ILD Optimization and Validation

F.Gaede, DESY

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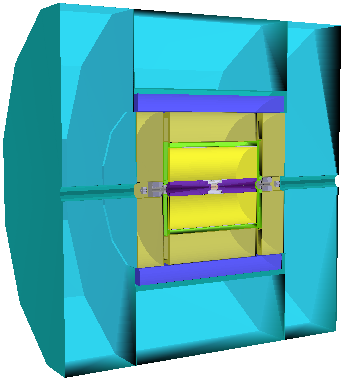
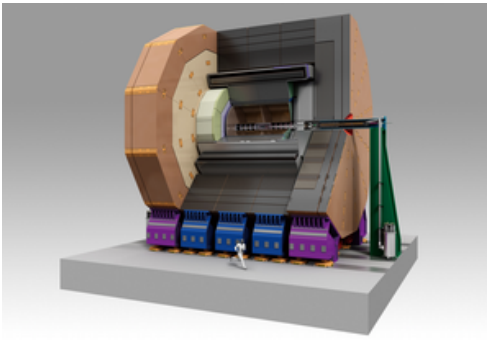
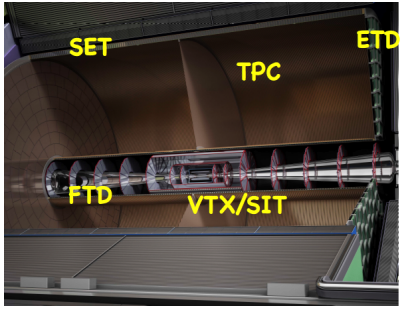
Outline

- The ILD Optimization Process
- ILD Software Tools
- Monte Carlo Mass production
- Validation
- Detector performance
- Summary and Outlook



The ILD detector





- ILD detector optimized for *PFA*
  - some *similarities* to the current CLIC detector model
  - most obvious differences: **tracking system based on a large TPC** and different dimensions

The ILD optimization process

- ILD is a very mature detector concept based on extensive R&D and testbeam studies
  - demonstrated to achieve the physics requirements for ILC - see ILD TDR (2012)
- nevertheless we continue to further optimize the ILD detector based on solid and well tested arguments, wrt.
  - **Subdetector performance**
  - **Physics performance**
  - **Cost scaling**
- this process is based on
  - demonstrated testbeam performance of the sub-detector prototypes
  - detailed and realistic physics simulations
    - also for technology choices and variations of the dimensions
- plan to write an *ILD Design Report (IDR)* in time for the Update to the European Strategy
  - started a *large scale Monte Carlo production* for detector benchmark studies

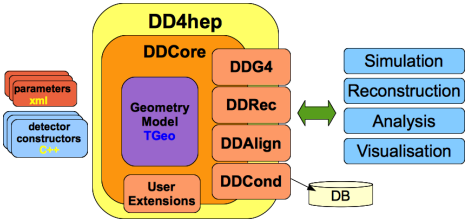
Large Scale Monte Carlo production

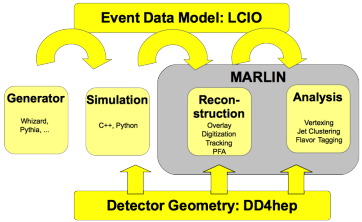
- produced a complete $500 fb^{-1}$ SM sample at 500 GeV*
- defined a set of *benchmark reactions* testing various aspects of the detector performance
- plan to carry out these analyses with *different ILD detector models*

