GSI Helmholtzzentrum für Schwerionenforschung GmbH

Document Title

Detailed Specification of Optical Beam Profile Screen Diagnostic at the Collector Ring (CR)

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Abstract

This document contains the *Detailed Specification* of the beam diagnostic component 'Optical Beam Profile Screens' for the Collector Ring (CR).

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Division/Group/Supplier

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1. Purpose

The purpose of this document is to specify the detailed requirements of Optical Beam Profile Screens for the collector ring (CR) [1] at FAIR [2], focusing on the functionality of the detector. All specific Information about geometrical and functional parameters can be found in this document. Whenever requirements are specified in the General Specifications [3], Technical Guidelines or Common Specifications for the Beam Diagnostics [4] they are only referenced in this document. The related documents are listed in the Appendix II.

No legal or contractual conditions are treated in this document, all related information is given in the General Specification [3].

2. Scope

The document describes Optical Beam Profile Screens as destined for the collector ring. Two different scenarios are taken into account.

- low current application: $\sim 10^4$ particles (first turn diagnostic)
- high current application: $\sim 10^{10}$ pions or 10^9 rare isotope during standard operation

The Optical Beam Profile Screens described here are not suitable for a permanent beam profile measurement at nominal design currents, due to beam- and radiation-induced material damage. Online diagnostics at nominal design currents will be realized with non-intercepting monitors, as IPMs in synchrotrons and IPMs/BIF-monitors in HEBT-sections, see detailed specifications [24], [25] and [26].

3. Responsibilities

The responsibilities with respect to changes and modifications of the document are in the hands of the beam diagnostic department of the GSI Helmholtz Centre for Heavy Ion Research GmbH (GSI) Darmstadt. The Document Release and Approval Procedure is described in [3] and [4].

4. General Functionalities

4.1. Overview

Optical Beam Profile Screens are intercepting devices to measure a 2-dimensional intensity distribution of the ion beam in the transversal plane. In contrast to methods implying direct projections as SEM-grids, BIF-monitors and IPMs, screens detect all kinds of possible intensity distributions as hollow-beams or sickle-shaped beams. Beam-profile projections along the vertical and horizontal axis can be derived from the 2-D image, as well as center of mass or higher statistical moments.
Driven by the differential energy loss of the ion beam, scintillating screens are excited to fluorescence levels. Important parameters like the light yield *Y*, the decay time τ, the opacity *O* and the radiation hardness are determined by the material properties of the scintillator and the actual beam parameters.

Optical Beam Profile Screens are typically used for low current applications in transport sections or as a first turn diagnostics of a synchrotron and whenever a two-dimensional intensity distribution is important to know. A schematic drawing of a typical optical beam profile screen setup with its major components 1) – 7) is shown in Figure 1.

