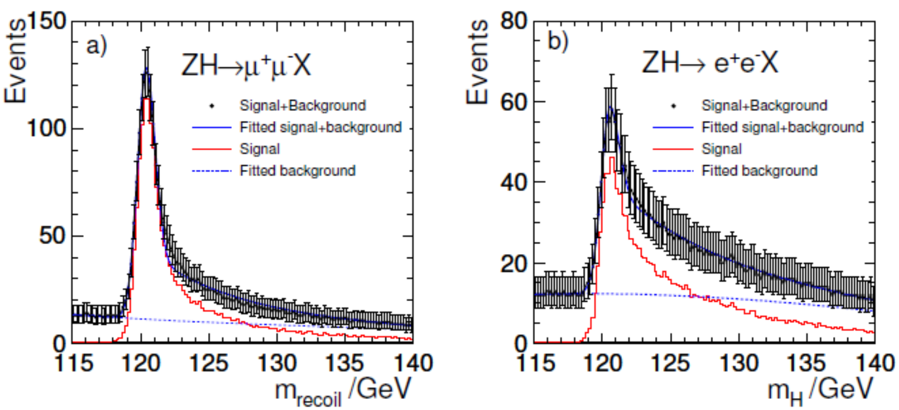
- have a baseline technology choice (and options) for each subsystem
- have a reasonable level of engineering reality
- show integration with BDS system and satisfy push-pull
- demonstrate their abilities to provide data for successful execution of designated physics benchmarks

ILC PHYSICS

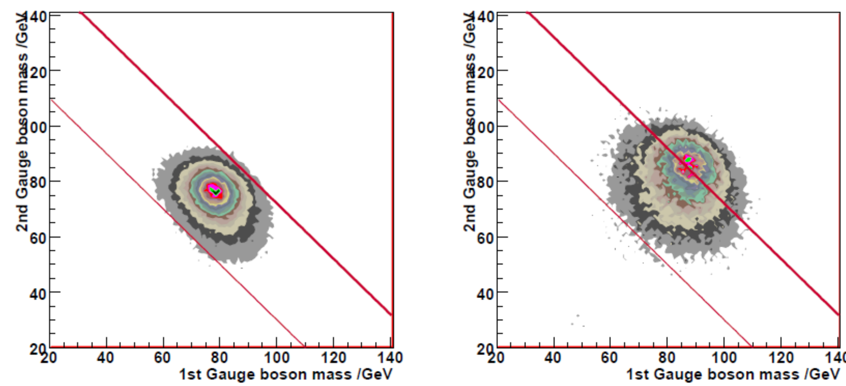
For the LOI's:

- Higgs
- SUSY
- Top
- Tau's

1. $e^+e^- \to e^+e^-H\,,\ \mu^+\mu^-H\,,\ \sqrt{s}$=250 GeV;
2. $e^+e^- \to ZH\,,\ H \to c\bar{c}\,,\ Z \to \nu\bar{\nu}\,, q\bar{q}\,,\ \sqrt{s}$=250 GeV;
3. $e^+e^- \to ZH\,,\ H \to \mu^+\mu^-\,,\ Z \to \nu\bar{\nu}\,, q\bar{q}\,,\ \sqrt{s}$=250 GeV;
4. $e^+e^- \to \tau^+\tau^-\,,\ \sqrt{s}$=500 GeV;
5. $e^+e^- \to t\bar{t}\,,\ t \to bW^+\,,\ W^+ \to q\bar{q}'\,,\ \sqrt{s}$=500 GeV;
6. $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- / \tilde{\chi}_2^0\tilde{\chi}_2^0\,,\ \sqrt{s}$=500 GeV.



ILD – Higgs-strahlung 250 fb^{-1}



SiD – Chargino/neutralino separation

PHYSICS

DBD Benchmarks

- e+ e- → ν ν H : Higgs branching ratio @1TeV
  - Test detector performance for simplest context
- e+ e- → t t H : Top Yukawa coupling @1TeV
  - Detector performance for complex (8 jet) events
- e+ e- → W+ W- : In-situ polarization measurement @1TeV
  - Detector performance for high energy jet
  - Capability of forward detector elements

- **Each group repeats one of the LOI processes @500 GeV with the final detector configuration**,

  and with the same event sample
- Beam polarization taken into account
- All relevant physics back grounds to be included

PHYSICS

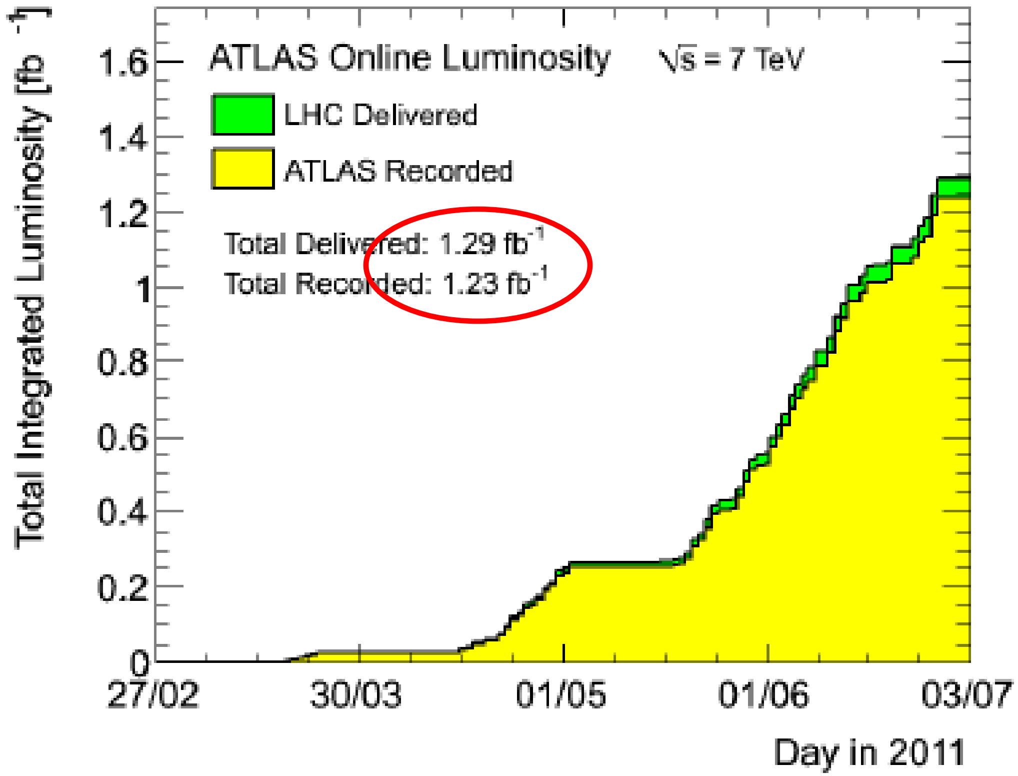
CRITICAL QUESTIONS:

-> Is there any new physics?!
-> Is there a Higgs boson (SM-like or any other type)?
-> What is the mass/energy scale of the new physics?
-> What is the nature of the new physics?
-> What can the LHC, sLHC tell us about the new physics?
-> What could a linear collider tell us about the new physics?
-> What can a linear collider tell us about “known” physics?
-> Which range of energies is needed for a Linear Collider?

