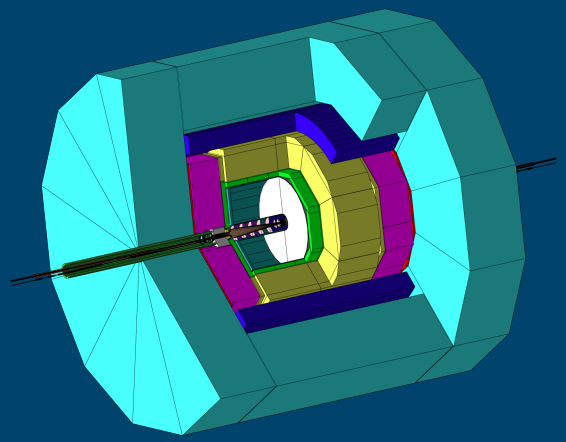
HEPHY

Institut für Hochenergiephysik

Forward Tracking at ILD
Ruminations by the Vienna Group



Winfried A. Mitaroff

ECFA-ILC-CLIC Joint IWLC 2010
Geneva, 18 - 22 Oct. 2010

What is the "forward region" ?

- **Very forward region**
  - $5^0 < \vartheta < 11.5^0$: only FTD measurements contributing,
  - Range of FTD 1 (2) starts where that FTD 6 (7) ends.
- **Intermediate region**
  - $11.5^0 < \vartheta < 25.5^0$: complex mix of VTX + FTD + TPC,
  - FTD: only FTD 1 … 3, plus FTD 4 until $\vartheta < 16.5^0$,
  - TPC: 10 pad-rows @ 11.5^0 … 100 pad-rows @ 25.5^0.
- **Barrel + FTD 1 only**
  - $25.5^0 < \vartheta < 36.7^0$: VTX + FTD 1 + SIT + TPC.
- **ETD: $9.8^0 < \vartheta < 36.9^0$**
  - Ignored by track fitting: cannot contribute to precision,
  - Useful for PFA (pattern recognition link to fwd. ECAL).

The ILD_00 detector layout

Very forward region:

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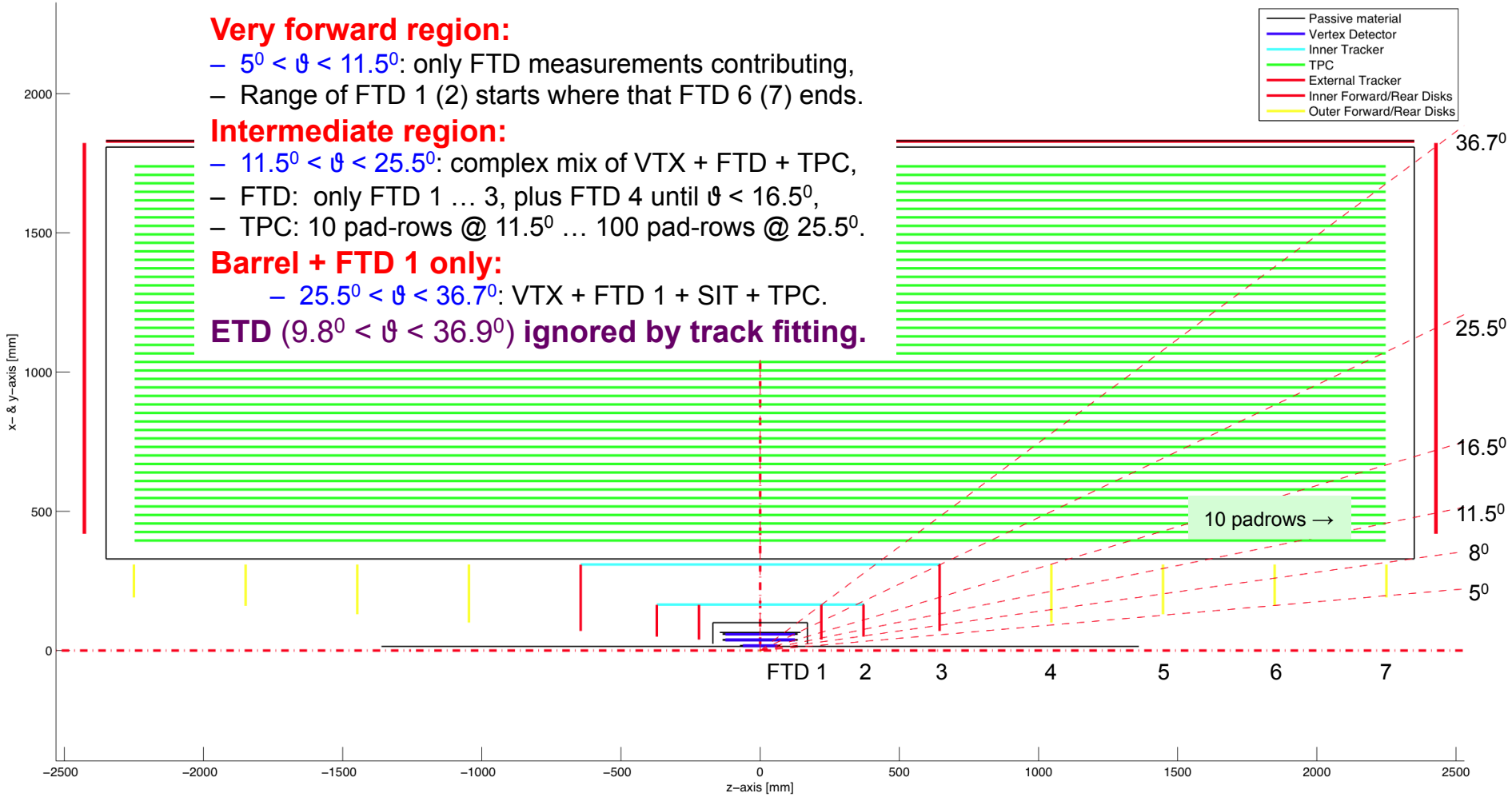


Tasks w.r.t. forward tracking

1. FTD geometry description, \ not
2. FTD drivers in Mokka, } discussed
3. FTD digitizings in Marlin. / here
4. FTD stand-alone track search
   (very fwd. and intermediate regions, $5^0 < \vartheta < 25.5^0$),
5. TPC-supported track search
   (optional in intermediate region, $11.5^0 < \vartheta < 25.5^0$),
6. DAF-based final hit associations,
7. Precision forward track fit.

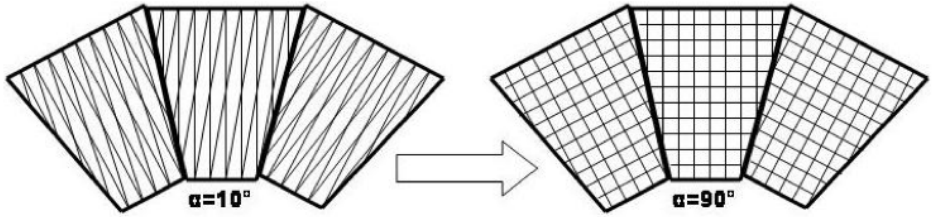
- Region $25.5^0 < \vartheta < 36.7^0$ is “mostly barrel” (VTX, SIT, TPC) with only one FTD 1 ⇨ barrel or fwd. task ?