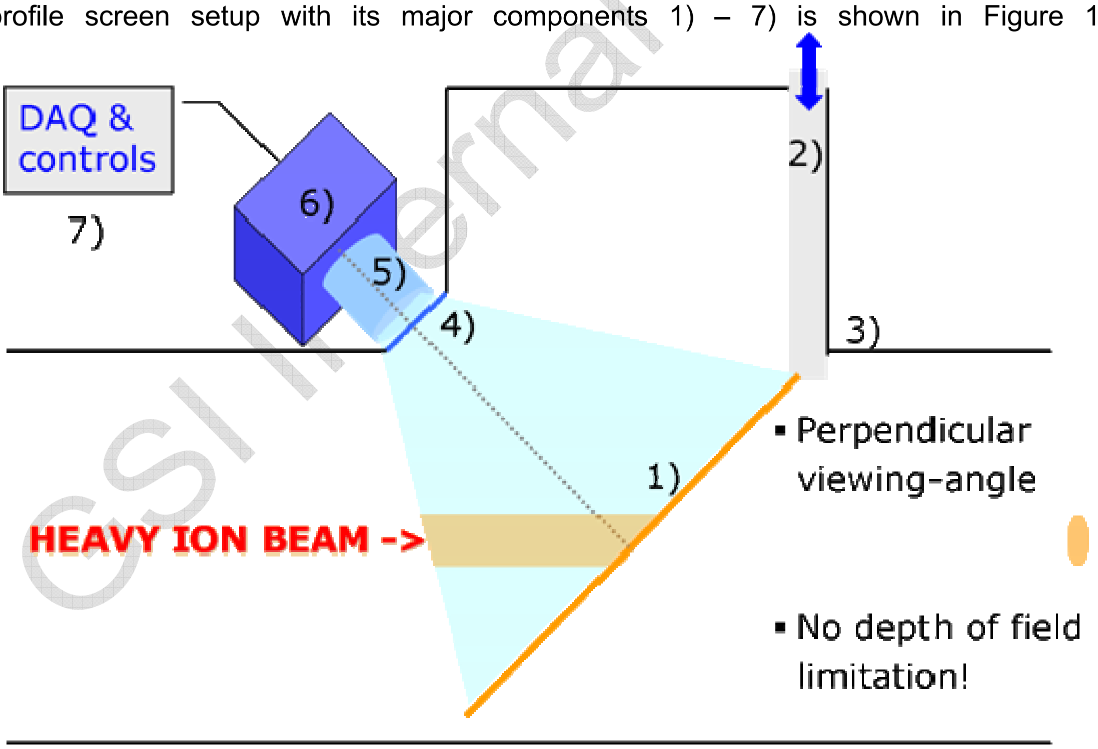

Fig. 1: Schematic drawing of a large area scintillating screen

4.2. Constituents of the BD Component

The BD component 'Optical Beam Profile Screens' consist of the parts assigned in the schematic drawing in Figure 1:

1) Optical scintillator made of luminescent material
2) Mechanical Drive to move the screen into the beam path and back again
3) Vacuum chamber to house and mount all the required components
4) Optical viewport with appropriate spectral transmission
5) Lens system with matched reproduction scale and remote iris
6) Digital camera with external trigger and adjustable integration times
7) Electronics and DAQ according requirements of the BD-department

4.2.1. Mechanical Components

- Optical scintillator, including support structure
- Mechanical drive Feed-through to move the scintillator in and out
- Adjustable mounting for the camera-systems
- Optical shielding for the camera-system to avoid incidence of ambient light
- Shielding material to protect the camera-system from gammas and neutrons
- Diagnostic-vacuum-chamber according all relevant guidelines

4.2.2. Optical Components

- Optical Viewport fitting a dedicated flange in the vacuum chamber
- Wide-angle lens-system with remote-iris capability
- Digital camera system with external trigger and adjustable integration times
- Optical shielding for the camera-system to avoid incidence of ambient light

4.2.3. Electronics and Data Acquisition

- Digital camera with FESA compliant interface and controls protocol
- FESA compliant image acquisition module (GigE, Firewire...)
- GUI for commissioning in order to test all functional parameters
- FAIR-timing compliant timing interface
- PLCs for slow control of the iris (0-5V) and to power calibration LED
- Oscilloscope/DAQ-card for an independent timing monitoring

4.3. Installation Locations and Special Requirements

The scintillator screen 'CR03DF-S' will be installed in the second straight section of the CR in front of the extraction line, see Technical Design Report Collector Ring (CR).