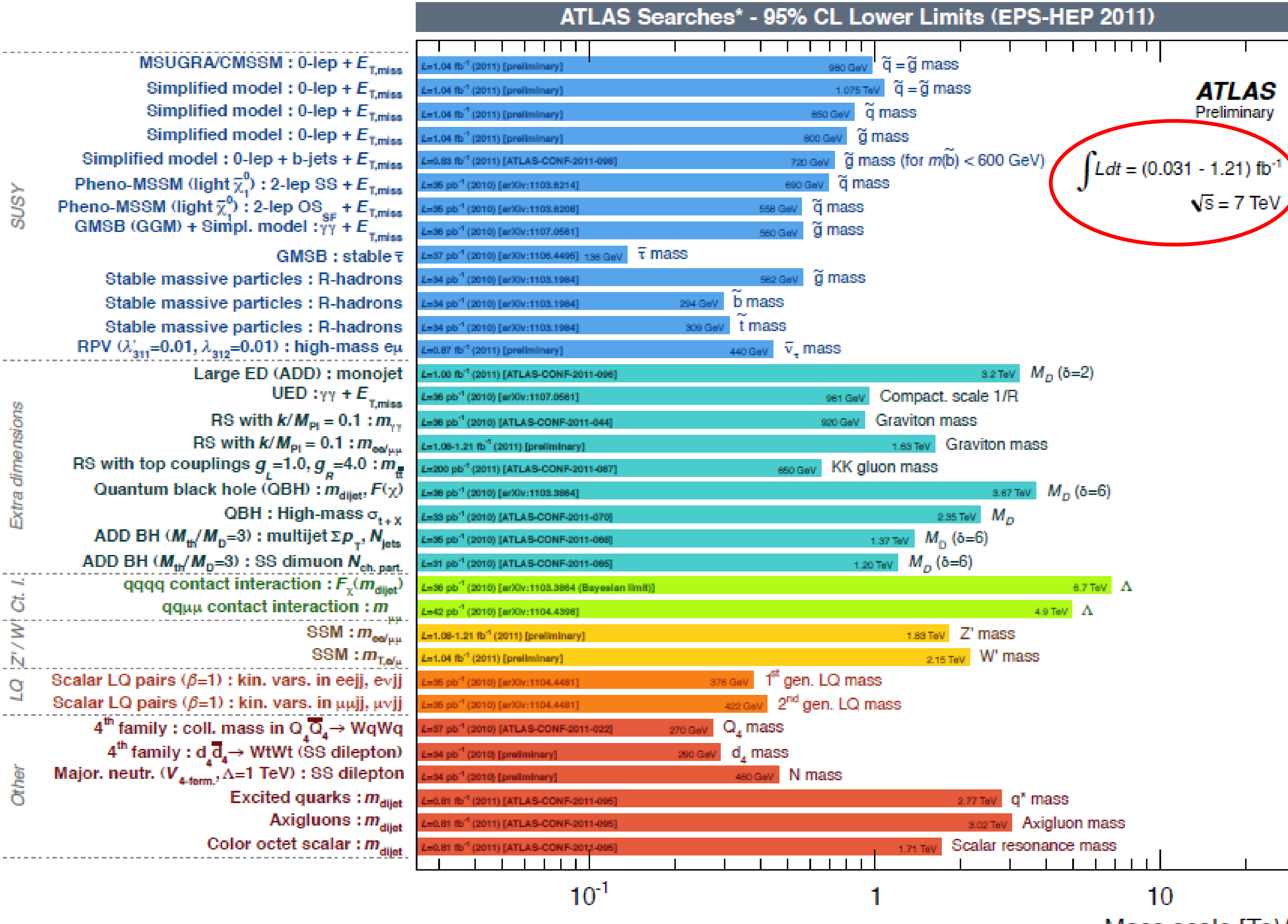
-> If the new scale is not ~1 TeV…where is it?
-> etc…

LHC status

Phenomenal performance!
Already profound influence on physics scenarios.



Could well reach 3-4 fb^{-1} in this calendar year!
…by the end of 2012…10 fb^{-1} ++ ??



*Only a selection of the available results shown

A Time of Transition – to a new level of understanding

What role(s) could the ILC play? Some examples:

✶ Higgs sector

✶ Additional heavy bosons

✶ Top sector

✶ Supersymmetry

Higgs Physics

Higgs or no Higgs – that is the question??

Combined fits to data indicate M_h < 160 GeV @95% CL

Observability: expected limits/discovery of light or heavy SM Higgs.

ILC: properties of SM Higgs measureable up to M(h) ~ 400 GeV for 500 GeV ILC

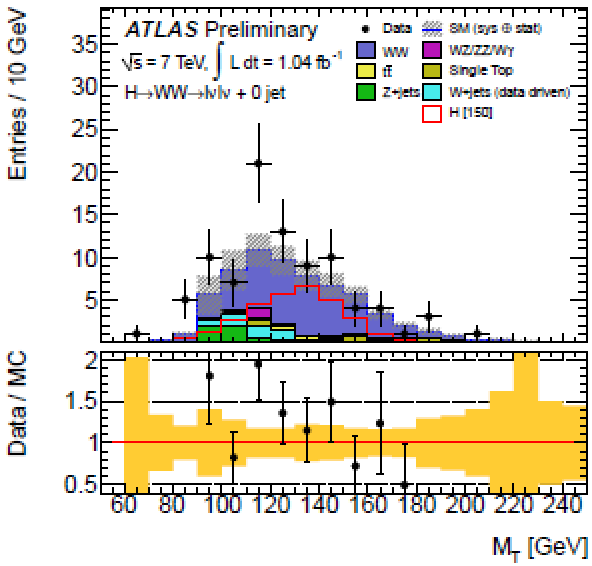
Comparison of precision measurements LHC vs. ILC

If the Higgs exists, then the ILC will be a vital tool for precision measurements of its properties! O(1%) accuracy on Higgs couplings.

