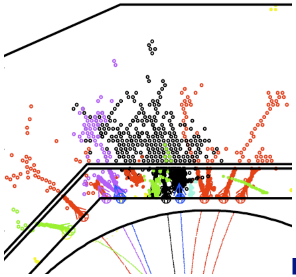
ILC machine and detectors - Introduction and power issues

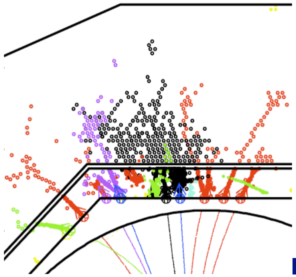
Felix Sefkow

Linear Collider Detector Power Workshop
LAL, Orsay, May 9-10, 2011



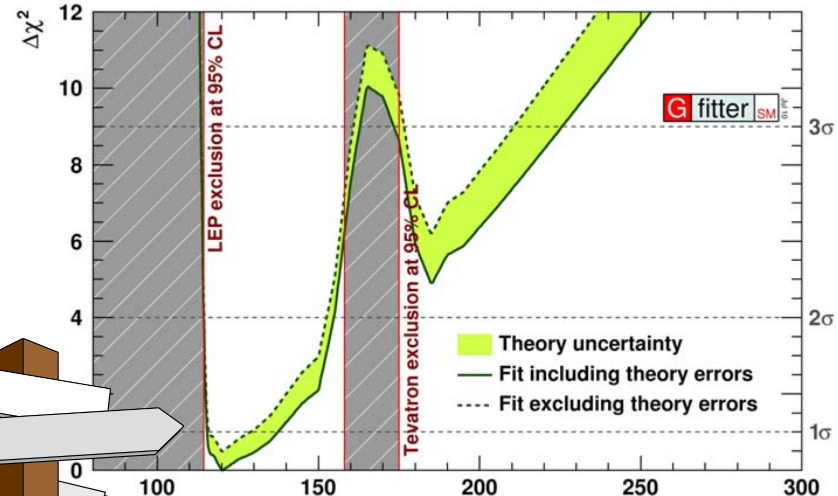
Outline

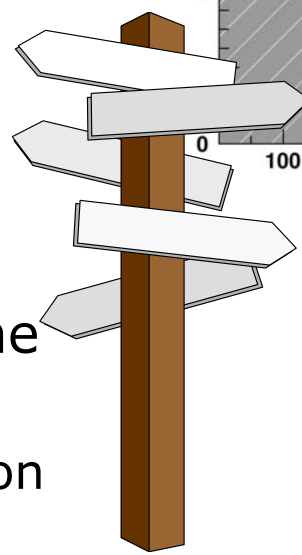
- Setting the stage: physics, machine, detectors
- Zooming in: interaction region and sub-detectors
- Switching on: Power pulsing



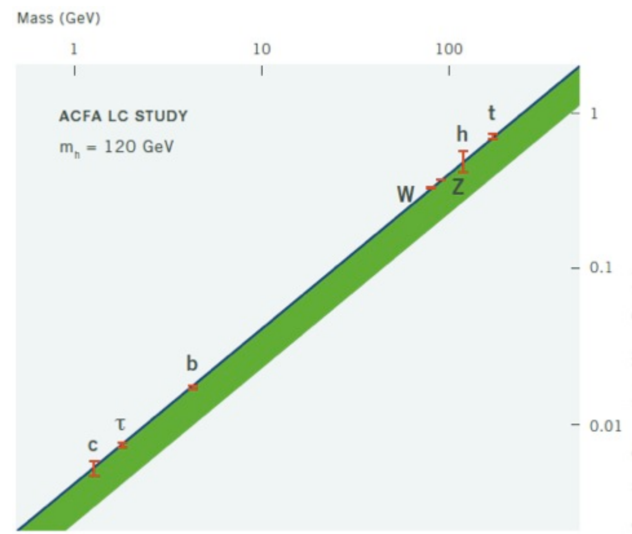
Physics case

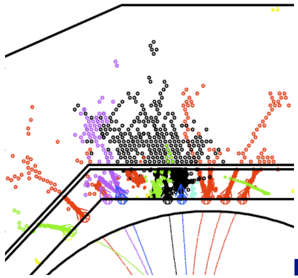
- The Higgs particle is expected to be light - in the SM
- If it exists, it will be discovered soon at the LHC
- In any case the LHC will point the way into the future of particle physics