4.4. Exemplary Realization at GSI

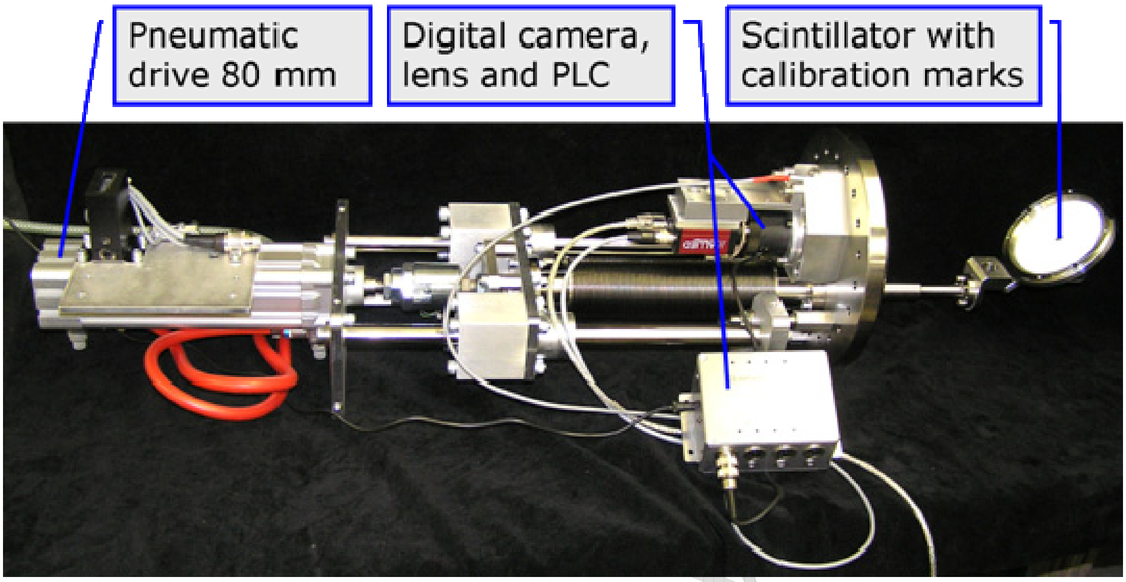

Fig. 2: Profile Screen as installed in Heidelberg Cancer Treatment Facility (HIT)

5. Mechanical Setup

All mechanical components have to be designed, following the guidelines for mechanical constructions inside a vacuum system: [b], [c], [e], [l], [o], [z], [aa] and [jj].

5.1. Mechanic Constituents of the BD Component

- Optical scintillator, including support structure
- Mechanical drive Feed-through to move the scintillator in and out
- Adjustable mounting for the camera-systems
- Optical shielding for the camera-system to avoid incidence of ambient light
- Shielding material to protect the camera-system from gammas and neutrons
- Diagnostic-vacuum-chamber according all relevant guidelines

5.2. Vacuum Parts

The diagnostic chamber, the optical scintillator and its support structure which is mounted at the mechanical drive are the only components installed inside the vacuum.

5.3. Mechanical Drive / Feed-through

The mechanical drive has to be built according the detailed specifications for the sub-components

A) Pneumatic Drive if a single screen with a single end position is sufficient
B) Stepping-Motor Drive if two positions for different targets have to be foreseen

5.4. Non-Vacuum Parts and Supports

The adjustable camera holder and all kinds of optical and radiation shielding have to be taken into account to fit the vacuum chamber design. Since an effective gamma-shielding will be much heavier than a standard installation, it has to be taken into account during the structural chamber design as well. To protect the camera against gammas and charged particles, a Pb-shielding of ≥ 10 cm wall-thickness should enclose the camera and other highly integrated support electronics.

5.5. Mechanical and Optical Alignment

A fine alignment using a theodolite will guarantee the screen to be adjusted centred to the beam-pipe, as well as tilted by 45 degrees, as depicted in Figure 1. A detailed specification and description of the alignment procedures is given in [4].

6. Optical Setup

- Optical Viewport fitting a dedicated flange in the vacuum chamber
- Wide-angle lens-system with remote-iris capability
- Digital camera system with external trigger and adjustable integration times
- Optical shielding for the camera-system to avoid incidence of ambient light

The required reproduction scale can be derived from geometric optics formulas for given object size, image size (≤ size of the sensor) and the minimal object distance according mechanical constraints. The focal length can be determined the same way.

The optical layout can be determined, as soon as the requirements for the spatial resolution, the maximum error of the statistical moments (***μ, σ***) and the required object size are defined, see chapter 12. Open Issues.

7. Electronics and Data Acquisition

- Digital camera with FESA compliant interface and controls protocol
- FESA compliant image acquisition module module (GigE, Firewire...)
- GUI for commissioning in order to test all functional parameters
- FAIR-timing compliant timing interface
- PLCs for slow control of the iris (0-5V) and to power calibration LED
- Oscilloscope/DAQ-card for an independent timing monitoring

7.1. Beam Line Electronics

For all the components installed in the beam line a radiation tolerant design or an effective shielding has to be considered. Whenever it is possible, sensitive electronics should be moved into the electronic rooms and will be connected via signal and supply cables. However, some of the components have to be installed in the beam line:
The digital camera, electronic range extender for the timing signal, fiber optic range extender for the camera interface (GigE, Firewire…).

7.2. Parts in Electronics Rooms

The image acquisition module, the PLC-satellite for iris and LED voltages, the range extenders, remote power plugs for all the power adaptors (hardware reset possibility) and the timing interface will be installed in the electronics room and linked via copper or optical fibers to the beam line electronics. Also a 3 channel DAQ-card for timing controls should be foreseen.