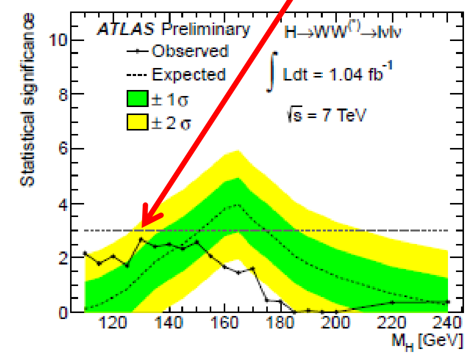
Higgs Physics @ 1 fb^{-1}

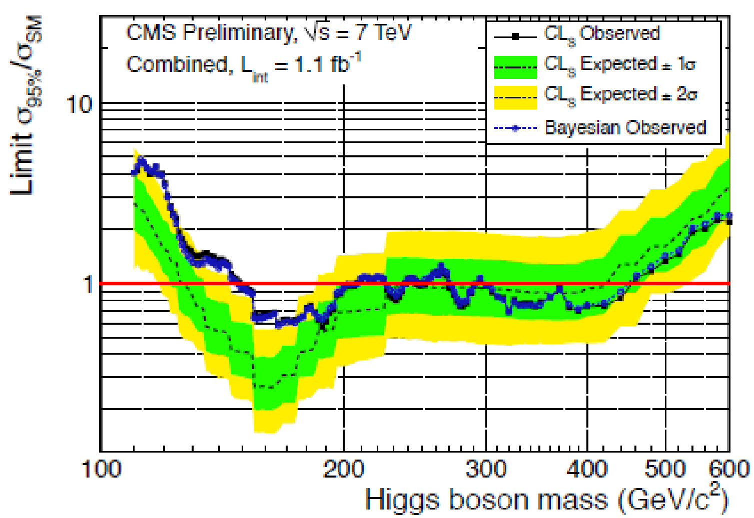
JONAS STRANDBERG
EPS, JULY 21, 2011

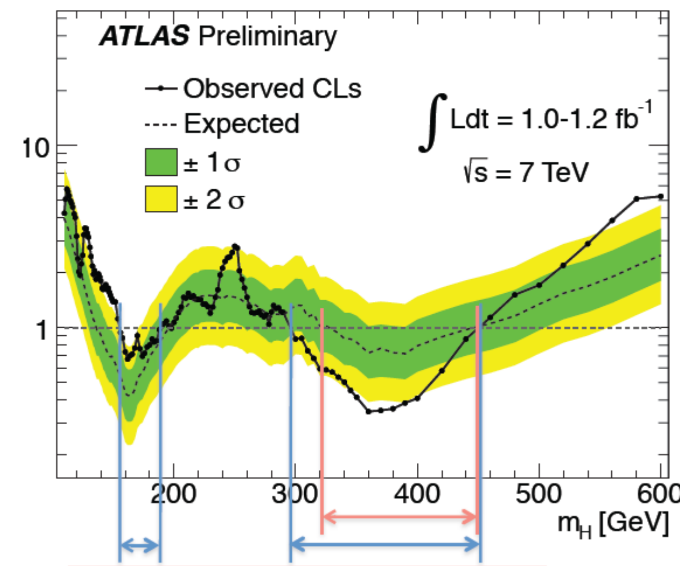
m_H = 150 GeV	Signal	WW	W+jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
Jet Veto	50 ± 11	260 ± 30	46 ± 17	80 ± 70	22 ± 8	17 ± 4	7.8 ± 1.5	430 ± 100	453
$\lvert \mathbf{P}_T^{\ell\ell} \rvert > 30$ GeV	48 ± 10	230 ± 20	38 ± 14	15 ± 6	19 ± 7	16 ± 4	7.3 ± 1.4	330 ± 50	371
$m_{\ell\ell} < 50$ GeV	34 ± 7	59 ± 8	11 ± 3	7 ± 4	2.7 ± 1.8	2.8 ± 0.8	0.9 ± 0.3	83 ± 11	116
$\Delta\phi_{\ell\ell} < 1.3$	30 ± 7	46 ± 6	5.8 ± 1.8	5 ± 3	2.7 ± 1.7	2.8 ± 0.8	0.8 ± 0.2	63 ± 9	89
m_T	21 ± 4	26 ± 3	2.9 ± 0.9	1 ± 2	1.6 ± 1.2	0.7 ± 0.4	0.6 ± 0.2	33 ± 5	49
ee	3.1 ± 0.7	3.7 ± 0.7	0.5 ± 0.2	0.4 ± 0.6	0.0 ± 0.6	0.0 ± 0.2	0.05 ± 0.19	4.7 ± 1	7
$e\mu$	11 ± 2	13.4 ± 1.9	1.7 ± 0.7	0 ± 0	1.1 ± 0.8	0.4 ± 0.3	0.4 ± 0.3	17 ± 2	21
$\mu\mu$	6.9 ± 1.5	8.8 ± 1.3	0.7 ± 0.5	0.5 ± 2.0	0.4 ± 0.8	0.3 ± 0.3	0.18 ± 0.19	11 ± 3	21



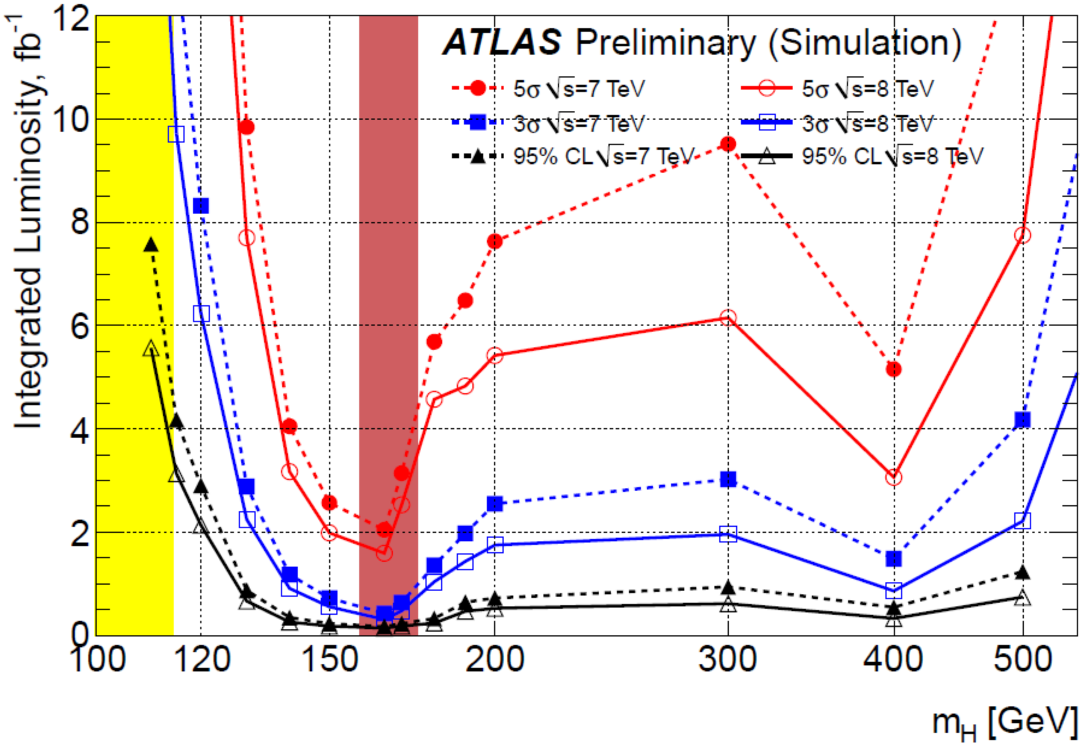
$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{\text{miss}})^2 - (\mathbf{P}_T^{\ell\ell} + \mathbf{P}_T^{\text{miss}})^2}$$







$155 < M_H < 190$ and $295 < M_H < 450$ GeV/c^2 excluded at @ 95% CL



Higgs Predictions

Figure 3: The luminosity required to give exclusion, evidence or discovery s with data at $\sqrt{s}$ = 7 or 8 TeV.

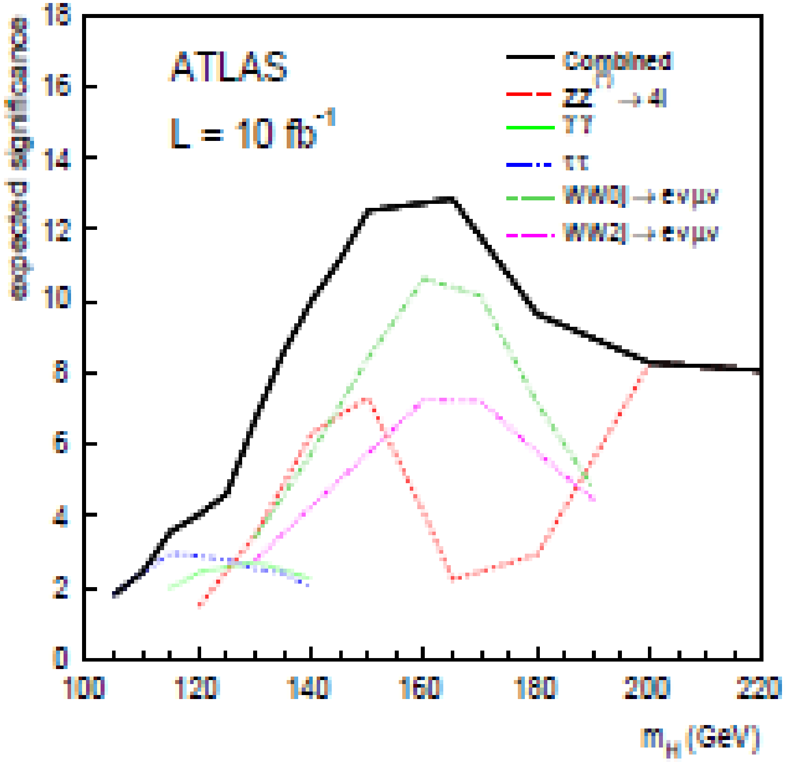
√s=7 TeV

ATLAS + CMS ≈ 2 x CMS	95% CL exclusion	3σ sensitivity	5σ sensitivity	
1 fb^{-1}	120 - 530	135 - 475	152 - 175	
2 fb^{-1}	114 - 585	120 - 545	140 - 200	
5 fb^{-1}	114 - 600	114 - 600	128 - 482	2011
10 fb^{-1}	114 - 600	114 - 600	117 - 535	2012