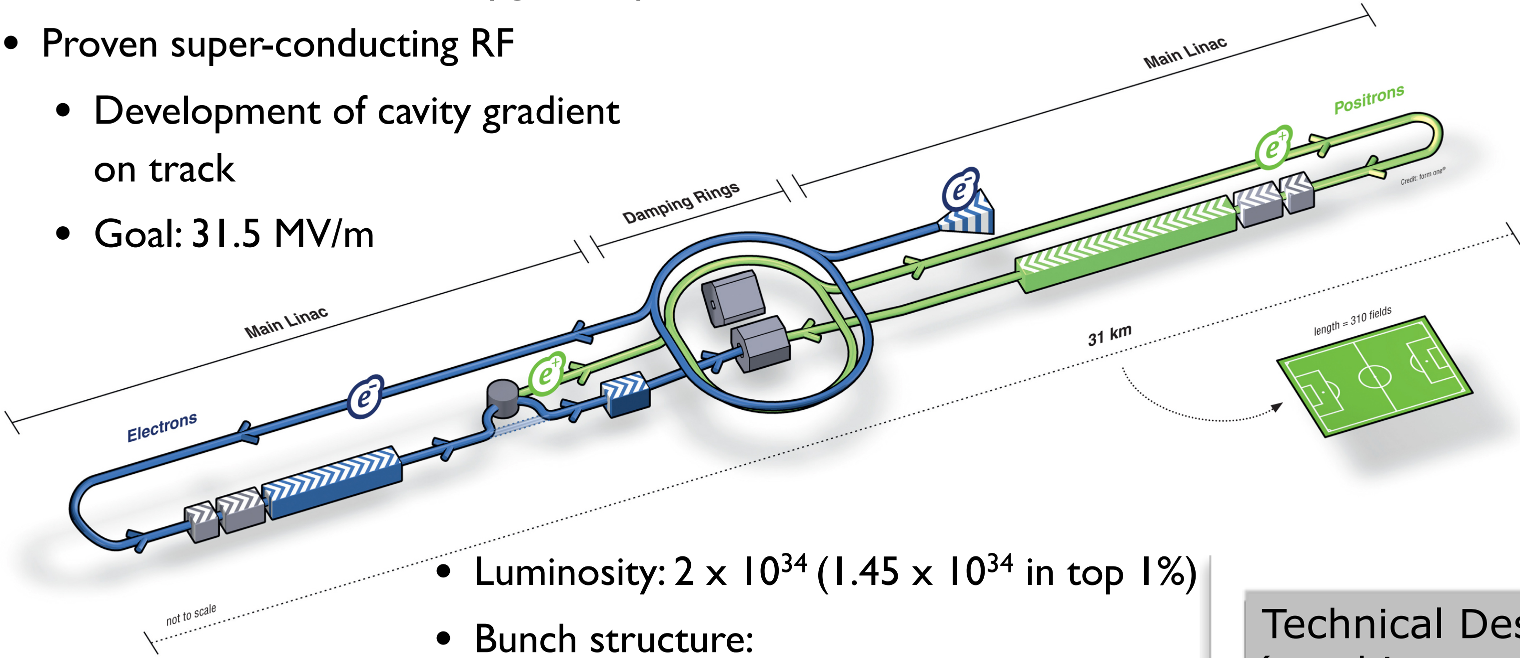
- The ILC is the e+e- machine which
  - is ideally suited for precision physics at 0.3-1 TeV
  - and is ready to be built



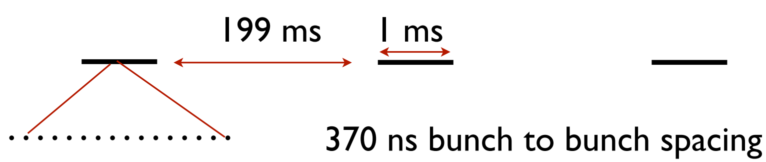


International Linear Collider

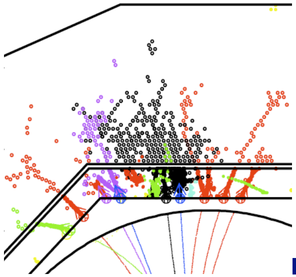
- The International Linear Collider ILC
  - 500 GeV center of mass, upgrade up to 1 TeV
  - Proven super-conducting RF
    - Development of cavity gradient on track
    - Goal: 31.5 MV/m



- Luminosity: 2 x 10^{34} (1.45 x 10^{34} in top 1%)
- Bunch structure:

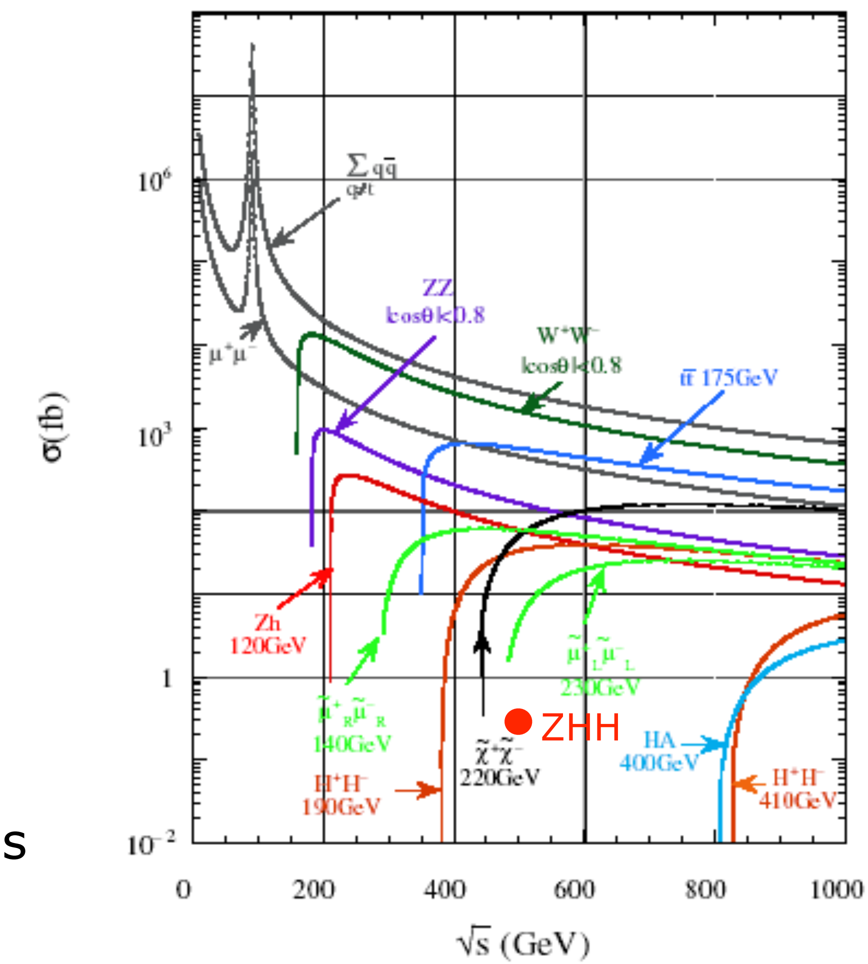


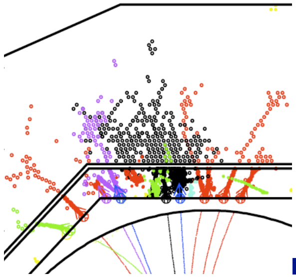
Technical Design Report (machine and detectors) due in 2012