7.3. Cabling

All cable connections specified in this document regard the cabling between the electronics room to the beam line (exact cable lengths have to be specified):
- 2 power cables for the timing and signal extension modules
- 3 trigger cables for trigger in, trigger ready and integration enable signal
- Image data cable (GigE, Firewire…)
- Slow control cable to set the iris opening

8. Timing Requirements

The digital camera requires TTL trigger signals with a 1 µs accuracy that will be provided by the adapted CERN timing system 'White Rabbit'. A timing receiver decodes the timing protocol and sends the required signals, see [44].

9. Data Acquisition Software

The data acquisition software will use FESA as a front end solution with a compliant middle ware. All parameters will be adjusted by the machine control system LSA. The user interfaces will be JAVA based. Slow controls and digital I/Os will be realized with PLCs [67]. A timing system with a decent accuracy and flexibility is foreseen as well. All components are described in the BD+DS_DAQ [44].
The digital camera should support the GenICam protocol-standard which specifies and guarantees all the required smart features as selectable integrations times, external trigger mode, gain values and many more, see [66].
Reliable commissioning software is mandatory, like (Beam-View) [68] which is already available and used as a standalone application on notebooks for example, see Figure 3.

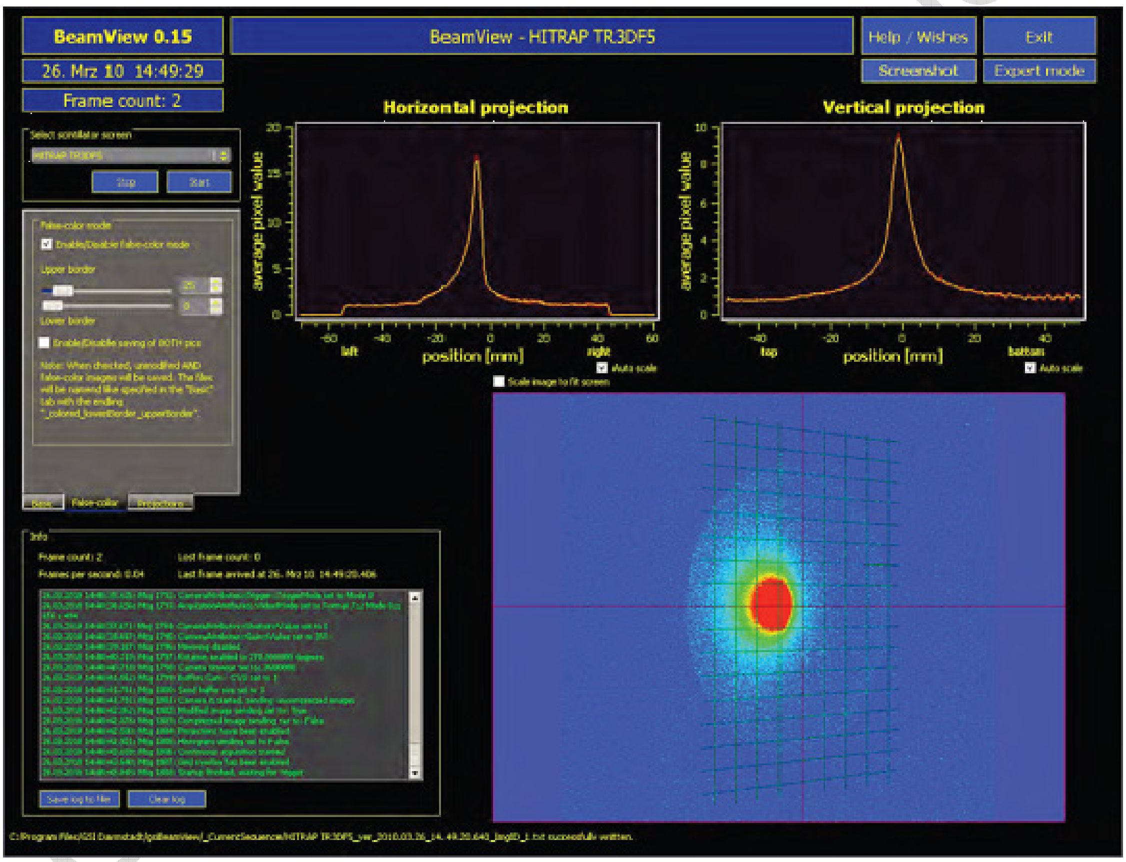

Fig. 3: Beam View software for commissioning and testing

10. Related Subsystems

This detailed specification contains three subsystems that are already specified in separate detailed specifications and are listed in this document just for the sake of completeness. All detailed specifications presented as subsystems are listed in the related documentation, see appendix II.