*using 500 GeV for comparison/cross check with DBD results

WG	Process	Physics	Detector	ECM
Higgs & EW	**H->bb/cc/gg**	**BR**	**c-tag, b-tag, JER**	**500 GeV**
	H->bb	mass	JER, JES	500 GeV
	ee->tautau	A_FB, tau-pol, A_LR	tau-reco	500 GeV
	H->mumu	BR	momentum resolution	500 GeV
	H->invisible	BR limit	JER, hermeticity	500 GeV
	WW->qqlv	MW, TGCs, beam pol.	JES, JER, electron, mu	500 GeV
	vvqqqqq	**QGCs**	**JES / JER**	**1 TeV**
	gamma Z	**A_LR, sigma_tot, JES**	**photon, JER/JES, e, mu**	**500 GeV**
Top, Bottom & QCD	tt->bbqqqq	x-section, AFB	b-tag, vertex charge, PID	500 GeV
BSM	low deltaM Higgsinos	natural SUSY	low-p tracking, PID, hermeticity	500 GeV
	mono-photons	**WIMPs / WISPs**	**photon reco, BeamCal**	**500 GeV**
	Zh, mh < 125 GeV	limit on ZZh coupling	p res, e reco, JER, hermeticity	500 GeV

ILD Software Tools: Simulation

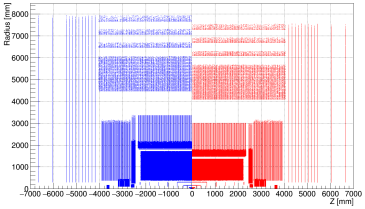




iLCSoft: common linear collider software ecosystem

- since a few years now based on DD4hep
- used by ILD, SiD and CLICdp (and testbeams)
- very **fruitful collaboration** with *strong contributions* from CLIC
  - e.g. GitHub, CI, ILCDirac,...

ILD Detector Models - large and small

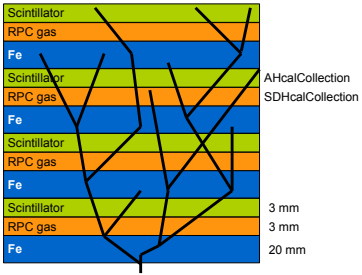


parameter	ILD_l5_vo2	ILD_s5_v02
B-field	**3.5 T**	**4.0 T**
VTX inner R	1.6 cm	1.6 cm
TPC inner R	33 cm	33 cm
TPC outer R	**180 cm**	**146 cm**
TPC half length	235 cm	235 cm
ECal outer R	202.5 cm	168.5 cm
HCal outer R	335 cm	301 cm

- re-implemented a new *DBD like*, large detector in DD4hep
- added a smaller model with dimensions *comparable* to the CLIC detector
  - smaller *R* somewhat balanced by larger *B-field*

ILD hybrid simulation

- implemented large and small models
- using a **hybrid** simulation scheme:
  - two sensitive layers per calorimeter layer
  - simulate **two technologies in one go**
  - *AHcal - SDHCal*
  - *SiEcal - SciEcal*
- use identical *absorber stack*
- replace electronics w/ *'other'* readout



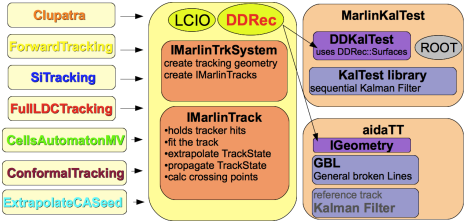
hybrid simulations are a new idea

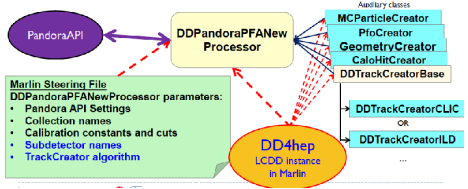
- have done detailed checks to demonstrate **consistent results** w/ stand-alone simulations
- allows to compare *different technologies* with the *same events*

ILD Reconstruction Tools

- **MarlinTrk:** tracking toolkit
  - different pattern recognition wrt CLICdp
- **PandoraPFA** particle flow
  - same as used for CLICdp
- **LCFIPlus** flavor tag, vertexing
  - same as for CLICdp
- **PIDTools**
  - PID (dE/dx, shower shapes, TOF)
  - different from CLICdp

reconstruction performance tested and validated in two dedicated test productions