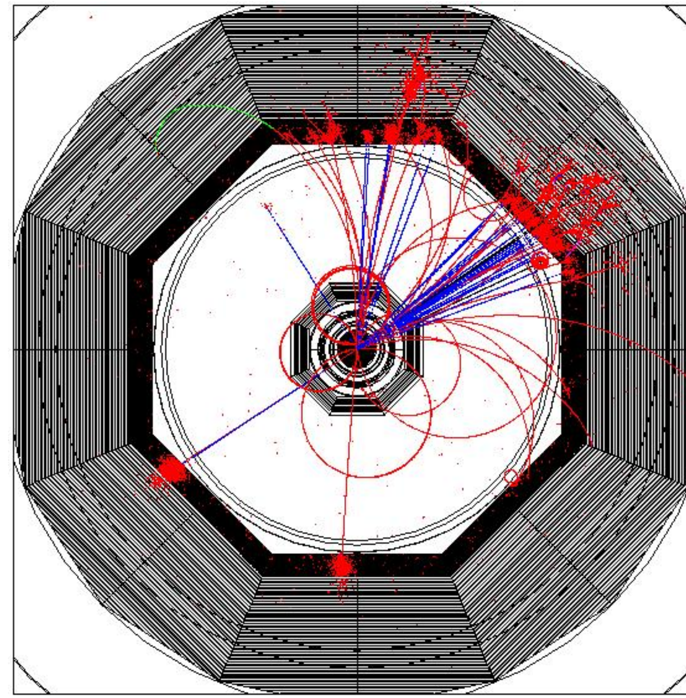
e+ e- final states at the ILC

- Q-Qbar events are boring
- Mostly 4-, 6-fermion final states, ee➔ ttH ➔ 8 -10 jets
- At ILC 500: E_{jet} = 50…150 GeV
  - Mean pion energy 10 GeV
- At ILC 1 TeV: E_{jet} < ~ 300 GeV
- Missing energy
- High momentum leptons
- Heavy quarks
- Relatively low rates
- Clean final states, low occupancies
- Low or moderate background





Detector requirements

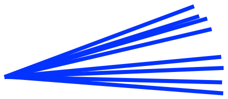


- With respect to the LHC:
- Radiation hardness not an issue (except very forward)
- Rate capability not an issue - triggerless operation

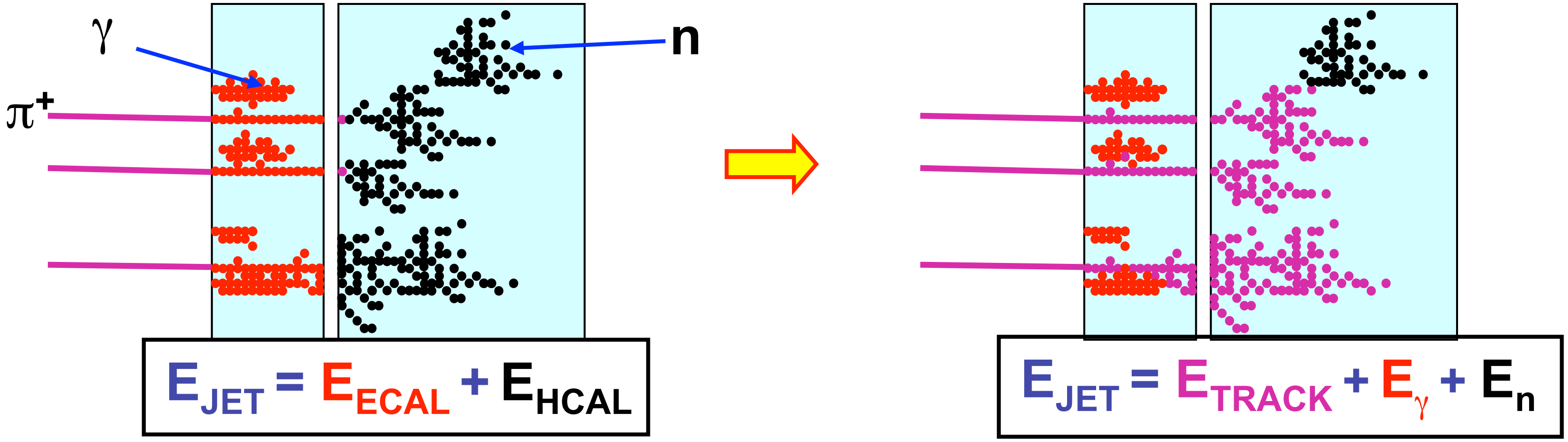
- Emphasis is on performance: tremendous challenge
- Vertex: 30x smaller pixels, 30x less material
- Tracking: 10x better momentum resolution, 6x less material
- Calorimeter: 2x better jet energy resolution, 100x more cells
  - drives the detector concepts

Particle Flow Calorimetry

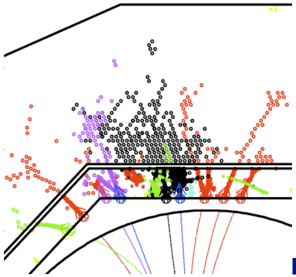
- **In a typical jet :**
  - **60 %** of jet energy in charged hadrons
  - **30 %** in photons (mainly from $\pi^0 \to \gamma\gamma$)
  - **10 %** in neutral hadrons (mainly n and K_L)



- **Traditional calorimetric approach:**
  - Measure all components of jet energy in ECAL/HCAL !
  - **~70 %** of energy measured in HCAL: $\sigma_E/E \approx 60\%/\sqrt{E(GeV)}$
  - Intrinsically "poor" HCAL resolution limits jet energy resolution

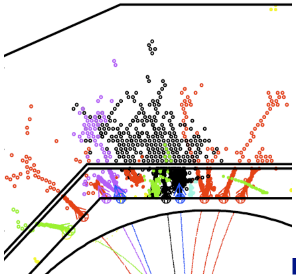


- **Particle Flow Calorimetry paradigm:**
  - charged particles measured in tracker (essentially perfectly)
  - Photons in ECAL: $\sigma_E/E < 20\%/\sqrt{E(GeV)}$
  - Neutral hadrons (ONLY) in HCAL
  - Only 10 % of jet energy from HCAL ⟹ much improved resolution