If the SM Higgs exists, we'll know its mass soon

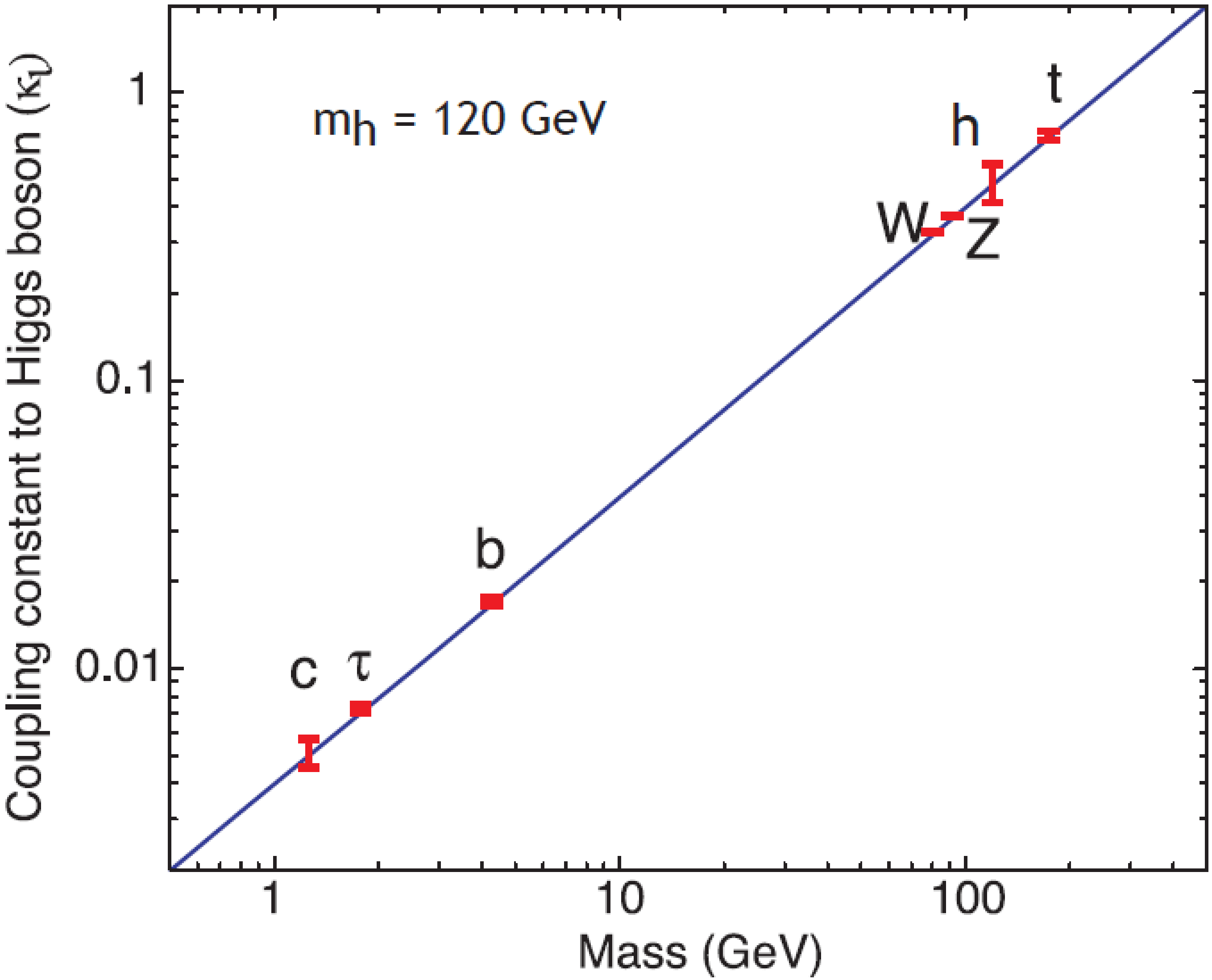
ALCPG 2011 Eugene: S. Dawson

Higgs Physics @ 14 TeV and 10 fb^{-1}



So we will have a definite answer on the Higgs and if it exists.

Higgs mass couplings



ACFA LC study

Higgs Physics – ILC measurements

500 Gev, 500 fb^{-1}

Observable	Expected precision	Reference
SM-like Higgs with $M_H \approx 120$ GeV		
M_H [GeV]	0.04 %	[40]
Γ_H [GeV]	0.056 %	[40]
g_{HWW}	1.2 %	[40]
g_{HZZ}	1.2 %	[40]
g_{Htt}	3.0 %	[40]
g_{Hbb}	2.2 %	[40]
g_{Hcc}	3.7 %	[40]
$g_{H\tau\tau}$	3.3 %	[40]
g_{Htt}	7 %	[45]
g_{HHH}	22 %	[40]
$\mathrm{BR}(H \to \gamma\gamma)$	23 %	[40]
CP_H	4.7σ diff. between even and odd	[46]
GigaZ Indirect M_H [GeV]	7 %	[47, 48]
Heavy SM-like Higgs with $M_H \approx 200$ GeV		
M_H [GeV]	0.11 %	[49]
direct Γ_H [GeV]	34 %	[49]
$\mathrm{BR}(H \to WW)$	3.5 %	[49]
$\mathrm{BR}(H \to ZZ)$	9.9 %	[49]
$\mathrm{BR}(H \to b\bar{b})$	17 %	[50]
g_{Htt}	14 %	[45]
Additional Measurements for Non-SM Higgs with $M_H \approx 120$ GeV		
$\mathrm{BR}(H \to \text{invisible})$	< 20 % for BR > 0.05	[40]

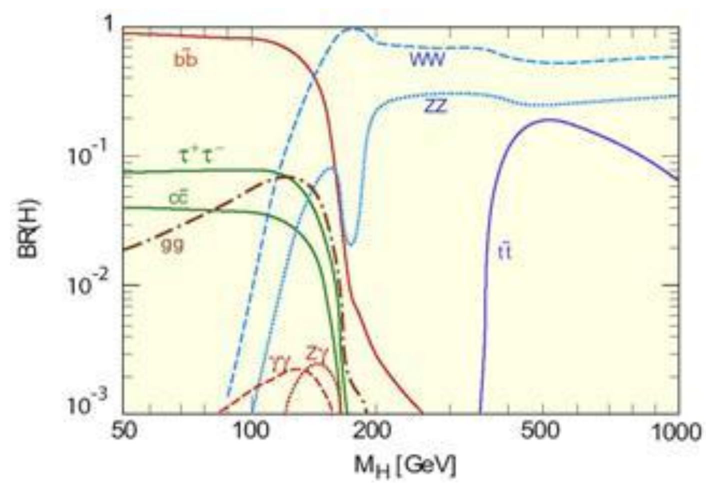
arXiv:0909.3240 [hep-ph]

LHC @ 14 TeV with 300 fb^{-1}:

M(h) < 150
Couplings to fermions 15-30%

Couplings to gauge bosons 10-15%

but NO determination of Higgs self coupling.

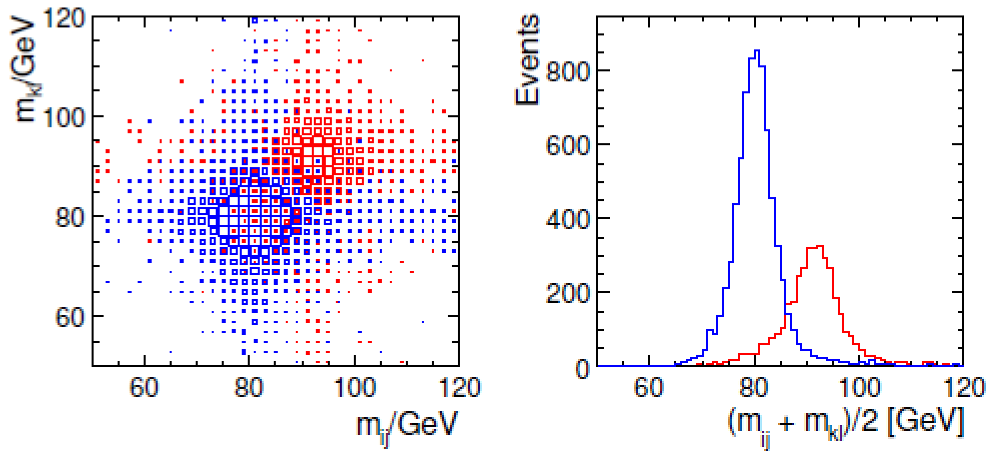


No Higgs (seen…or exists)

If no fundamental Higgs boson is found:

- non-standard Higgs, hard to observe, suppressed couplings,… the LHC could eventually determine M_h to 10-30 GeV from the ZH rate (arXiv:0909.3240[hep-ph]) , but an ILC would be guaranteed to see a peak in M_x in e^+e^- -> ZX

