TAG – Tracking Report

Panda-Meeting, GSI, 13-Dec-2006

Plenary

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Scope of the tracking TAG

- Subject
  - Formulate tracking requirements
  - Space resolution
  - Time resolution
  - Momentum resolution
  - Develop criteria for design choices

- Deliverables
  - Adjustment of detector parameters
  - Roadmap to TDR: deliverables and milestones

Meetings

We have had a couple of meeting during the last year, starting in Feb. 2006:

PresenceMeetings

- March 9th, TU Dresden:
- June 13th, 17:00 - 18:00, GSI - KP3:
- September 4th, 16:30 - 18:00, CR:
- December 11th, 11:30 - 13:00, GSI - KP1:

VrvsMeetings

- February 21th:
- October 12th:
- November 10th:
- December 5th, 16:00:

Approach

- Tracking detectors are:
  - The micro vertex detector – MVD.
  - Central tracker – CT which will be either a TPC or STT.
  - Forward tracker – FT which will be either MDC or Straws.
  - Muon detectors are not regarded as tracking detectors.
- We recognised that a definition of all requirements is not possible within our timeframe.
  - Physics driven requirements demands a lot of simulations which are not available yet.
  - Define the central issues and questions which have to be answered by the simulation for each tracking detector individual.
  - Also define the key parameters of the detector and the according figure of merit to judge on them.
  - In order to do so we defined a bunch of benchmark channels for the tracking in PANDA
- Identification the important design choices
  - Define criteria and procedure
- Proposal of a reasonable timeframe of sub-detectors TDRs

Benchmark channels

4 tracking benchmark channels identified:

- $\bar{p}p \rightarrow D^{*+}D^{*-}$ and $\bar{p}p \rightarrow D^{+}D^{-}$ with
  - $D^{*\pm} \rightarrow D^{0}\pi^{\pm}$ and $D^{0} \rightarrow K^{-}\pi^{+}$, $D^{0} \rightarrow K^{-}\pi^{+}\pi^{-}\pi^{+}$ or $D^{0} \rightarrow \overline{K}^{0}\pi^{+}\pi^{-}$, all single sided under special consideration of the slow π coming from the D* decays.
  - important for MVD but also for CT → K, π tracking and momentum measurement.
- $\bar{p}p \rightarrow \Lambda\Lambda \rightarrow p\pi p\pi$
  - consider $\bar{p}p \rightarrow \Xi\Xi$ channel to incorporate also cascade decays.
  - Λ reconstruction, partly only with CT (~15%) → tests vetexing capabilities of CT.
- $\bar{p}A \rightarrow J/\Psi X \rightarrow llX$
  - high p_T lepton tracks in multi-track environment → CT important for momentum measurement and tracking.
- $\bar{p}p \rightarrow \bar{p}p$ elastic scattering
  - important for FT, nearly irrelevant for CT and MVD.

This doesn’t mean that only these channels should be considered but for detector optimization work we don’t need full physical picture

Requirements & questions to the simulations

Devoted special TAG Sessions to the different tracking detectors to discuss in detail the requirements, open questions how to address them, so far 2 detectors done:

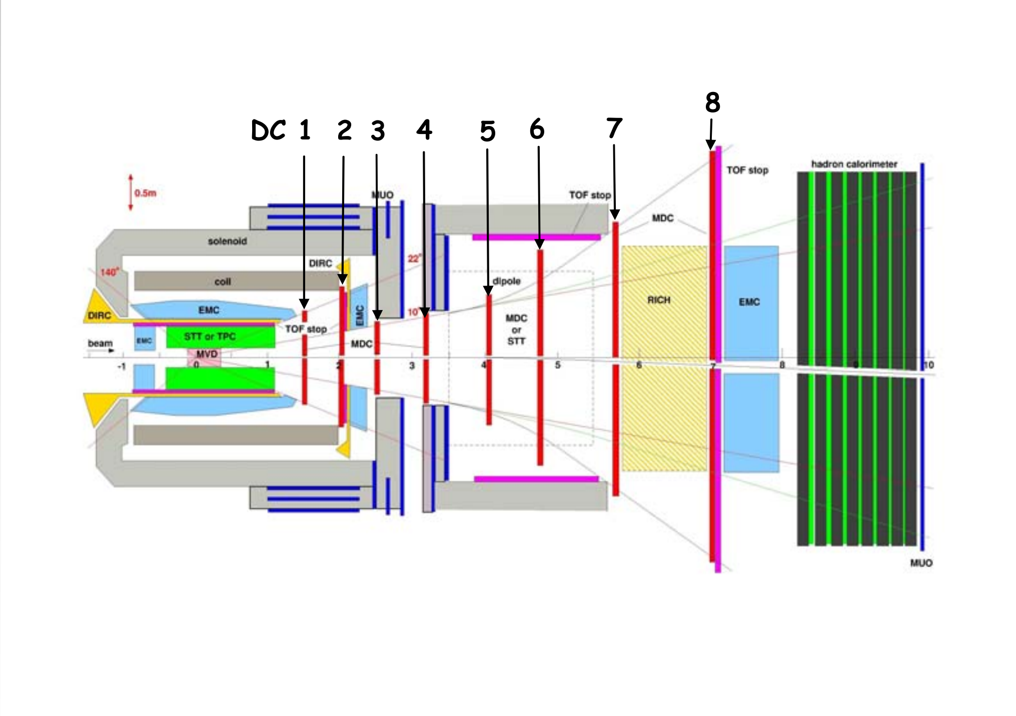
- Forward Tracker (including the different design options) – Nov 06 by J. Smyrski
- Micro vertex detector – Dec 06 by F. Hügging

TPC and STT scheduled for Jan 2007

Requirements and design choices for the forward tracking

Jerzy Smyrski, Jagiellonian University

Cracow, Poland



Requirements for the FT (1)

Target spectrometer Forward tracking detectors:

- Angular range: (5°,22°)
- The area $\theta < 5°$: non-sensitive
  - (to keep the counting rate possibly low
- Max. counting rate/wire for 1 cm cells: ~10^5/s (?)
  - will be determined for pbar-p processes using the DPM event generator; it has also to be checked for pbar-A interactions
- Max. rate/cm2/sek.: $0.7 \cdot 10^4$
  - for pbar-p processes, z=172 cm, x=15 cm ($\theta = 5°$)
- Max. ageing: 0.2 C/cm/year
  - for gas amplification $5 \cdot 10^4$
- Material budget for active area: < 0.01 X_0
  - comparable with the central tracker
- Material budget of frame for $\theta < 5°$: ?
  - studies including geometry and material budget of the beam-pipe required
- Multiplicity of tracks: a few/event
  - for pbar-p interaction
- Double track resolution: 3 mm
  - typical achievable

Requirements for the FT (2)

- Magnetic field: 2 T
- Non-uniformities of the field: ?
  - have to be determined for the present positions of the chambers, influence on the chamber performance has to be studied with GARFIELD
- Momentum resolution: ~1%
  - resolution comparable with one of the central tracker
- Pos. resolution per detection plane: σ =0.2 mm
  - intrinsic resolution + uncertainty of wire positions + uncertainty of calibration
- Number of packages of detection planes and total extension in the z-direction: ?
  - simulations needed; suggested simplified track and momentum reconstruction: simulation of tracks including energy losses and multiple scattering in the detector volumes + smearing of track positions in MVD, DC1, DC2,.. + fit of a helix to the track positions
  - Key parameter are modelled by various scenarios:

    Space available for chambers: Δz=40 cm, 60 cm, 80 cm;

    Number of detection planes: 12, 18;

    Detection planes grouped in one, two, three packages

    Figure of merit: $\Delta p/p(p,\theta)$

Requirements for the FT (3)

Forward Spectrometer tracking detectors:

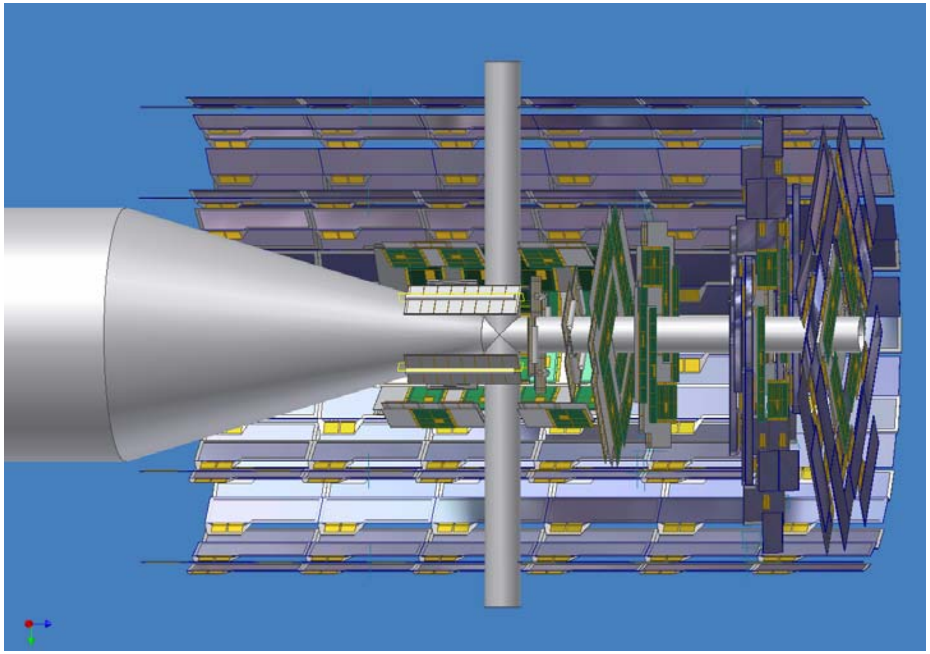
- Angular range: (~1.5°,5°-10°) (DC3, DC4)
  - The lower limit (1.5°) has to be investigated in simulations of background (high rate) and of selected channels e.g. pp -> ΛΛ (measurements at very forward angles)
- Max. counting rate/wire for 1 cm cells: ~10^5/s (?)
  - will be determined for pbar-p processes using the DPM event generator
- Max. rate/cm2/sek.: $0.9 \cdot 10^4$
  - for pbar-p processes, z=278 cm, x=7.3 cm (θ = 1.5°)
- Max. ageing: ~0.3 C/cm/year
- (for gas amplification $5 \cdot 10^4$)
- Material budget for active area: < 0.015 X_0 chambers + 0.015 X_0 air between D3 and DC8
- Multiplicity of tracks: 1-2/event
  - for pbar-p interaction
- Double track resolution: 3 mm
  - not critical

Requirements for the FT (4)

- Max. magnetic field along wires: 1 T
- Stray magnetic field: < 0.5 T
  - has to be checked with the current field maps and current positions of DC4 and DC7 chamber
- Pos. resolution per detection plane: σ =0.3 mm
  - intrinsic resolution + uncertainty of wire positions + uncertainty of calibration
- Momentum resolution: ~1%
  - has to be checked in simulations analogical to ones for the FS chambers
- Momentum acceptance of the tracking system
  - one of channels under study for definition of requirements is pp -> ΛΛ ;simulations are needed to determine the acceptance

    Figure of merit: Δp/p (p,θh) where θh - angle with respect to the vertical symmetry plane

MVD Design: Rev 14b



~540 modules in 4 barrel & 6 disk layers

- Geometry:
  - pixel barrels at R= 27; 50 mm
  - strip barrels at R= 75; 125 mm
  - 2 single sided pixel disks at Z= 20; 40 mm
  - 4 double sided mixed disks at Z =60; 85; 145; 185 mm
  - closest distance to beam-pipe: 2 mm (disks)
  - overall length: 40 cm
- 140 pixel modules
  - 0.15 m^2 active silicon
  - ~6.5 Mio readout channels
- 400 strip modules
  - 0.5 m^2 active silicon
  - ~70,000 readout channels
- 2 kW power dissipation inside the MVD

Basic requirements for MVD: pixel

- spatial resolution in r-phi ➔ < 100µm (for momentum measurement)
- spatial resolution in z ➔ < 100µm (especially for D-tagging)
- time resolution ➔ < 50ns (for separation of 'DC'-beam 10^7 events/s)
- triggerless readout ➔ track rate up to 720 kHz (peak) and 54 kHz (average) per chip of size $7.6x8.2mm^2$
- low material ➔ < 1.2 % per layer (for low momentum particle tracking)
- modest radiation hardness ➔ $\sim 3x10^{14}$ n_{eq} / cm^2
- moderate occupancy ➔ up to 16 kHz (peak) and 350 Hz (average) for $50x400µm^2$
- amplitude measurement ➔ dE/dx for particle identification