Detector concept

- large radius and length
  - to separate the particles
- large magnetic field
  - to sweep out charged tracks
- “no” material in front
  - stay inside coil
- small Moliere radius
  - to minimize shower overlap
- small granularity
  - to separate overlapping showers



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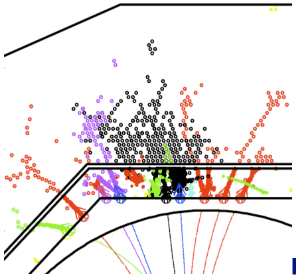
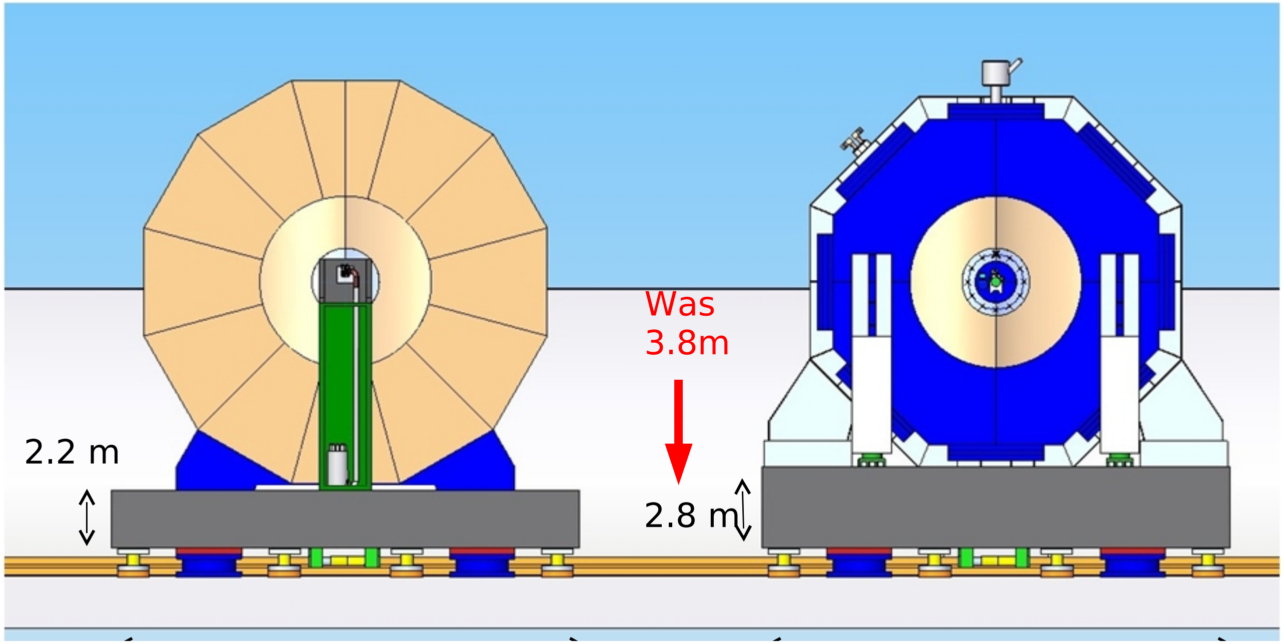


ILC detector concepts

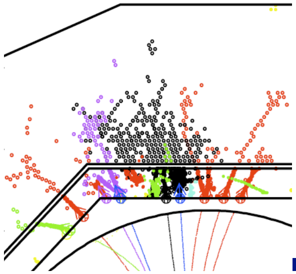
- PFLOW involves entire detector:
- ECAL and HCAL inside (CMS-like) solenoid
- Highly segmented and compact calorimeters
- ILD: TPC for highest pattern recognition efficiency, B=3.5T
- SiD, higher B, smaller R, Si tracker, similar calorimeters

