PANDA Technical Assement Group: Tracking

Draft 1.1

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Contents

1 Introduction

This document is a working document dealing with the effort made by the PANDA Technical Assessment Group (TAG) tracking. Main scope of this TAG is the definition of requirements for the tracking detectors and the procedure needed to come to a final concept and layout of the PANDA tracking system. Apart from the author members of the TAG are:

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- K.-T. Brinkmann
- P. Gianotti
- B. Ketzer
- S. Neubert
- J. Ritman
- J. Symrski
- M. Steinke

Of course contributions from other members of the PANDA collaboration is welcome too.

Since this is a working document it reflects the current status of the work and will be updated regularly after discussions among the TAG team until it reaches its final version. Therefore comments and remarks are included to highlight where more work is needed or inaccuracies and mistakes are given.

2 Requirements for the tracking detectors

Requirements for the tracking of the PANDA detector should be derived from the important physic channels. To ensure an easy access to the required information we defined a small set of channels which are regarded as the most important concerning the tracking properties of PANDA and will therefore serve as tracking benchmark channels in future (see section 2.1).

Furthermore the requirements for each tracking component inside PANDA are given individually to accommodate the specific technology of each detector. Up to now the values are based on experience and educated assumptions about the needs within PANDA and the possibilities of the detectors types. A validation of the given resolutions is necessary within the new simulation framework as soon as possible.

Finally the overall tracking requirements for PANDA are summarized in terms of track-, vertex- and momentum-resolutions taking into account a combined tracking system to which all tracking components contribute.

2.1 Benchmark channels for tracking

It is clear that the requirements for the PANDA tracking system must be driven by the physic goals of PANDA. In the TP a lot of benchmark channels are given and optimization of the tracking detectors with respect to all of them seems not very suitable. To streamline the discussion and the needed simulation work on this topic we decided to choose a smaller subset of channels which can be regarded as 'tracking benchmark channels'. This means definition of tracking requirements and optimization of detectors should be done with respect to these channels in the first place.

The channels reflect the main applications of tracking detectors inside PANDA like high precision track measurement and subsequently high precision momentum measurement for charged particles in an energy region from 100 Mev up to 15 GeV. Furthermore special emphasize is given to the secondary vertex capabilities for c- and s-quark particles. In particular the tracking benchmark channels are:

- $\bar{p}p \to DD$ with $D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$ or $D^0 \to \bar{K^0}\pi^+\pi^-$ and $\bar{D^0} \to K^0\pi^+\pi^-$ resp.; both single sided. This channel sets mainly the requirements for secondary vertex finding capabilities of the MVD in the case of close displaced vertices. Moreover a good tracking of all involved charged particles is necessary.

- $\bar{p}p \to \bar{\Lambda}\Lambda \to p\pi^-\bar{p}\pi^+$ which has to be distinguished from the K^0 production, i.e. $\bar{p}p \to K^0_S K^{\pm}\pi^{\mp}$ with $K^0_S \to \pi^+\pi^-$. In this sense the channel is similar to the previous channel regarding the tracking but the reconstruction of the Λ decay vertices also relies on the outer tracking detectors.

- $\bar{p}A \to J/\Psi X \to \mu^+\mu^- X$ serve as a benchmark channel for high p_T charged tracks in a multi-track environment.

- Finally the elastic $\bar{p}p$-scattering $\bar{p}p \to \bar{p}p$ could serve as benchmark in particular for the forward tracking detectors.

  We believe that these channels are the most relevant for the tracking properties of PANDA but of course we encourage a careful verification of the de-

spatial resolution σ_s for track points	rφ = 100 μm z = 100 μm
resolution σ_v for vertex reconstruction	x = 100 μm y = 100 μm z = 100 μm
time resolution σ_t	20 ns
relative resolution Δp/p for charged particle momenta	1%

Table 1: Requirements for the pixel part of the MVD.

duced requirements with other channels once the optimization of the tracking system layout has been done.