Fwd. track search strategies

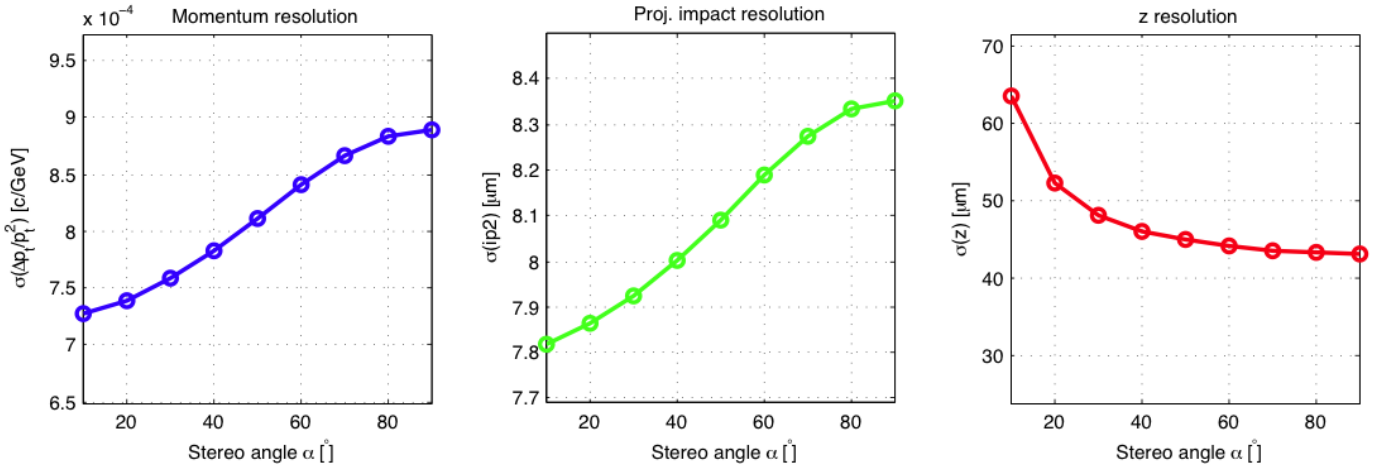
- **Stand-alone in FTD:**
  - This is the only possible strategy in the very forward region,
  - Various algorithms exist – which to chose needs careful study,
  - For small ϑ, hits from beamstrahlung-induced background may cause further problems (we need a reliable estimate),
  - Layout for optimized track resolution (e.g. strip orientation and stereo angle) not necessarily optimal for track search.
- **Combined TPC–FTD:**
  - This may be an optional strategy for the intermediate region:
  - Inward extrapolation of tracks found by local PR in the TPC, FTD hits tested against and associated to them,
  - Timing problems hopefully solved by “time stamps”.
- **Soft hit association:**
  - Hits may be shared among tracks, and the final association relegated to track reconstruction based on the DAF.

M. Valentan (SiLC, Santander 2008)

Polar angle $\vartheta = 7°$ (hits all FTDs), absolute momentum $p = 250\,\mathrm{GeV}/c$ (design energy), 1000 muons per point



(Stereo angle w.r.t. radial vector)



Forward track reconstruction

- **Algorithms used:**
  - Based on the Kalman Filter, with robustification by the adaptive Deterministic Annealing Filter (DAF):
  - (1) Testing and updating the track hypothesis (hit associations) by identifying and removing “outliers”, and resolving ambiguous associations from the track search,
  - (2) Performing a precision track fit.
- **Special features:**
  - Flexible track propagation in the complex intermediate region,
  - Energy loss of electrons modeled by the Gaussian Sum Filter (GSF) ⇨ requires extension of the LCIO data model,
  - Magnetic field distortions by the “anti-DiD” taken into account (small “Billoir corrections” on helices, or Runge-Kutta).

Track model for the GSF

- Energy loss of electrons and positrons is dominated by bremsstrahlung. It is a stochastic process which can be modeled by the Bethe-Heitler formula.
- A track $\mathbf{p}_k$ reconstructed with proper treatment of bremsstrahlung is described by a mixture of M_k Gaussian measurement vectors $\mathbf{p}_k^i$: its p.d.f. is

$$\wp(\mathbf{p}_k) = \sum_{i=1}^{M_k} \gamma_k^i \cdot \Gamma(\mathbf{p}_k; \mathbf{p}_k^i, \mathbf{V}_k^i), \qquad \sum_{i=1}^{M_k} \gamma_k^i = 1$$

  with $\Gamma(\mathbf{p}_k; \ldots)$ being a multivariate Gaussian p.d.f. of mean $\mathbf{p}_k^i$ and covariance matrix $\mathrm{cov}(\mathbf{p}_k^i, \mathbf{p}_k^i) \equiv \mathbf{V}_k^i$. In general the means need not to be equal.
- Each component $i = 1 \ldots M_k$ of the mixture corresponds to one hypothesis on the virtual measurement, with the weight γ_k^i being its probability.
- In practice, a number of components $M_k \leq 6$ is sufficient.