Strong EWSB $e^+e^- \rightarrow \nu_e\bar{\nu}_e q\bar{q}q\bar{q}$

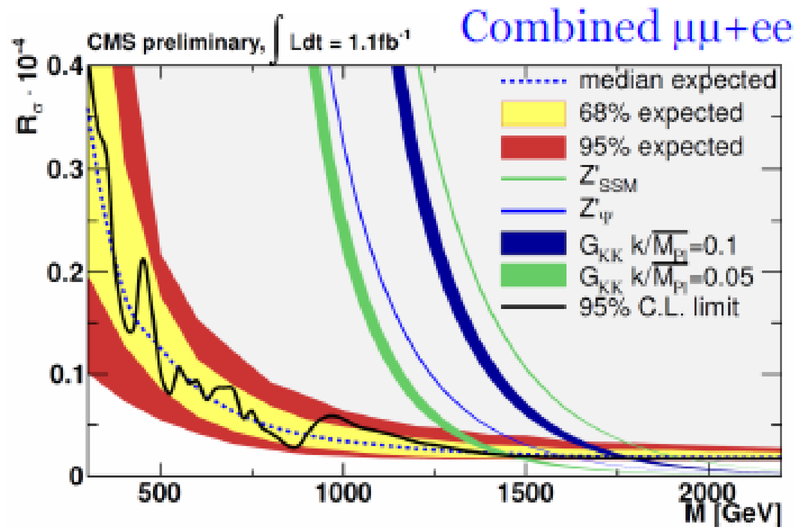


ILD Study @ 1 TeV

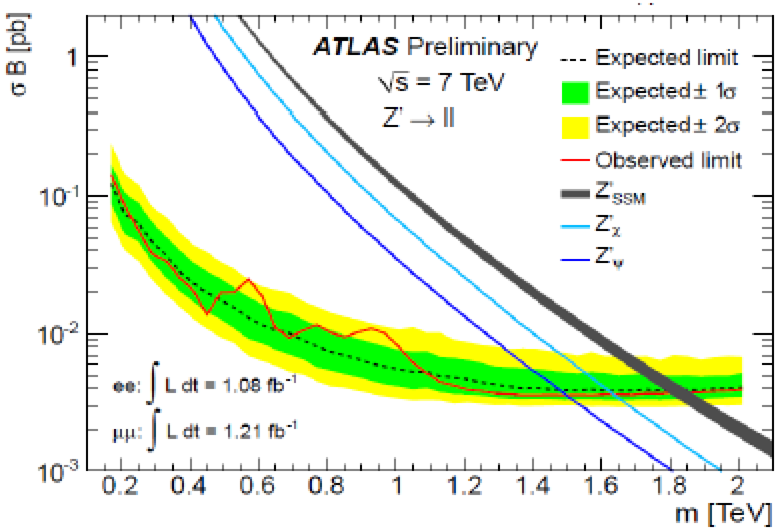
Using the power of ILC calorimetry to resolve W, Z in hadronic mode

Additional Heavy Vector Bosons

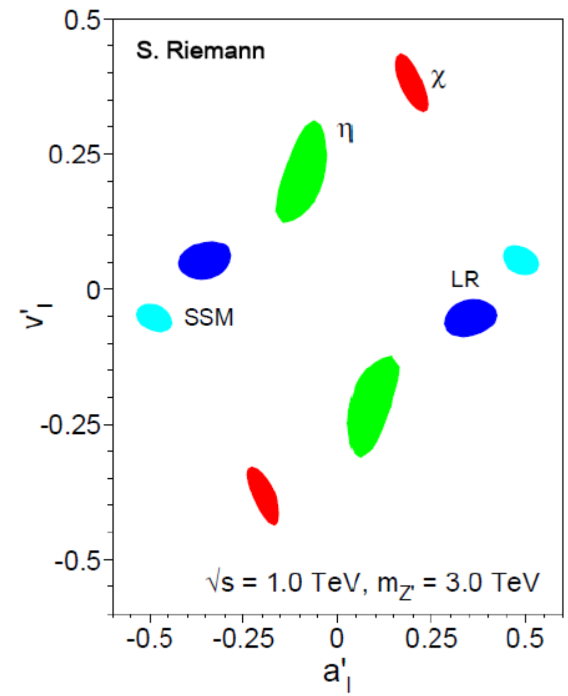
CMS



ATLAS



ILC Indirect Z' Coupling Determinations

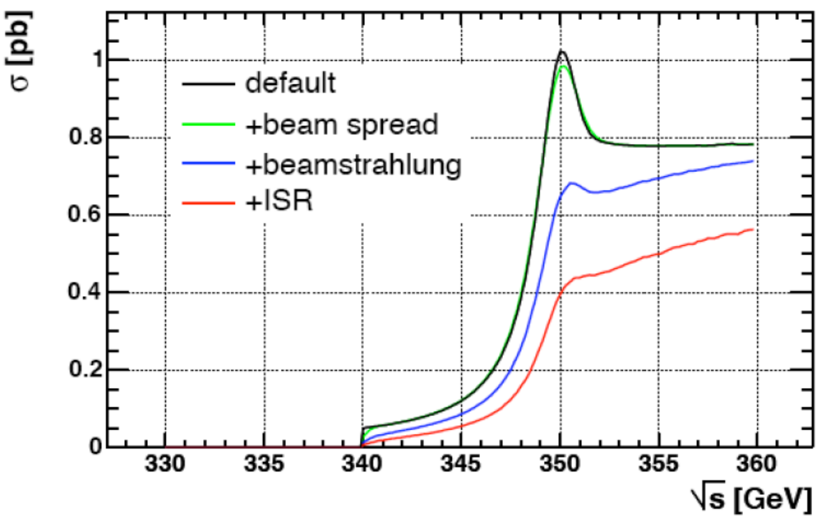


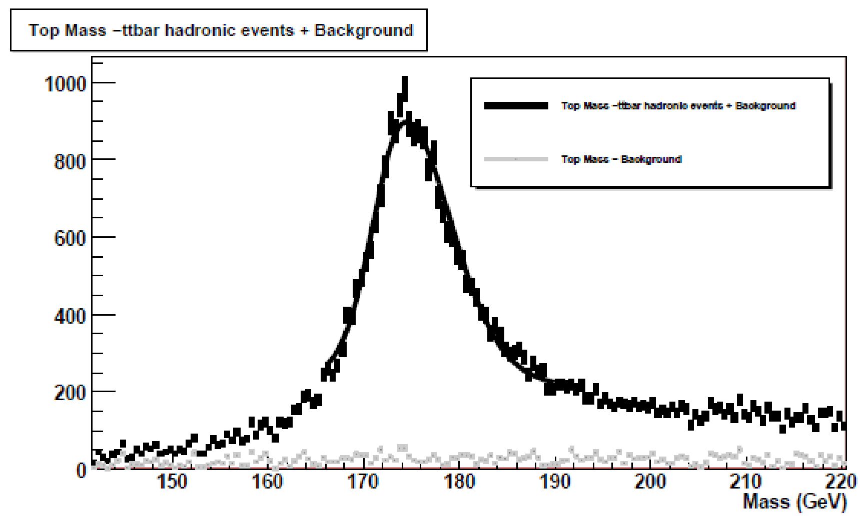
For M(Z') < 3-4√s found at LHC then couplings can be found at ILC from asymmetry measurements using polarized beams.

Tom Rizzo

Top Physics

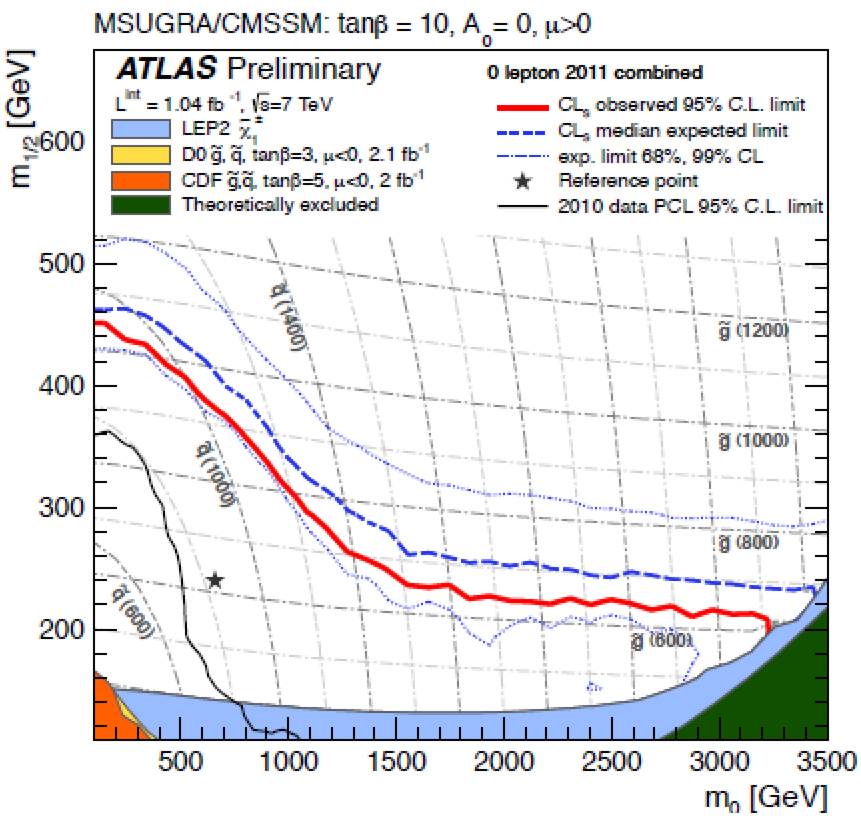
- Critical sector to explore (particularly if no/confusing NP signals at the LHC)
- A probe of new physics
- Key role in EWSB via loop effects
- Must determine top mass precisely plus couplings to SM bosons
- Also extract mass from top threshold studies
- Measure FB asymmetry (polarized beams)