Basic requirements for MVD: strip

- spatial resolution in r-phi ➔ < 100µm (for momentum measurement), to be confirmed by simulations.
- spatial resolution in z ➔ < 100µm, to be confirmed
- time resolution ➔ at least < 50ns (for separation of 'DC'-beam 10^7 events/s); better < 2ns (for DAQ event de-convolution and ToF)
- triggerless readout ➔ number are now available (R. Jaekel)
- occupancy ➔ numbers are now available (R. Jaekel)
- low material ➔ < 1% per layer (for low momentum particle tracking)
- modest radiation hardness ➔ ~10^{14} n_{eq} / cm^2
- amplitude measurement ➔ dE/dx for particle identification

MVD Simulations: defining FE electronics

- Data loads (strip and pixel part)
  - rates & rate distributions – peak rates, average rates
  - energy deposit - global and locally, peak and average → define dynamic range

Channels: background $\bar{p}p$ & $\bar{p}A$ FoM: track rate, hit rate, data rate, occupancy & dynamic range

- time structure and ordering (strip and pixel part)
  - latency distributions
  - beam fluctuations on various timescales
  - overlapping of events

Channels: background $\bar{p}p$ & $\bar{p}A$ FoM: time resolution, occupancy & dynamic range of timing informations

Note: these simulations need input/interactions with dedicated electronics simulations!

MVD Simulations: geometry optimization (1)

- variation of pixel size and shapes
  - [50x400 μm²]; 100x100 μm²; 50x200 μm²; 200x50 μm²
  - different relative orientations of layers

Channel: $\bar{p}p \rightarrow \bar{D}D$ FoM: position resolution & vertex resolution

- strip optimization
  - modules size and shape

    rectangular vs wedge for the disks
  - pitch sizes

Channel: $\bar{p}p \rightarrow \bar{D}D$ FoM: position resolution & vertex resolution

- positions of forward disks and barrels → 'strangeness layout' vs. 'charm layout'
  - number and position of disks
  - Layout of disks – only pixel, mixture of strips and pixel
  - barrel layer radii

Channels: $\bar{p}p \rightarrow \bar{D}D$, $\bar{p}p \rightarrow \Lambda\Lambda$ FoM: secondary vertex resolution, momentum resolution (?)

MVD Simulations: geometry optimization (2)

- variation of sensor thickness (strips and pixels)
  - 200 µm - 100 µm

Channels: $\bar{p}p \rightarrow \bar{D}D$ FoM: position resolution, signal resolution, dE/dx resolution

- sensor sizes and shapes (to optimize material)
  - size and dead zone ratio (for pixel)
  - arrangement options: overlap layout vs straight layout (for pixel and strip)

Channels: $\bar{p}p \rightarrow \bar{D}^*D^*$ FoM: position resolution, momentum resolution, vertex resolution

- structural support, services (cables, cooling,…)
  - different inhomogeneous distributions
  - identify areas to put things

Channels: $\bar{p}p \rightarrow \bar{D}^*D^*$ FoM: position resolution, momentum resolution, vertex resolution

- other layout option
  - effect of target pipe hole
  - constant radius vs. constant angle for beam pipe

Channels: $\bar{p}p \rightarrow \bar{D}^*D^*$ FoM: position resolution, momentum resolution, vertex resolution

MVD Simulations: optimization of performance goals

- optimize $\bar{D}^*D^*$ ($\bar{D}D$) resolving power
  - input needed: efficiency / purity requirements to be settled!
  - limited amount of variation, strategy:

    → key parameters to be defined after basic geometry optimization!

    → keep a number of constraints that are already "established"

    → respect boundary conditions!

    → optimize $\bar{D}^*D^*$ (or $\bar{D}D$), then check background performance

Channels: $\bar{p}p \rightarrow \bar{D}D$ and $\bar{p}p \rightarrow \bar{D}^*D^*$ FoM: D^* and D-tag efficiency and purity, secondary vertex resolution

Design Choices

Identification of the important design choices:

- for the Forward tracker:
  - 2 different design options of Drift Chambers (MDC)
  - Straws for the FT
- for the Central Tracker
  - Time Projection Chamber
  - Straw Tube Tracker

Discussion of the criteria for that choices and the procedure to be done together with the detailed requirements discussion of each detector!