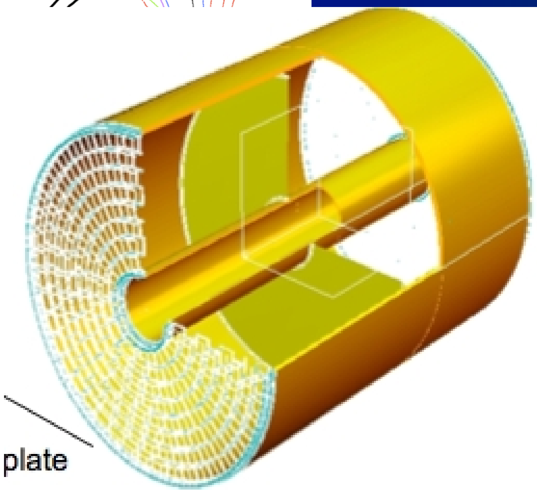
2 detectors push-pull operation



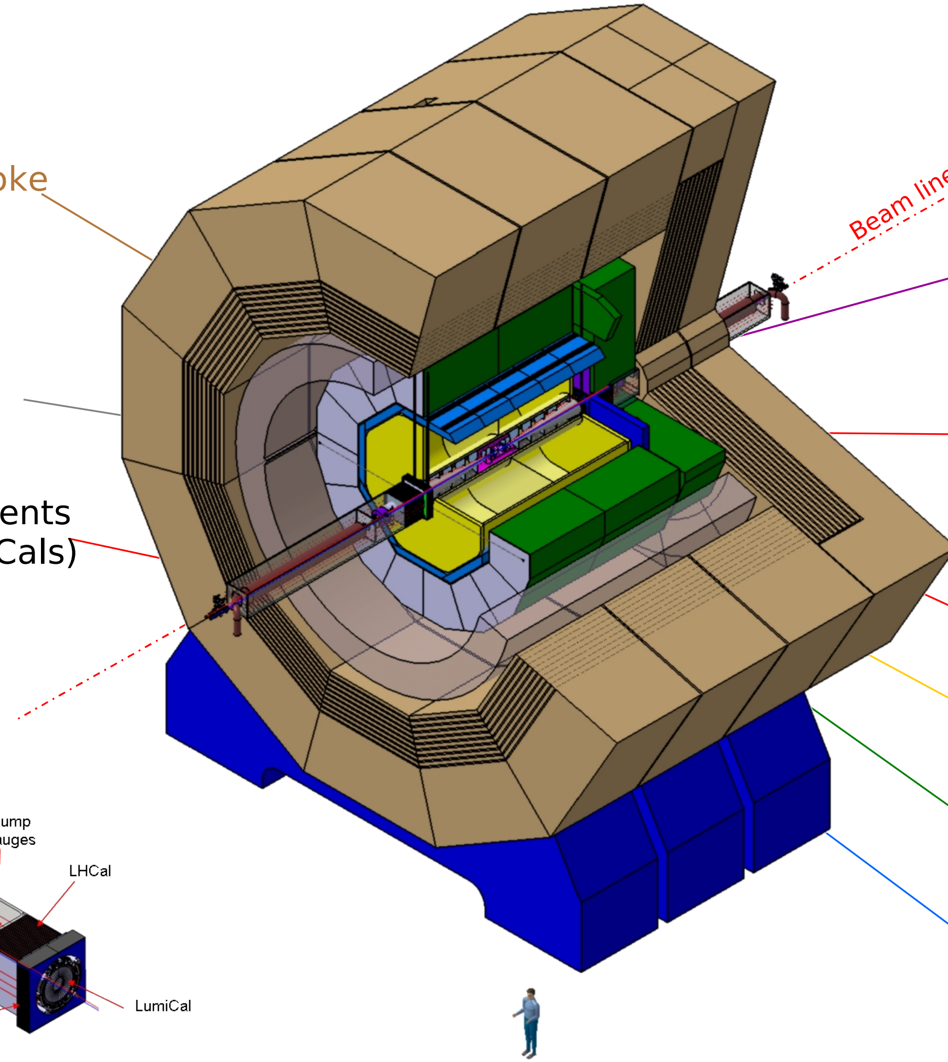
Calorimeter for ILC

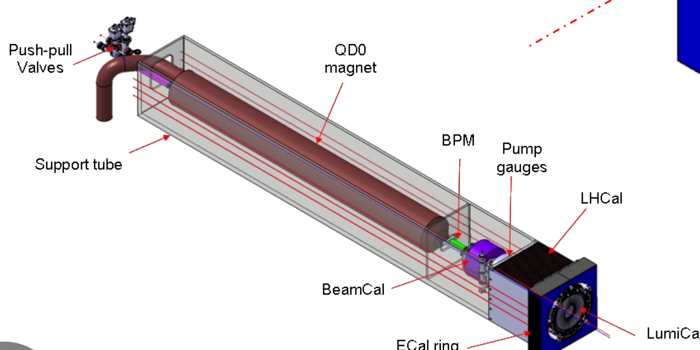
ILD



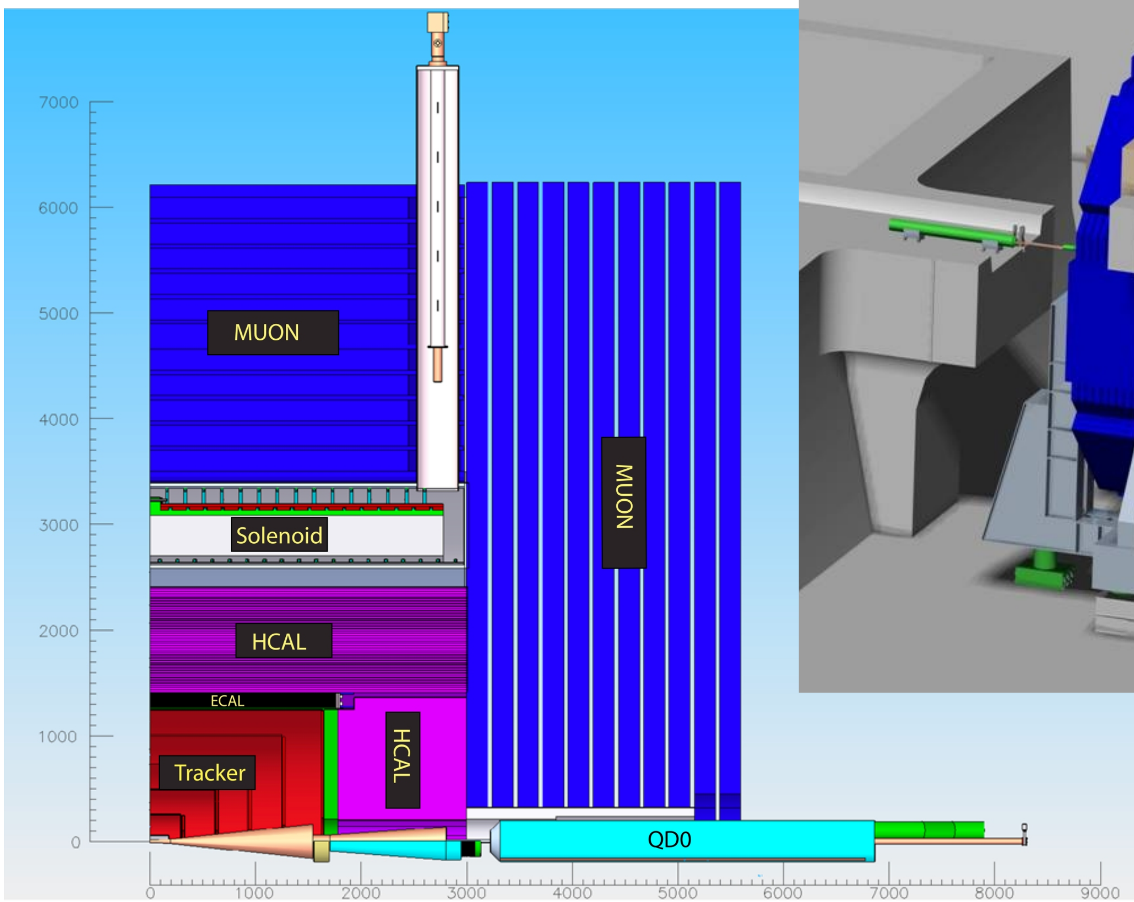


plate


eturn Yoke
Coil
Forward components
(QD0 magnet – FCals)
Beam line
ETD
VTX
SIT
FTD
SET
TPC
HCal
ECal