10.1. Vacuum Chambers

All mechanical components are grouped and common parts as vacuum chambers are specified as a subsystem [48].

10.2. Mechanical Drives

Mechanical drives and feed troughs' have to fulfil a bunch of demanding requirements, like the leak rate & mechanical reliability. Thus they are specified as subsystem [47].

10.2.1. Pneumatic Drive

The 'Case A)' as discussed in Chapter 6.3 with two positions can be realized in reliable design, using a pneumatic drive which is specified as a subsystem [51].

10.2.2. Stepping-Motor Drive

The 'Case B)' as discussed in Chapter 6.3 requires three ore more positions and is typically realized, using a stepping motor drive which is specified as subsystem [45].

10.3. DAQ

The subsystem DAQ [44] contains all kinds of control (fast/slow) and data acquisition and will be realized in close collaboration between GSI-BD department and GSI-Controls department.

11. Technical Parameter List

This technical parameter list is a draft version until now and has to be modified and completed substantially, as soon as the relevant calculations are performed.

Device	***Parameter***	***Value***	***Unit***
Mechanical dimensions			
Vac. chamber	*Overall **length**/height/width* *Nomenclature* *Installation point*	***800**x600x600*	*mm*
Drive	*Total travel* *No. of positions* *Accuracy*		*Mm* *µm*
Shielding	*Pb-shield thickness* *Optical shielding*		*mm*
Beam parameters			
Beam	*Particles* *Charge state* *Current min max* *Energy min max* *Envelop min max*		
Detector materials			
NaI (Case A)	*optical decay time* *Intrinsic resolution* *Required efficiency*	*230*	*ns*
Al_2O_3 (Case B)	*optical decay time* *Intrinsic resolution* *Required efficiency*	*3400000*	*ns*
Imaging system			
Sensor	*Size/resolution* *Full well* *Required QE* *Maximal noise level*		*mm*
Object (screen)	*Size/working distance*		*mm*
Lens	*Reprod. Scale / focal length* *Max. Vignetting* *Max. Distortion* *Min. Depth of field*		*mm / mm* *%* *%* *mm*
DAQ	*Digital resolution* *Frame rate* *Gate time (min. - max)* *Timing accuracy*		*Bit* *1/s* *S* *ns*

Table 1: Parameters of all relevant components

12. Open Issues / Questions

- **Complete the Technical Parameter List**
- **Expected Light Yields -> to be calculated**
- **EDMS Document numbers**
- **Calculating the depth of field**
- **Decide about the reproduction scale**

I.Attached Documents

If applicable, insert a list or brief description of documents (up to 99 documents are possible) which are attached to the main document. Following the FAIR Document Types and Naming Convention [71], the identification of the attached documents are: "FAIR-aa-bbcc-000.xx". (xx = Number between 01 and 99).

The first paragraph contains all design reports and the general-, common- and detailed-specifications of FAIR and the GSI-BD-department:
General documents (orange), single components (light orange), sub systems (light yellow), device classes (light green) and machine systems (light pink). Non-GSI-documentation is listed (light blue) as well as technical guidelines vacuum (light grey).