Design Choices for FT

Three different design options are considered:

- MDC with cathode wires
- MDC with cathode foils (Dubna design)
- Straw Tube Design

Main criteria are:

- High rate behaviour
- Ageing rate - test of prototypes with radioactive sources
- Reliability - checked in a long term (~0.5 year) test
- Compactness of design important in view of the limited space inside TS
- Material budget

Procedure will include prototype tests with accelerators beams during 2007, source tests and long term tests

- Decision between straws and MDC by end of 2007
- Final design decision by end of 2008 after all tests finished

Design Choices for the CT

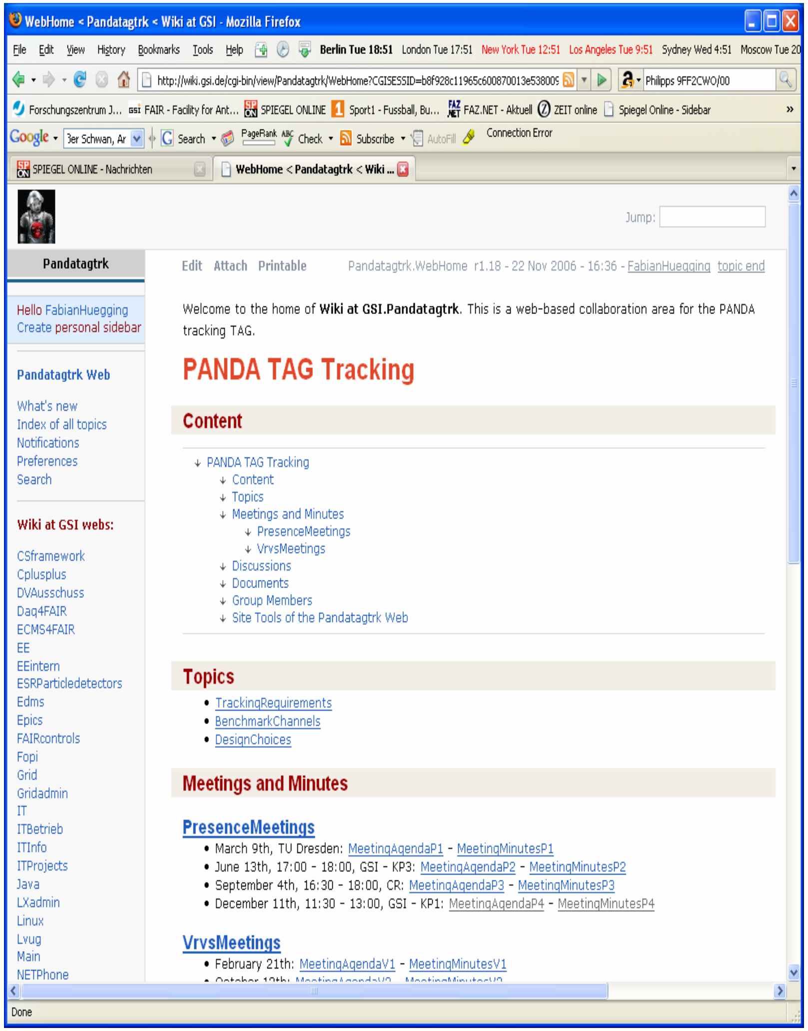
This has not been discussed in detail up to now, but it is clear that:

- Both option needs time for building and testing realistic prototypes → this requires roughly 2 years!
- Criteria for that decision have to be worked out during the requirement discussion.
- Procedure of this decision needs to be defined, this may include an external review session which gives an advice to the CB

More details will be clear after the CT session in Jan/Feb 2007

Communications of results

- Results of the TAG are posted on the Wiki page of the TAG
  - meeting agendas & minutes
  - additional information about the tracking detectors
  - up to now it is not open to the public, but everyone interested can just ask one of members to get access
- Final document summarizing the results will be drafted ~Mar/Apr 2007



Status & next steps

- Definition of benchmark channels — Done
- Discussions on requirements and simulation questions for each sub-detector
  - MVD — Done
  - MDC — Done
  - STT — Jan/Feb 2007
  - TPC — Jan/Feb 2007
- Design choices, definition of criteria and procedure.
  - MDC design1, MDC design2 or Straws — Done
  - TPC – STT — Jan/Feb 2007
- Towards a TDR — started - Mar 2007