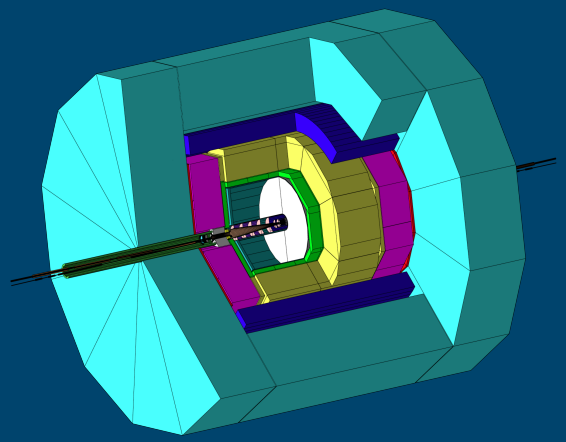
HEPHY

Institut für Hochenergiephysik

Forward Tracking I – Ruminations by the Vienna ILDsoft Group



R. Frühwirth, W. Mitaroff, M. Valentan

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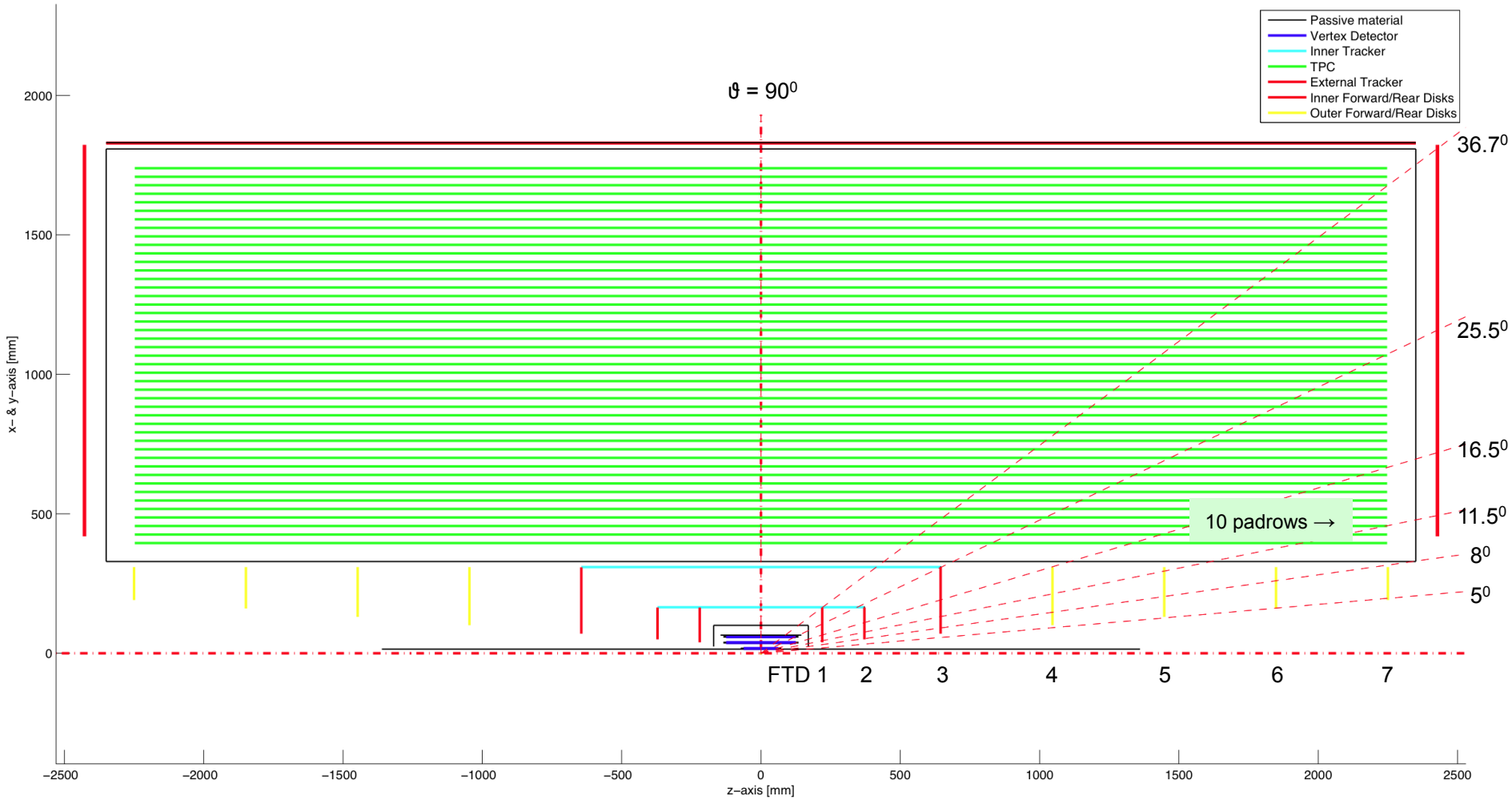
What is the "forward region" ?

- **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;
  - The **ETD** ($9.8^0 < \vartheta < 36.9^0$) is being ignored so far.