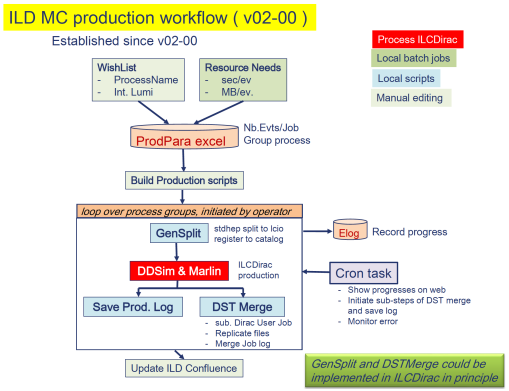
Last Test Production done with v01-19-06

- uds-events, E=30-500 GeV, (10k)
- $\gamma, K_L^0, \pi^0, K_S^0$, p=1-100 GeV, (20k)
- $\mu^{+-}, \pi^{+-}, e^{+-}, K^{+-}, p^{+-}$, p=0.2-150 GeV (100k)
- μ^{+-} at fixed p and θ values
- γ, 10 GeV, $\theta = 5^\circ - 14^\circ$
- aa_lowpt and pair-bg, 500GeV
- 100k events of bb, cc, qq at 91 GeV
- 100 k events of 6b, 6c, 6s, 6d, 6u at 500 GeV
- 6f_ttbar semi-leptonic and hadronic, 500 GeV
- $H \to$ invisible and $H \to WW^* \to 4q$, 500 GeV
- 2f_z_l, 500 GeV (for tau study)
- resonance calibration samples (JPsi, Eta, H)

validation and testing

- these samples have been checked in quite some detail
- nevertheless discovered subtle but important issue with FSR on lepton decays, half way through the production: needed to fix and re-start ...

MC production with ILCDirac



Computing Resource for 500 GeV case

- CPU time and data size was estimated by KEK batch (~23HS06/CPU), 50 events/process, 1 Detector(large) and 1 CAL option

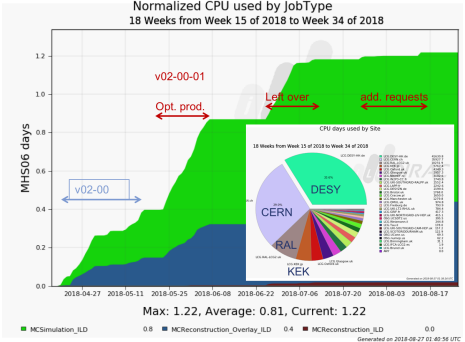
				CPU days		Data size(GB)		
Process	Nb.Procs	k Evts	Nb. Jobs	SIM	REC	SIM	REC	DST
uds	12	120	430	30	13	385	379	6
single	94	1,520	589	37	36	382	307	4
higgs	32	951	6,189	322	243	4,367	4,417	72
2f	8	3,780	16,475	1,198	706	14,386	13,740	215
4f	40	11,289	48,219	3,108	1,726	33,369	34,721	475
5f	200	2,029	7,627	520	342	6,175	6,442	116
6f	188	6,907	530,029	2,900	2,564	38,456	40,506	725
aa_4f	80	816	2,344	158	115	1,794	2,042	41
flavortag	5	535	5,329	290	262	3,943	4,142	76
Sum	659	27,947	617,231	8,563	6,007	103,257	106,696	1,732

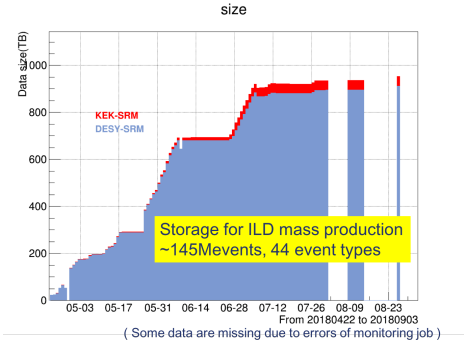
- Resource needs for all samples.