References: *R. Frühwirth*: Computer Physics Comm. **154** (2003) 131.
W. Adam, R. Frühwirth, A. Strandlie, T. Todorov: CMS note 2005/001, CERN.

Fwd. tracking implementation

- The user API should be common for barrel and forward tracks.
- However, the implementation is suggested to be separate and complimentary for the barrel and the forward regions:
  - Optimal track search algorithms will differ for barrel and fwd.,
  - Internal track representations may differ (e.g. $1/p_T$ vs. 1/P),
  - Coordinated independence of the two programming teams.
- A small MarlinReco control processor for the required top-level steering “barrel vs. fwd. calls”, transparent to the user.
- Coordination is enhanced by a common skeleton toolkit (GenFit or KalTest), and a pool of utility classes and libraries.
- Both implementations will rely on common interfaces, e.g. for
  - Using available results from a previous track search in TPC,
  - Persistency by the new LCIO data model, augmented for GSF,
  - Interfacing to the new GEAR geometry toolkit.

Sharing of responsibilities

In discussions at the ILD Software Workshop (DESY, July 2010) and thereafter, we agreed on a sharing of tasks for the new ILD tracking:

- DESY Hamburg:
  overall coordination, all barrel tracking;
- Spain (Santander, Valencia) and HEPHY Vienna:
  all forward tracking, with the sub-tasks:
  - (1-3) FTD geometry, Mokka drivers, digitization: Spain,
  - (4) FTD stand-alone fwd. track search: Spain and Vienna,
  - (5) TPC-supported fwd. track search: Vienna,
  - (6,7) DAF-based fits, precision track fit: Vienna.

Start of active work coinciding with the AIDA kick-off (Feb. 2011).

Manpower & funding aspects

- **Commitment:**
  - Expect a diploma student, or a PhD student in his/her first year, to start work on sub-tasks 4-7 in Feb. 2011.
  - If possible, to be extended by a follow-up study of background radiation in the forward region, starting 2012.
- **AIDA Proposal:**
  - Within EU's fp7, time frame 2011-14, submitted Dec. 2009, approved April 2010, Kick-off Feb. 2011. 9 Work Packages.
  - WP 2 "Common Software Tools" (F. Gaede, P. Mato):
  - Task 2 of 2: "Reconstruction Toolkits for HEP", Sub-task 1 of 4: "Tracking Toolkit" – DESY, Santander, Valencia, Vienna.
  - Clear separation generic vs. detector-dependent functionality.
  - Expect 1/3 refunding for 4 student-years, and travelling costs.

Off-topic: news from Vienna

- **Vertex Reconstruction Toolkit (RAVE):**
  Implemented a Gaussian Sum Filter (GSF) for processing tracks fitted with a GSF (see my talk at TILC '09). Source level compatibility of the algorithms with those of CMS is beneficial for quick inclusion of further improvements. Support and maintenance kept alive; latest version in the repositories:
  - `http://projects.hepforge.org/rave/`
  - `http://stop.itp.tuwien.ac.at/websvn/` click `marlinrave`
- **Fastsim Tool ("LiC Detector Toy", LDT):**
  Used for ILD's LoI and CLIC detectors' CDR. Improvements foreseen to be done next: implementation of a GSF, and of inclined and conical surfaces. Documentation (User's Guide 2.0) and source codes in the repository:
  - `http://stop.itp.tuwien.ac.at/websvn/` click `lictoy`
- **A new tracking and vertexing "bible":**
  A. Strandlie, R. Frühwirth: Track and vertex reconstruction: from classical to adaptive methods. Rev.Mod.Phys. 82 (2010) 1419.
  - `http://wwwhephy.oeaw.ac.at/p3w/ilc/reports/ASEpub/10_RevModPhys.pdf`