ILD_00 detector layout

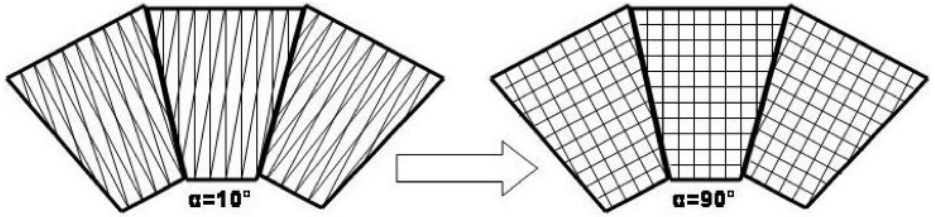


Fwd. track search strategies

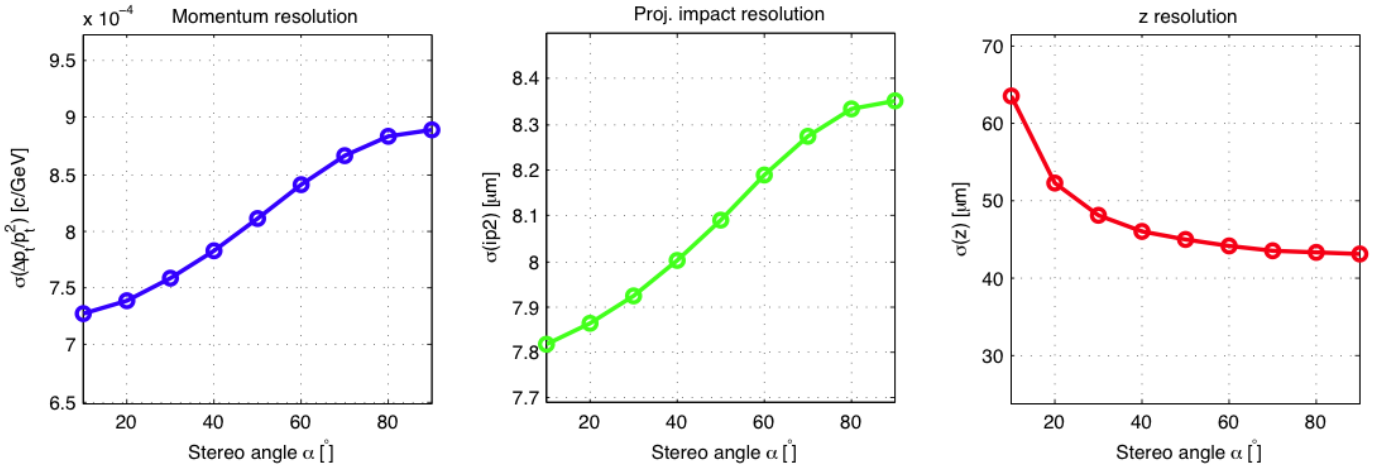
- **Stand-alone in FTD:**
  - There exists no alternate strategy in the very forward region;
  - For small θ, hits from beamstrahlung-induced background may cause problems (we need a reliable estimate);
  - Layout for optimized track resolution (e.g. strip orientation and stereo angle) not necessarily optimal for track search.
- **Combined TPC-FTD:**
  - Could be a possible alternative for the intermediate region:
  - Inward extrapolation of tracks found by local PR in the TPC, FTD hits tested against and associated to them.
- **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)



Fwd. track reconstruction (1)

- **The processor:**
  - Separate from and complimentary to the one for Barrel region;
  - 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.

Fwd. track reconstruction (2)

- **Interfaces:**
  - To be embedded as a separate processor into MarlinReco;
  - Some top-level steering required for “Barrel vs. Fwd. calls”;
  - Rely on the results from a previous Forward Track Search;
  - Interface to the LCIO 2 data model, augmented for GSF;
  - Interface to the existing vertex reconstruction toolkit RAVE;
  - Interface to a new “Geometry Toolkit” developed at CERN.
- **Design ideas:**
  - Clear separation between generic and detector-dependent functionality (helping re-use in other environments);
  - Usability of the skeleton toolkit GENFIT (*Höppner* et al.) ?
  - Profit from experience gained by CMS and Belle II software.

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.

Manpower & funding aspects

- **HEPHY Vienna:**
  - Commitment of the Vienna ILD Group to take full responsibility of the new Forward Track Reconstruction processor;
  - Expect a first diploma student to start work this autumn;
  - Later do a study of background radiation in the forward region.
- **AIDA Proposal:**
  - Submitted to EU's fp7 for period 2011-14, decision mid 2010 ?
  - WP 2 of 9 "Common Software Tools" (*F. Gaede, P. Mato*):
  - Task 2 of 2: "Reconstruction Toolkits for HEP", Sub-task 1 of 4: "Tracking Toolkit" – DESY: coordination and "Barrel Tracking" (*St. Aplin*), HEPHY: "Forward Tracking" (*R.F., W.M.*);
  - Expect 1/3 refunding for 4 student-years, and travelling costs.

Off-topic: RAVE and MarlinRAVE

RAVE implemented a Gaussian Sum Filter (GSF) for processing tracks fitted themselves with a GSF (see my talk at TILC '09 in Tsukuba).

Tested so far only stand-alone with VERTIGO + RAVE, using CMS simulation data with electrons reconstructed by the GSF-enabled track fit of CMSSW.

Embedding in Marlin requires an extension of the LCIO data model for handling GSF-fitted tracks. Important when new track reconstruction processors implement a GSF for electron tracks.

Support and maintenance kept alive. Latest versions in the repositories:

`http://projects.hepforge.org/rave/`

`http://stop.itp.tuwien.ac.at/websvn/listing.php?repname=marlinrave`