Total for 500 GeV	CPU(HS06 year)	Storage (TB)
2 Size x 1 Cal	1,882	423
2 Size x 2 Cal	2,657	640

- rely heavily on support of ILCDirac by CLIC group

Computing resources for ILD mass production





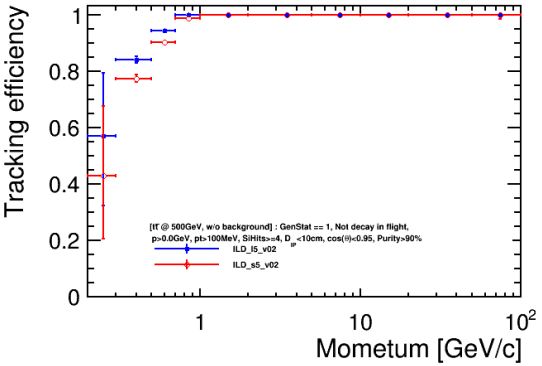
- used non-negligible computing resources (small wrt. LHC needs)
- use DESY as T0, 30% of CPU from CERN

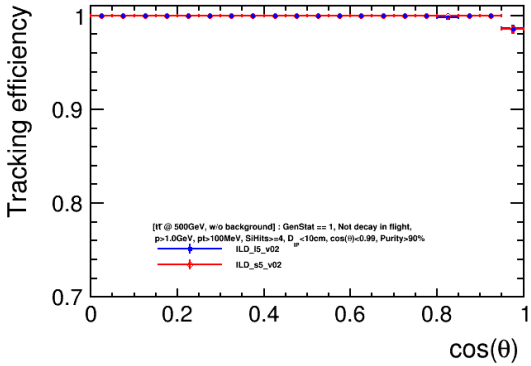
first results and ongoing work

- start with reproducing the *standard detector performance* plots:
  - tracking efficiency (ttbar @ 500 GeV)
  - inverse momentum and impact parameter resolutions
  - JER for uds di-jet events
- do this for the *large* and *small* model

- later look into additional detector performance plots
  - more differential resolutions
  - closer to real physics analysis, e.g. reconstruct bosons w/o background etc.
  - to be done yet ...

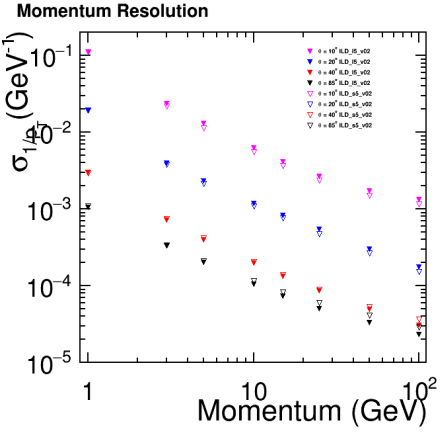
Tracking Efficiency - v02-00 - ILD Preliminary

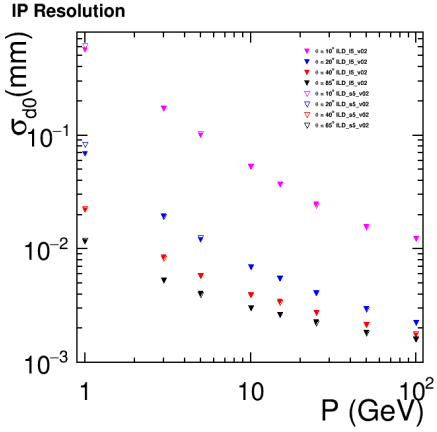




- observe only slightly worse tracking efficiency for smaller detector (B-field!)

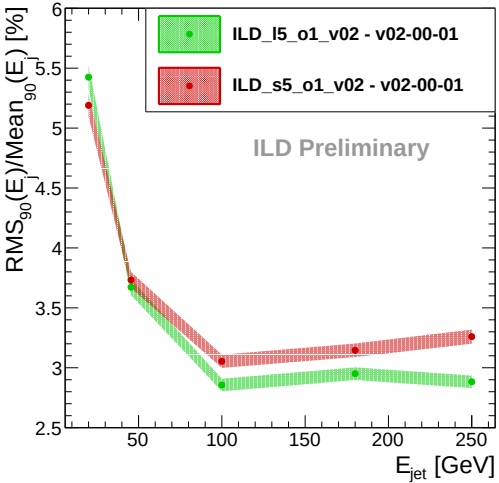
Tracking Resolution - v02-00 - ILD Preliminary