2.2 Requirements for the Micro Vertex Detector (MVD)

The tables reflects our current assumptions for the MVD and shouldn't be taken to literally. It should rather propose the format of the data we need in the end although for instance important details like geometrical and momentum ranges are missing up to now. Please make comments about the requested format which of course can be different for the three detectors

Main physical requirements for the pixel and strip detectors inside the Micro Vertex Detector can be found in table 1 and table 2 respectively; further requirements for the MVD are:

- Radiation tolerance up to $3 \cdot 10^{14}$ n$_{eq}$cm^{-2} for the innermost layers.
- Material budget less than 4% of a radiation length for the entire MVD including all support structures and services.
- Readout capable to cope with a triggerless readout architecture at an average annihilation rate of 10^7 per second and a peak rate up to $3 \cdot 10^7$.
- $\frac{dE}{dx}$-resolution in the order of a few percent (?) for a dynamic range from 1 to 20 (?) m.i.p. energy.
- ...

Furthermore one can find a first estimation of the expected performance for the MVD pixel and strip part based on experience in table 6, second column and

spatial resolution σ_s for track points	rφ = 100 μm z = 500 μm
resolution σ_v for vertex reconstruction	x = 100 μm y = 100 μm z = 1 mm
time resolution σ_t	2 ns
relative resolution Δp/p for charged particle momenta	1%

Table 2: Requirements for the strip part of the MVD.

spatial resolution σ_s for track points	rφ = ? z = ?
resolution σ_v for vertex reconstruction	x = ? y = ? z = ?
time resolution σ_t	?
relative resolution Δp/p for charged particle momenta	?

Table 3: Requirements for the Central Tracker.

third column respectively. This ’educated guess’ should serve as starting point for implementation into the fast simulation. More detailed information like momentum and acceptance dependencies of the resolutions will come as soon as they are available.

We can now distinguish between the requirements which will be derived from physics and the ’expected performance’ of the detector types. Although the proposed detectors have been designed to match the - up to now not really settled - requirements there can be differences between requirements and expectation, even a better expectation is possible.

2.3 Requirements for the Central Tracker

The main requirements for the central tracking devices are listed in 3. Apart from them more requirements are:

- Material budget less than 1% of a radiation length including all support structures and services.
- Resistance against ageing effects of the order 0.1-1 C per cm and year.

spatial resolution σ_s for track points	rφ = ? z = ?
resolution σ_v for vertex reconstruction	x = ? y = ? z = ?
time resolution σ_t	?
relative resolution Δp/p for charged particle momenta	?

Table 4: Requirements for the Forward Tracker.

- High rate capability ...
- ...

A first approximation of the expected performance for the different proposed options can be found in table 6, column 4-6.

2.3.1 Straw Tube Tracker (STT), tilted tubes

This and the following subsections can be used for special remarks to the different options under discussion, if needed!

2.3.2 Straw Tube Tracker (STT), straight tubes

2.3.3 Time Projection Chamber (TPC)

2.4 Requirements for the Forward Tracker

The main physical requirements for the Forward Tracker are given in table 4; more requirements are:

- High rate capability up to $3 \cdot 10^4$ per cm and second.
- Operation in a non-uniform magnetic field with variation up to 0.3 T
- ...

A first approximation of the expected performance for the different proposed options can be found in table 6, column 8 and 9.

spatial resolution σ_s for track points	rφ = ? z = ?
resolution σ_v for vertex reconstruction	x = ? y = ? z = ?
time resolution σ_t	?
relative resolution Δp/p for charged particle momenta	?

Table 5: Summary of the tracking requirements of the combined PANDA tracking system.

2.4.1 Mini Drift Chambers (MDC)

2.4.2 Straw Tubes (ST)

2.5 Overall tracking requirements

The global tracking requirements of the entire PANDA tracking system are summarized in table 5.

Again, here we could agree upon a format of the desired data in the first place. For sure the given format is insufficient to reflect for instance acceptance and momentum variations. Please comment.

3 Design choices

There are several design choices which have to be taken in the next years; it is agreed that the three most important ones are:

1. Central Tracker: Straw Tube Tracker (STT) or Time Projection chamber (TPC).
2. Central Tracker: Skewed STT design or charge division and/or time difference techniques, if STT is chosen.
3. Forward Tracker: MDC or Straw Tubes.
4. Forward Tracker: High-rate MDC design (i.e. ”PSI design”) or ”Dubna design”, if MDC is chosen.

There are of course many more choices to be taken, e.g. the different mechanical design options for STT, the number of layers needed for the forward spectrometer or the choice of the Pixel FE-chip. Many of them deal with the particular design of the sub-detector and are therefore not as controversial as others. Rather such decisions will evolve naturally during the R&D phase and may not need any formal procedure. However, all chosen options must at least demonstrate that the required criteria coming from physics or from technical aspects are fulfilled.