Push-pull
Valves
QD0
magnet
Support tube
BPM
Pump
gauges
LHCal
BeamCal
ECal ring
LumiCal

SiD



7000
6000
5000
4000
3000
2000
1000
0
MUON
MUON
Solenoid
HCAL
ECAL
HCAL
Tracker
QD0
0
1000
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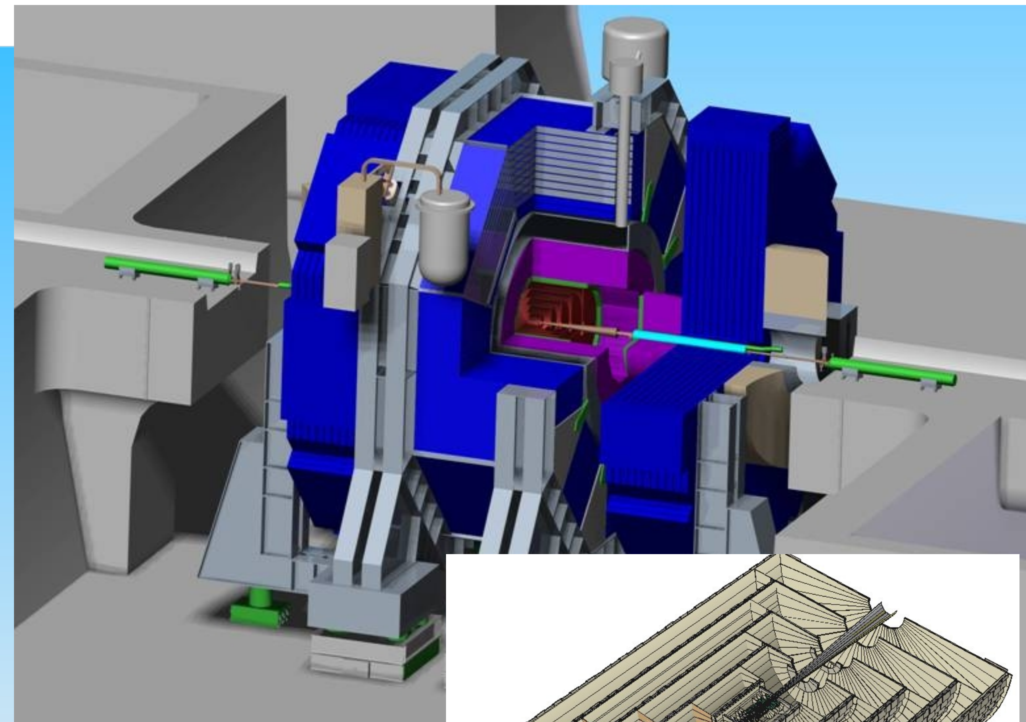
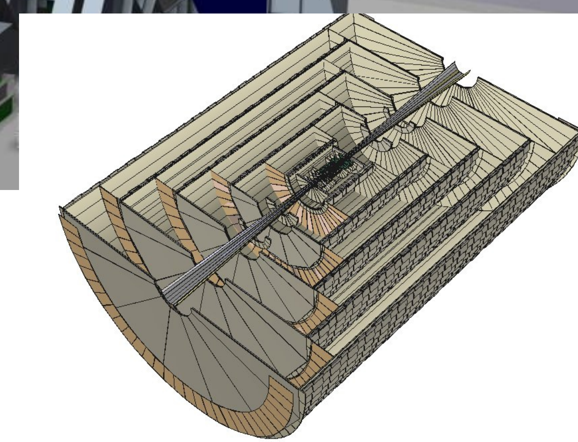
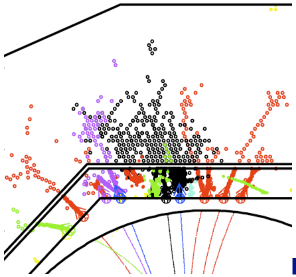
3000
4000
5000
6000
7000
8000
9000



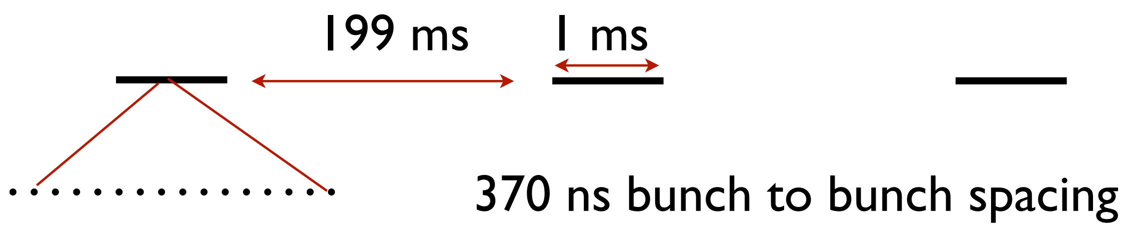




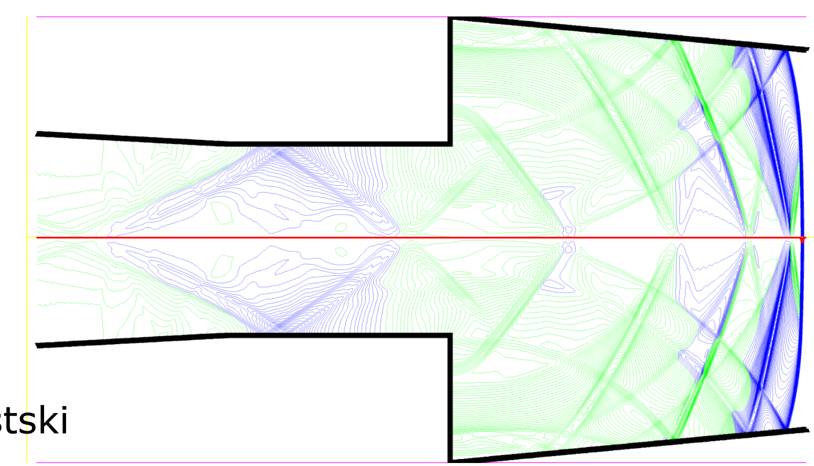
ILC specifica

- Implications on power from the machine side:

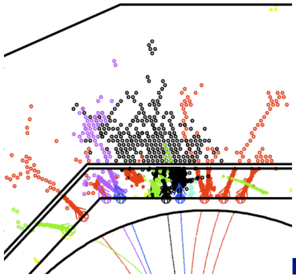
- Bunch structure: duty cycle of 1% suggests power cycling (“power pulsing”)



- Additional heat load from wake field induced currents in the beam pipe
  - SiD calcuclation 30 W, ILD similar
  - same order of magnitude as vertex detector read-out



S. Novokhastski



SiD subdetectors

- power estimates based on kPix chip
  - up to 1024 channels, power pulsed, 20 μW/ch
  - used in tracking and calorimetry

KpIX Counts	Count	Channels	Power
Tracker	29630	1024	607
EMCal	105863	1024	2168
Hcal	37222	1024	762
Muons	9049	64	12
Total	181764		3549 W

M. Breidenbach

- VXD unknown
  - aim < 50-100 W
  - influences design choice
- Power distribution: DC DC conversion, x1/8

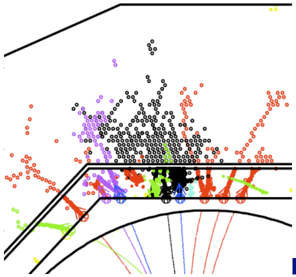
ILD sub-detectors

- Examples:

- Vertex detector: detailed studies give 20-30 W
  - based on preset design plus change 0.35 to 01.8 μ
  - take switchable and non-switchable parts into account

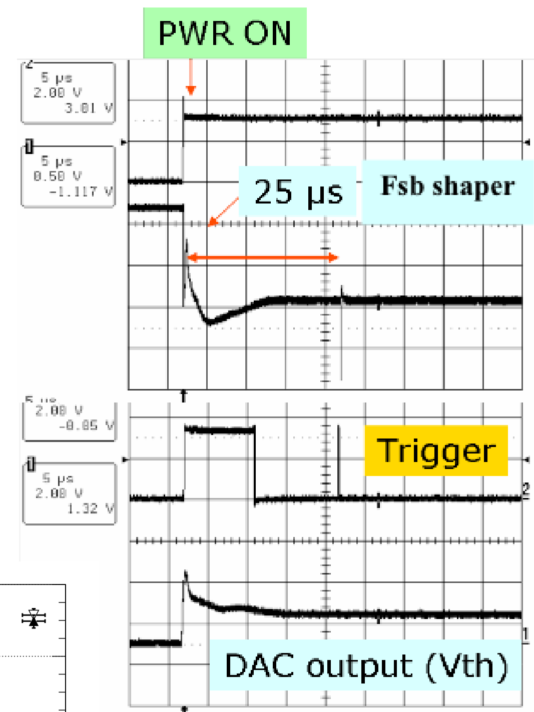
- TPC: studies started
  - 100W / m2 assumed, based on S-ALTRO chip, 1.5% duty cycle

- Calorimeters: based on ROC ASIC family from Orsay
  - HCAL, scint option: 8M channels give 300 W
  - 40 μW/ch, 25 μW/ch pulsed (1%), 15 μW/ch DC /SiPM bias)
  - biggest challenge: ECAL, high compactness and channel density

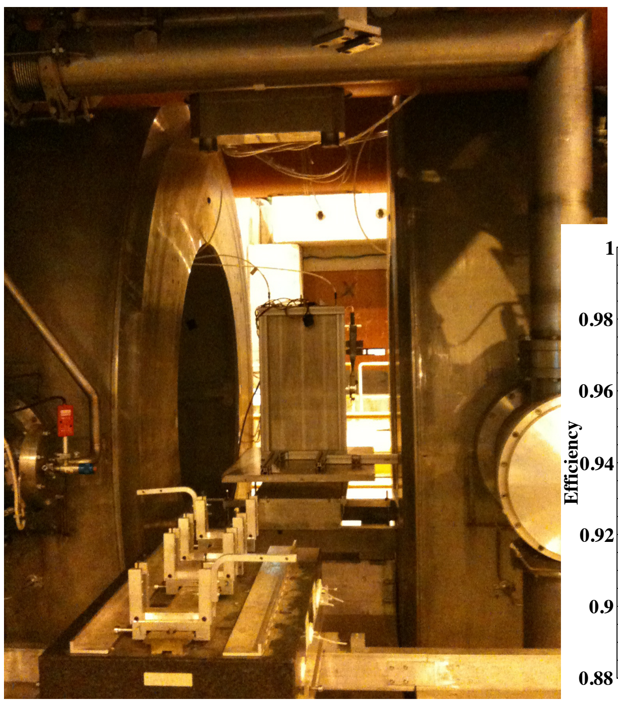


Tests of power pulsing

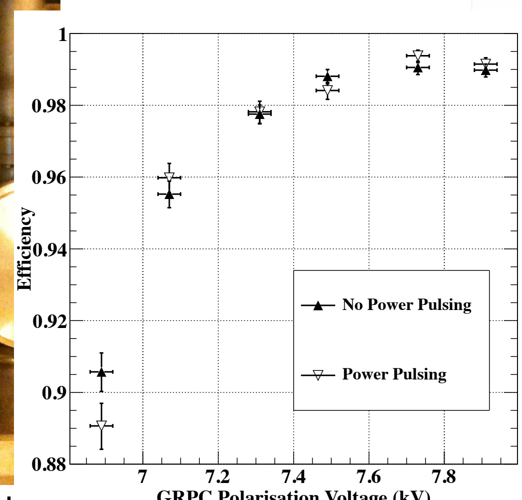
- Electronics stand-alone:
  - 25 μs relaxation time
- RPC system test in 3 Tesla
  - no effect on efficiency scan