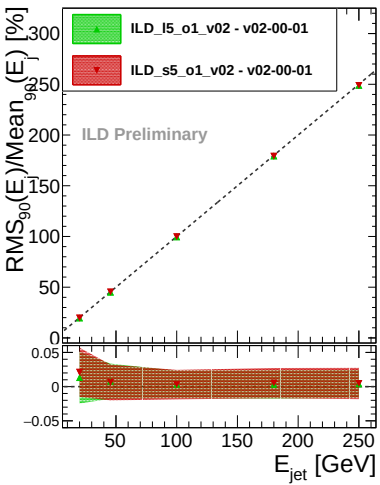




- observe almost *compatible* inverse momentum and impact parameter resolution

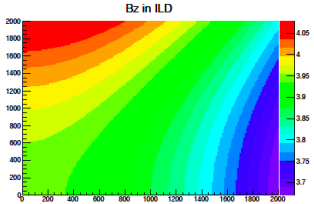
Jet Energy Resolution - v02-00-01





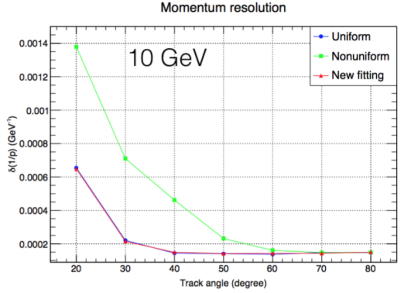
Tracking performance w/ non-homogeneous B-field

- current tracking performance plots are created with homogeneous B-Field and w/o pair background overlayed
  - to be used for large scale Monte Carlo production for detector optimization and physics studies



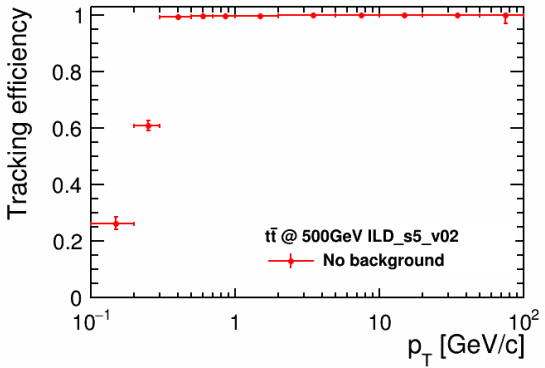
goal: study tracking performance with pair bg overlay and realistic field map

- KalTest can cope with this in principle, however not compatible w/ MarlinTrk interface and current pattern recognition
- field for **future development** (also w/ CLIC ?), e.g. using ACTS



Improving the pattern recognition: ConformalTracking

- observe improved pattern recognition performance with ConformalTracking (developed by/for CLICdp)
- some technical issues in getting it to work fully for ILD
  - currently cannot handle strip layers in FTD
  - need correct replacement of Si-/Forward-/FullLDC-Tracking chain
  - continue to work on this ...
- also did not observe equally good efficiency as seen by CLICdp



ILD standard tracking

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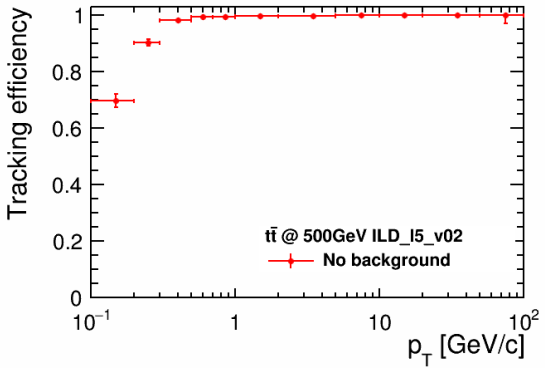
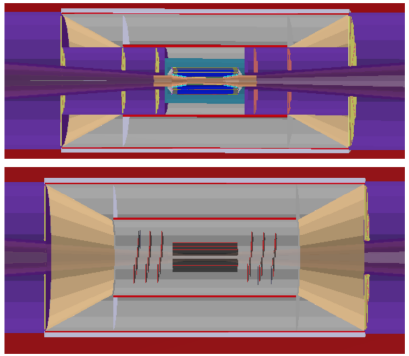
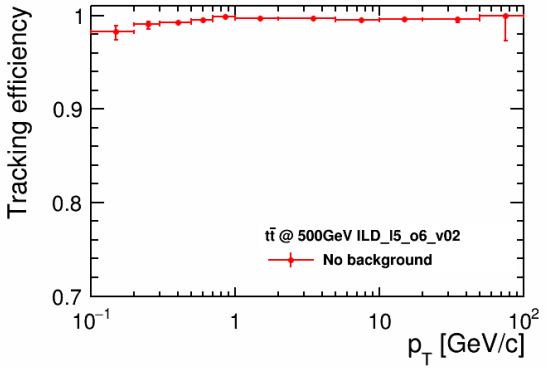