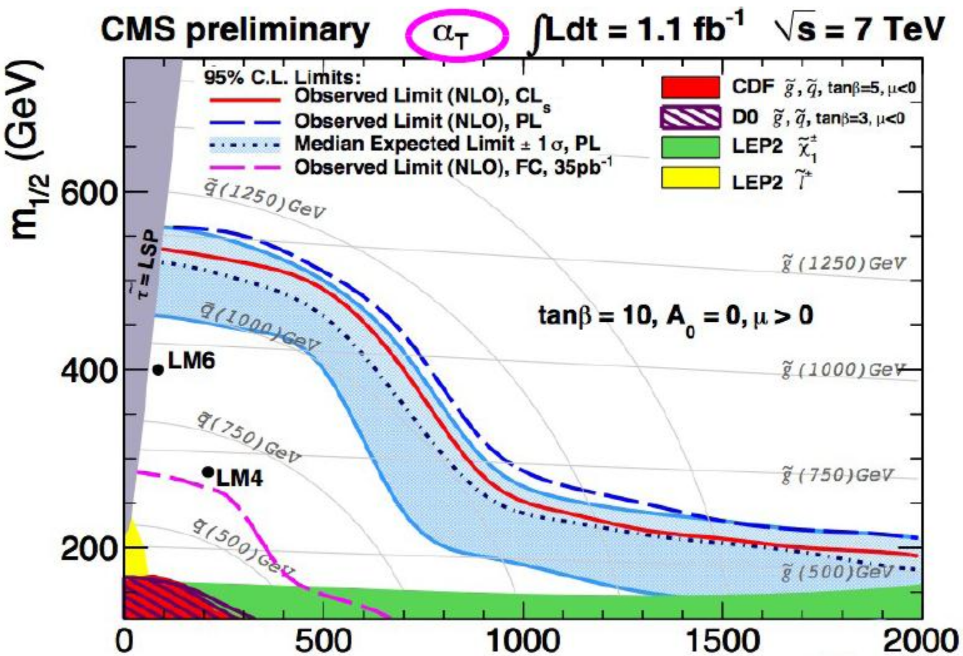




LOI studies: Δm_t ~ 30-40 MeV

Supersymmetry
LHC results/EPS





Supersymmetry

We ~knew that we would be unlikely to be able to pair-produce squarks and gluinos at an ILC…the Tevatron results showed this.

If there is no discovery, the possible SUSY mass scale will be pushed higher and higher. This is OK as long as a stop squark (and presumably LSP) stay below 1 TeV (to regulate the quadratic Higgs mass divergence)

The critical question for an ILC is: will there be a useful part of the SUSY spectrum that remains accessible at 500 Gev or 1 TeV, and is therefore amenable to precision studies?

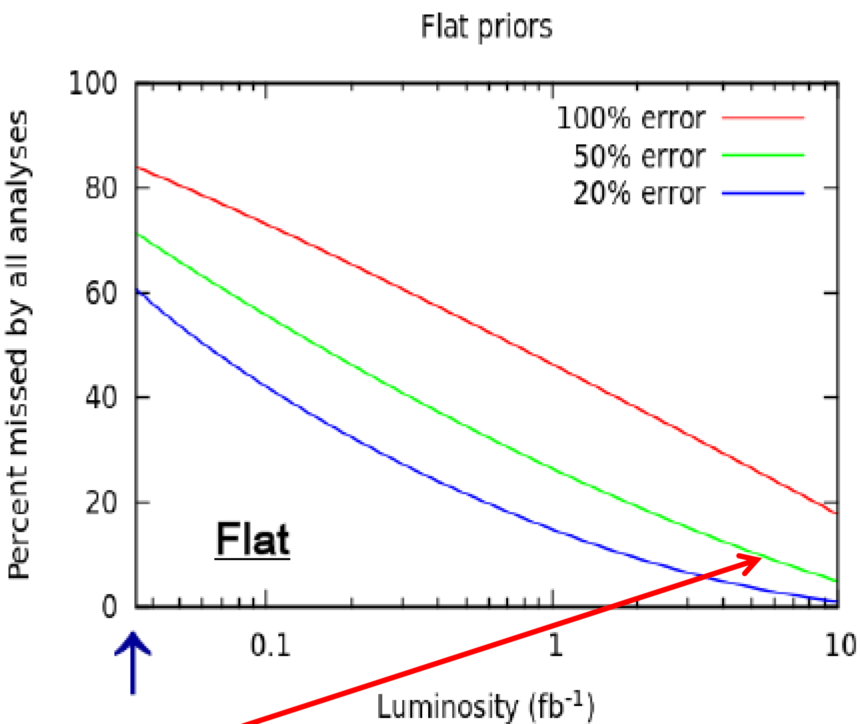
Key point: Sven Heinemeyer (2011)

The LHC searches (mainly) for colored particles,
the ILC is (also) searching for uncolored particles!

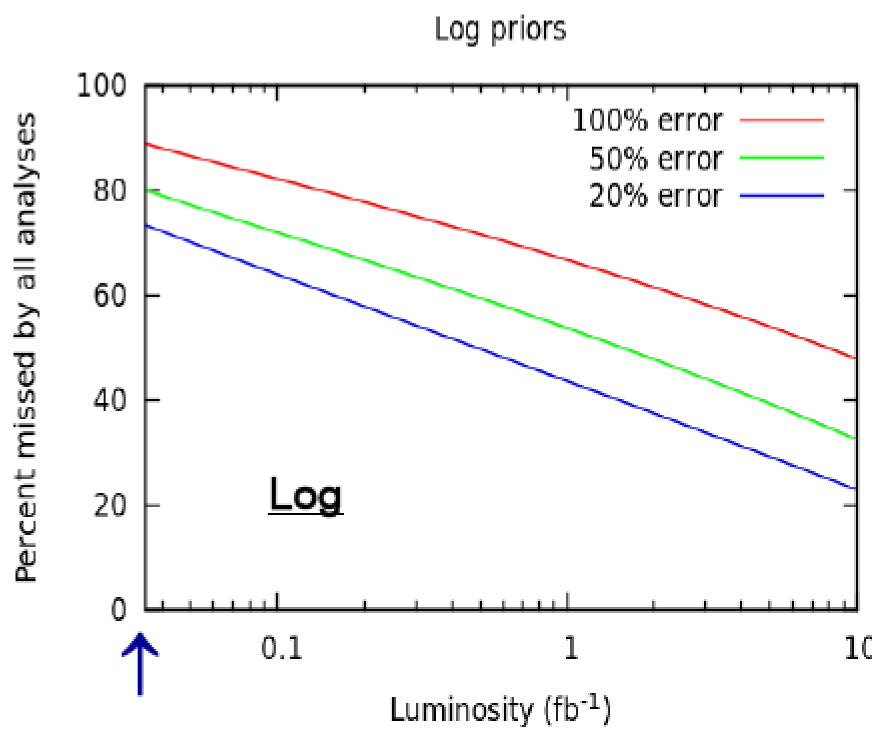
Any inference from one sector to the other is strongly model dependent!

Supersymmetry (pMSSM)

All SUSY masses < 1 TeV



All SUSY masses < 1 TeV
except m(sq), m(gl) < 3 TeV



Shrinking space in which SUSY can hide!