3.1 Criteria for design choices

The criteria given here are mostly connected to the already mentioned 'important design choices'. Of course they can also serve as input for other design choices even if no formal procedure takes place.

1. Sufficient performance to reach the requirements driven by the physics goals of PANDA, in particular:
   - Space and vertex resolutions.
   - Capability to cope with expected rates.
   - Efficiency and multiplicity issues.
   - Time resolution and trigger issues
2. Technical feasibility of the concept:
   - It has to be demonstrated by a test beam of a prototype (can be scaled down).
   - Readout concept.
   - Data handling issues.
   - Particle identification possibilities (if appropriate).
   - Mechanical issues.
   - Interaction with beam-pipe (if appropriate).
3. Feasibility of the production:
   - Person power.
   - Available infrastructure.
   - Financing issues.
4. Influence on other detector components.
5. Complexity and costs during the operation and maintenance.

We will at least mark the most important criteria for each choice, most likely around the end of our work. Or this list will evolve to separated lists for each decision.

3.2 Roadmap towards a decision

Since not all of the required criteria can be fulfilled on the same time scale or with the same effort a two step procedure is proposed.

1. For each design choice a report covering items 1., 3.b, 4., and 5 shall be prepared 6-12 months after the process started. Afterwards it will be refereed by an internal group and a decision may be taken by the CB if appropriate.

2. After a further evaluation period which should not exceed the time scale for the sub-detector TDR a final report covering all criteria for each choice will be prepared and presented to a group of internal and external experts (Design Review). The reviewers are asked to formulate a recommendation to the CB for a final decision.

As already pointed out not all design choices or design options need to go through the whole process but the criteria should be valid for all decisions. For each 'design choice decision' the described process shall be adjusted accordingly.

Not discussed at all up to now! Please comment!

4 Milestones to a PANDA TR

The current schedule to prepare a Technical Review of the PANDA detector (TR) until end of 2007 or early 2008 might clash with the time needed to take all necessary design choices. Therefore different options might be presented in the TR although an already taken decision is desirable. However, this TR is an intermediate step towards the individual sub-detector Technical Design Reports (TDR) which will come roughly a year later. It is an important milestone for the PANDA project and a definitive time frame for the open design choices must be given in this TR. Apart from a more detailed technical description of detector components the implementation of the production must be covered too. This includes productions milestones as well as feasibility and financing of the production. Many of the given information can of course go to the different TDRs as well to avoid duplication of the work. But in contrast to the TR the TDRs shall be as close as possible to the detector as it will be built. In order to cope with the tight FAIR/PANDA schedule the sub-detector TDRs should by finished by mid/end of 2009.

However, the scope of this document is not the planing for these 'official' paperwork but the definition and planing of the needed tracking detector work including open R&D questions. Therefore the proposed milestones could be:

1. Final Draft of this document concerning tracking requirements: October 2006

2. Fix time frames for design choices: December 2006 (?).

3. Definition of work-packages for sub-detector R&D: December 2006(?).

4. Preparation of summary reports for the design choice options: ?.

5. Detailed outline of the sub-detector chapters of the TR: June 2007.

Any opinions concerning the date from the sub-detectors?

5 Appendix

	MVD		CT			FT	
Requirement for	Pixel	Strips	STT, tilted	STT, straight	TPC	MDC	ST
spatial resolution σ_s for track points	rφ = 40 μm z = 40 μm	rφ = 40 μm z = 100 μm	rφ = ? z = ?	rφ = ? z = ?	rφ = ? z = ?	rφ = ? z = ?	rφ = ? z = ?
resolution σ_v for vertex reconstruction	x = 100 μm y = 100 μm z = 100 μm	x = 100 μm y = 100 μm z ¿ 1 mm	x = ? y = ? z = ?	x = ? y = ? z = ?	x = ? y = ? z = ?	x = ? y = ? z = ?	x = ? y = ? z = ?
time resolution σ_t	20 ns	2 ns	?	?	?	?	?
relative resolution Δp/p for charged particle momenta	1%	1%	?	?	?	?	?

Table 6: Expected performance of the different detector options for the tracking system of PANDA.