ILD ConformalTracking

ConformalTracking: ILD with CLICdp VXD

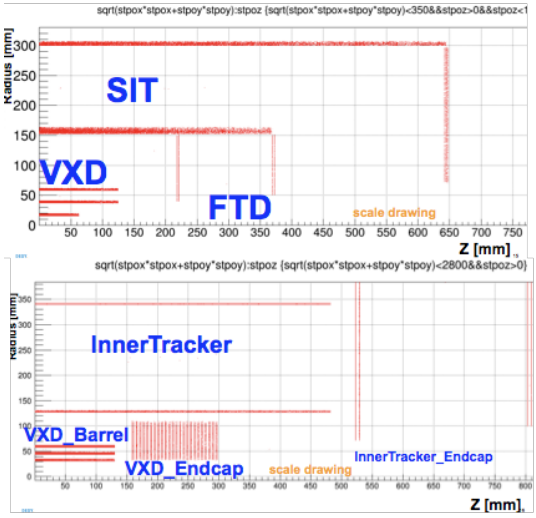


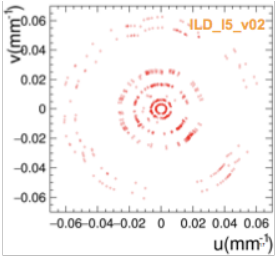


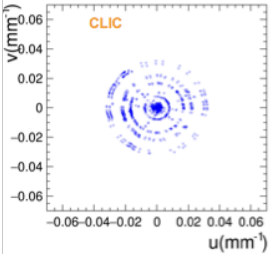
ILD-CLICdp-VXD ConformalTracking

- CLICdp VXD layout with end cap seems to be quite favorable for patt-rec
  - some of the effect could also be algorithm tuning ...

ILD and CLIC geometry in real and conformal space

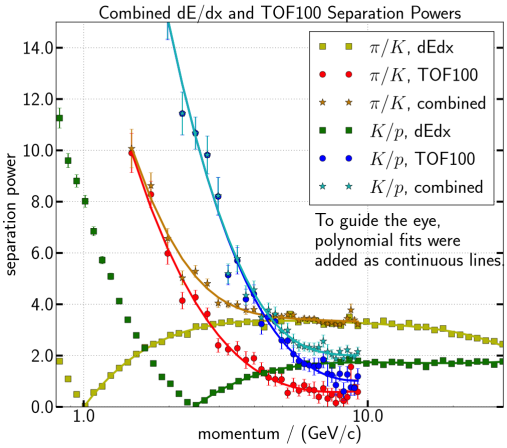






Time of Flight measurement for PID

- started to investigate how TOF measurement in the calorimeters could help particle identification
- write out various TOF estimators in current production
  - based on Ecal hit time information
  - with *0ps, 10 ps and 50 ps* single hit resolution
- **next step:** demonstrate how this could improve physics analyses



Summary and Outlook

- ILD has started an optimization process
- using a full 500 GeV SM Monte Carlo production and selected benchmark channels
- created a large and small model to investigate *performance-cost* trade-offs
- analyses continue - plan to write IDR by end of this year
- started to investigate the use of *ConformalTracking* for ILD

Outlook

- will continue to improve the LC software tools
  - tracking, EDM, *multuthreading*,. . . .
- like to continue the successful collaboration on software with CLIC