T. Rizzo (March 2011)

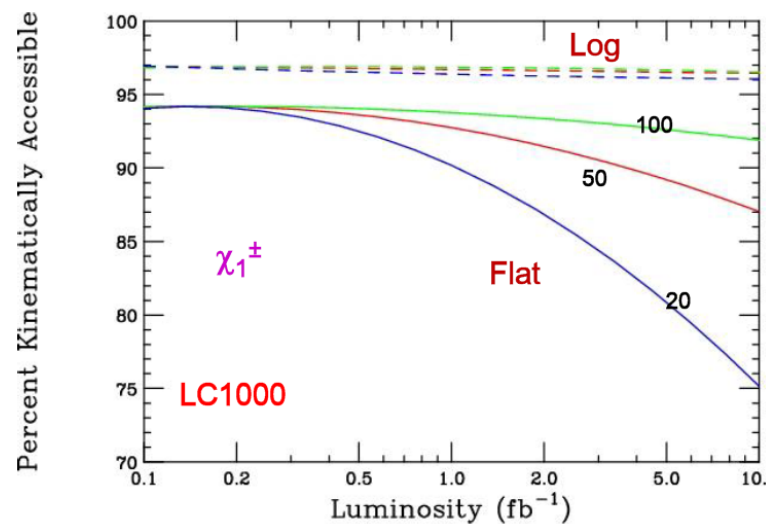
Supersymmetry

	$\sqrt{s} = 500$ GeV		$\sqrt{s} = 1$ TeV	
Sparticle	Flat	Log	Flat	Log
$\tilde{e}_L$	0	37	63	142
$\tilde{e}_R$	0	72	53	223
$\tilde{\tau}_1$	2	142	165	338
$\tilde{\tau}_2$	0	11	9	69
$\tilde{\nu}_e$	0	42	64	146
$\tilde{\nu}_\tau$	0	85	81	236
$\tilde{\chi}_1^0$	26	507	587	626
$\tilde{\chi}_2^0$	4	397	352	557
$\tilde{\chi}_3^0$	0	136	57	357
$\tilde{\chi}_4^0$	0	5	5	66
$\tilde{\chi}_1^\pm$	25	467	505	608
$\tilde{\chi}_2^\pm$	0	17	16	170
$\tilde{g}$	0	0	27	5
$\tilde{d}_L$	0	3	73	24
$\tilde{d}_R$	1	18	63	157
$\tilde{u}_L$	0	5	81	24
$\tilde{u}_R$	0	14	86	79
$\tilde{b}_1$	0	20	103	189
$\tilde{b}_2$	0	0	3	4
$\tilde{t}_1$	1	2	94	58
$\tilde{t}_2$	0	0	0	0

Set of models NOT found at 7 TeV with 10 fb^{-1} and $\delta B = 20\%$

1 TeV ILC

Things do change a lot at LC1000… a very large fraction of models have accessible charginos.



ILC Physics potential

1. Precision measurements of $e^+e^- \to f\overline{f}$
   relevant to Z' models, extra dimensions, compositeness

2. Precision measurements of $e^+e^- \to W^+W^-$
   relevant to strongly interacting Higgs sectors

3. Precision measurements of m_t and $e^+e^- \to t\overline{t}$
   relevant to precision electroweak and/or
   strongly interacting sectors with Higgs and top

4. Precision measurements of the Higgs boson couplings
   testing whether this particle actually gives 100% of the
   mass of all quarks, leptons, and bosons

5. And, for any new particles discovered or suggested by LHC
   their detailed characterization and measurement of
   quantum numbers -- and relevance to cosmic dark matter

The Future

The Accelerator – complete the TDR for 500 GeV ILC, and continue studies for 1 TeV, adapt to the changing scenarios as LHC results emerge. Develop large scale production sources and strategies.

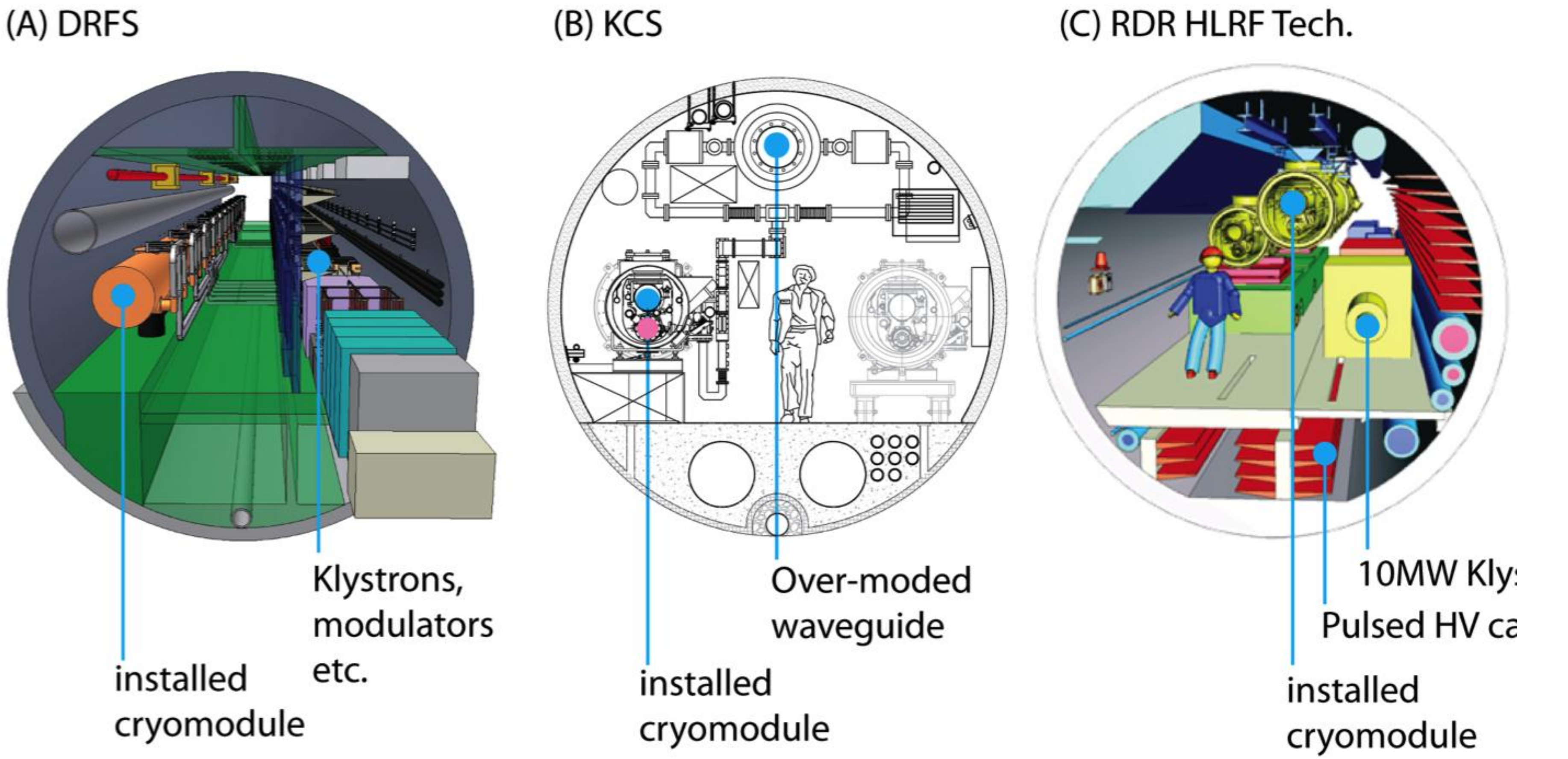
The Detectors – complete the DBD's and relevant physics benchmarks…matched to evolving LHC results. Continue critical R&D.

The Physics – follow the LHC results closely and keep updating the ILC capabilities in changing scenarios!

Bottom line: position the accelerator and detectors to be ready to respond to physics opportunities!

Additional Material

Main Linac Tunnel Solutions



Backup solution

BAW1-TLCC
Outcome

Table 1: Technical Design Cavity Performance Specification and R & D Goal.