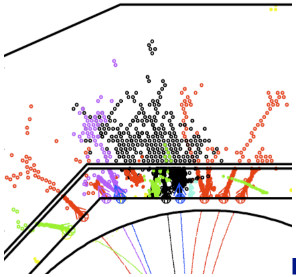


N. Seguin-Moreau



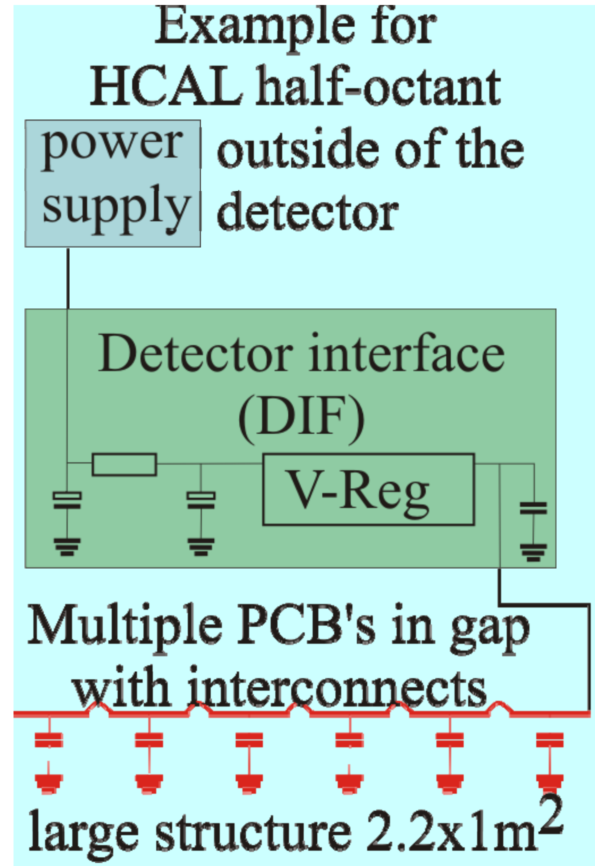
I.Laktineh



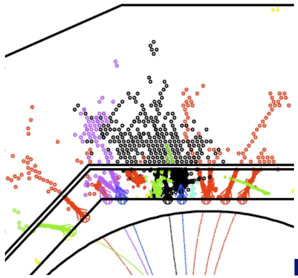


Pulsed power distribution

- Average currents are not critical
  - SiD estimates about 200A for entire detector
  - ILD up to 600 A for ECAL
- Peak currents are 1000x higher: buffer charge locally
  - externally only commercial DC supplies
  - minimize e.m. interference
  - can be done with manageable capacitors
- Still to be worked out for all subsystems



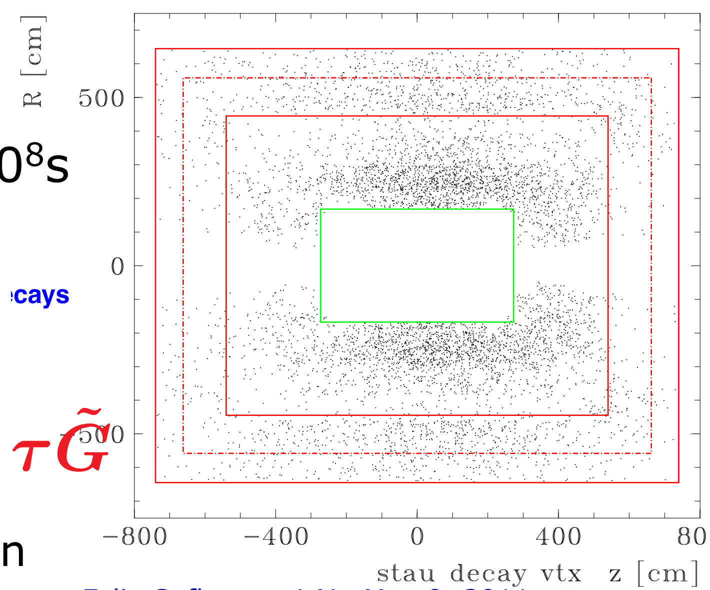
P.Göttlicher



Power pulsing downsides

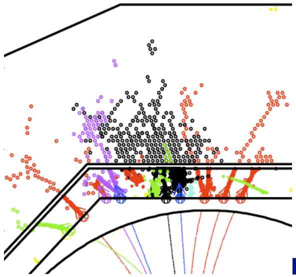
- Detector is not sensitive between bunch trains
- Calibration: only 1% of cosmic muons available
  - in a highy granular detector, cosmics are less powerful
  - halo muons are still in time
  - novel techniques: imaging calorimeters use tracks in showers
- Exotic physics channels:
  - NLSP may be long-lived, 10^2 -10^8s
  - decays in calo

cays



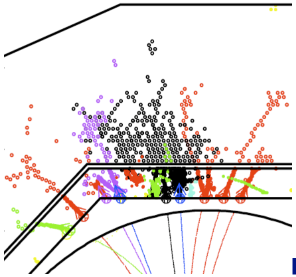
$$\tilde{\tau}_1 \longrightarrow \tau\tilde{G}$$

HU Martyn



Summary

- ILC machine and detectors approaching technical design phase
- Detectors feature extreme channel counts and must meet stringent demands on compactness and material budget
- Accelerator bunch structure suggests power pulsing for the entire detector
  - novelty in particle physics
  - system aspects to be evaluated



Conclusion

- Open issues:

- understand heat loads *everywhere, including interfaces*, and identify needs for reduction

- develop cooling concepts
- identify needs for insulation between detectors

- Evaluate power distribution concepts
- - and develop standards!

Back-up slides