Cost-relevant design parameter(s) for TDR	**ML cavity gradient Project Specification**	**9-cell Cavity R&D Goal**
9-cell Cavity Gradient in Vertical Test, including 2^{nd} pass, with $Q_0 \geq 8E9$	35 MV/m, average w/ Spread: 28–42 MV/m ($\leq \pm 20$ %)	35 MV/m at 90 % yield (equivalent to $\geq$ 38 MV/m, average)
9-cell Cavity Gradient in Cryomodule Test	34 MV/m, average	34 MV/m, average. CM Gradient Test $\leq$ 3 % below Vertical Test
ML Operational Gradient with $Q_0 \geq 1E10$	**31.5 MV/m average, w/** Spread: 25–38 MV/m ($\leq \pm 20\%$)	31.5 MV/m, average. Operational gradient limit $\leq$ 1.5 MV/m below Cryomodule Test. Controls margin $\leq$ 3 %
Required RF power overhead for control (see RF Power Table link, below)	~10-15% (TBD)	

Superconducting RF

Table 2.2 Regional ILC SCRF technology development and testing centres.

Region	Cavity development: fabrication, process and test	Cryomodule assembly/test	Linac beam test centres (beam on date)
Americas	Three industrial partners, and Fermilab/ANL, JLab and Cornell	Fermilab/SLAC	ILCTA–NML (2012)
Asia	Three industrial partners, and PKU, IHEP and KEK	KEK	Quantum-Beam/STF-2 (2011/2013)
Europe	Two industrial partners, and DESY and CEA-Irfu	CEA-Irfu/CNRS-LAL/DESY for FLASH and E-XFEL	FLASH (from 2005)

Table 2.3 Milestones for the SCRF R&D programme.

Stage	Subjects	Milestones to be achieved	Year
S0	Nine-cell cavity	35 MV/m, maximum, at $Q_0 \geq 8\times10^9$, with a production yield of 50% in TD Phase 1, and 90% in TD Phase 2	2010/ 2012
S1	Cavity-string	31.5 MV/m, average, at $Q_0 \geq 10^{10}$, in one cryomodule, including a global effort, and 34 MV/m, average, in TD Phase 2	2010/ 2012
S2	Cryomodule-string	31.5 MV/m, average, with full beam loading and acceleration	2012

Table 2.7 Progress in cavity/cryomodule integration and tests for TTF/FLASH, NML, and STF.

Location	Year	Progress
TTF/ FLASH (DESY)	2005	TTF2/FLASH integration and test started
	2008	ILC 9-mA beam: first beam with 3-mA, 500-ms beam pulses
	2009	Operation with high-power ILC-like beam with 22-kW average power
	2011	Gradient-margin studies with long beam pulses
	2012	Studies of beam operation at the limits of gradient and RF power
NML (Fermilab)	2007	NML first cryomodule integration
	2010	Integration completed and cool-down started
	2012	Planned: NML accelerator system integration to be complete
	2013	Planned: Beam acceleration to start
STF (KEK)	2007	STF S-1: cavity/cryomodule system integration and test
	2010	S1-Global: cryomodule assembly and cold test
	2011	Planned: quantum beam integration and beam test to start
	2012	Planned: STF-2 accelerator system integration to be complete
	2013	Planned: STF-2 beam accelerator to start

Detectors @1 TeV

ILD

Letter of intent for ILD: focused on 500 GeV

ILD strategy:

Design a excellent detector for the ILD with potential to go to higher energies

- Large detector
- "Relaxed" performance on many systems

  example: magnetic field @ ILD: 3.5T
  increasing B-field improves performance

- Key components (e.g. HCAL thickness) already chosen with 1 TeV in mind

SiD

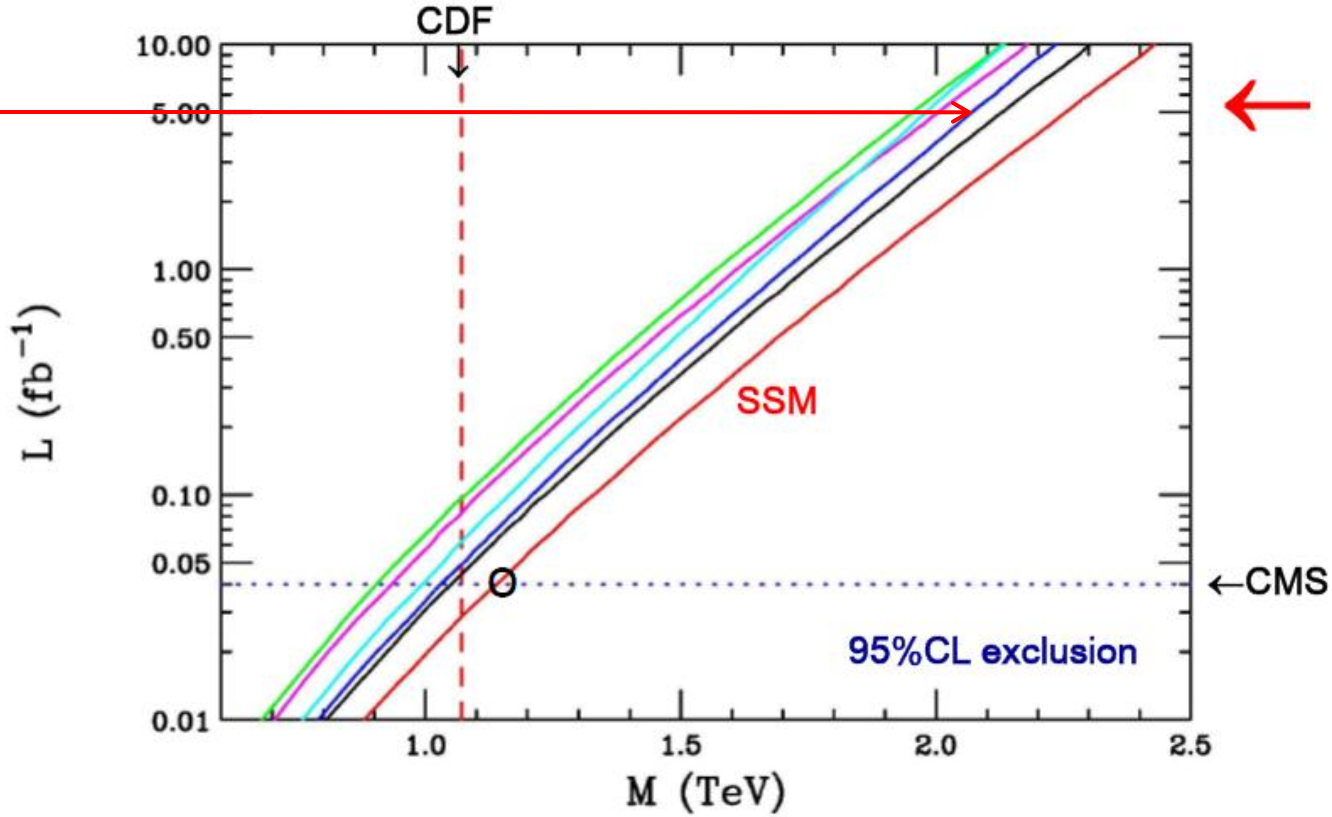
Central field is already at 5T

Demonstrated that track finding efficiency is good in jets @1 TeV

Calorimeter/jet energy resolution satisfies physics requirements with initial depth.

Note: both concepts benefit significantly from CLIC_SiD and CLIC_ILD studies by CLIC group

Additional Heavy Vector Bosons



Study (T. Rizzo): if no Z' seen with 5 fb^{-1}, but one exists, it is too heavy/weakly coupled to allow measurements at a 500 GeV ILC

pMSSM Model T. Rizzo et al.

- The most general, CP-conserving MSSM with R-parity
- Minimal Flavor Violation at the TeV scale
- The lightest neutralino is the LSP & a thermal relic.
- The first two sfermion generations are degenerate & have negligible Yukawa's.
- No assumptions about SUSY-breaking or unification

This leaves us with the pMSSM:

→ the MSSM with 19 real, TeV-scale parameters…

19 pMSSM Parameters

10 sfermion masses: m_{Q_1}, m_{Q_3}, m_{u_1}, m_{d_1}, m_{u_3}, m_{d_3}, m_{L_1}, m_{L_3}, m_{e_1}, m_{e_3}

3 gaugino masses: M_1, M_2, M_3

3 tri-linear couplings: A_b, A_t, A_τ

3 Higgs/Higgsino: μ, M_A, $\tan\beta$