II. Related Documentation

[1] TDR Collector Ring , M. Steck et al., 2008, EDMS: https:994392/1
[2] FAIR Baseline TR, H.H.Gutbrod et al, 09.2006, EDMS: tba
[3] General Specifications for FAIR, EDMS: tba
[4] FAIR-XXBDX-EF-001.V0.9_2, Commom Spec. Beam Diagnostics for FAIR
[5] BD+DS_OptProfile+IPM_1S, EDMS: tba
[6] BD+DS_OptProfile+IPM_, EDMS: tba
[7] BD+DS_OptProfile-BIF_PL+T+F, EDMS: tba
[8] BD+DS_AC+FC_PL, EDMS: tba
[9] BD+DS_AC+BS_1S+CR, EDMS: tba
[10] BD+DS_AC+FCT_1S+T, EDMS: tba
[11] BD+DS_AC+FCT_CR, EDMS: tba
[12] BD+DS_AC+ACT_PL+PT, EDMS: tba
[13] BD+DS_AC+ACT_1S+CR, EDMS: tba
[14] BD+DS_AC+RT_T+PT+F, EDMS: tba
[15] BD+DS_DC+DCT_1S+CR, EDMS: tba
[16] BD+DS_DC+NDCCT_1S, EDMS: tba
[17] BD+DS_ElecProfile+MWPC_T, EDMS: tba
[18] BD+DS_ElecProfile+SEM_PL+T+PT, EDMS: tba
[19] BD+DS_ElecProfile+SEM_1S, EDMS: tba
[20] BD+DS_ElecProfile+SEM_CR, EDMS: tba
[21] BD+DS_OptProfile+SCR_T+PT+F, EDMS: tba
[22] BD+DS_OptProfile+SCR_1S, EDMS: tba
[23] BD+DS_OptProfile+SCR_CR, EDMS: tba
[24] BD+DS_OptProfile+BIF_PL+T+F, EDMS: tba
[25] BD+DS_OptProfile+IPM_1S, EDMS: tba
[26] BD+DS_OptProfile+IPM_CR, EDMS: tba
[27] BD+DS_POS+BPM_1S, EDMS: tba
[28] BD+DS_POS+BPM_T+PT+F, EDMS: tba
[29] BD+DS_POS+BPM_T+PT+F, EDMS: tba

[30] BD+DS_POS+PHP+TOF+BPM_PL, EDMS: tba
[31] BD+DS_PD+BLM_T_1S_CR_PT, EDMS: tba
[32] BD+DS_PD+PDC_, EDMS: tba
[33] BD+DS_Special+ClosedOrbitFeedback_1S, EDMS: tba
[34] BD+DS_Special+Scraper_CR, EDMS: tba
[35] BD+DS_Special+Iris_PL, EDMS: tba
[36] BD+DS_Special+SlitPair_PL, EDMS: tba
[37] BD+DS_Special+BunchStructureMonitor_PL, EDMS: tba
[38] BD+DS_Special+SchottkyPickUp+Tune_1S+CR, EDMS: tba
[39] BD+DS_Special+TransmissionInterlock_1S+CR, EDMS: tba
[40] BD+DS_Special+OuadrupoleBPM_1S+CR, EDMS: tba
[41] BD+DS_Special+BeamInGapMonitor_1S, EDMS: tba
[42] BD+DS_Special+ElectronCloudMonitor_PL, EDMS: tba
[43] BD+DS_Special+LossControl_PL, EDMS: tba
[44] BD+DS_DAQ_, EDMS: tba
[45] BD+DS_SubSys+StepperMotor, EDMS: tba
[46] BD+DS_GasValveGauge+BIF, EDMS: tba
[47] BD+DS_Mech+MechanicalDrives, EDMS: tba
[48] BD+DS_Mech+VacuumChambers, EDMS: tba
[49] BD+DS_Cryo+LocalCryoCCC, EDMS: tba
[50] BD+DS_SubSys+HighVoltage, EDMS: tba
[51] BD+DS_SubSys+PneumaticDrive, EDMS: tba
[52] BD+DS_SubSys+DetectorGasFlow, EDMS: tba
[53] BD+DevClass_POS, EDMS: tba
[54] BD+DevClass_PHP, EDMS: tba
[55] BD+DevClass_AC, EDMS: tba
[56] BD+DevClass_DC, EDMS: tba
[57] BD+DevClass_ElecProfile, EDMS: tba
[58] BD+DevClass_OptProfile, EDMS: tba
[59] BD+DevClass_PD, EDMS: tba
[60] BD+DevClass_SubSys, EDMS: tba
[61] BD+MC_PL, EDMS: tba
[62] BD+MC_1S, EDMS: tba
[63] BD+MC_T, EDMS: tba
[64] BD+MC_PT, EDMS: tba
[65] BD+MC_F, EDMS: tba BD+MC_CR, EDMS: tba
[66] GenICam camera protocol EMVA, Url: http://emva-conference.net
[67] PLCs with FESA, R. Haseitl, PCaPAC'10 WEPL009, EDMS: tba
[68] BeamView GUI, R. Haseitl, PCaPAC'08 WEP006, EDMS: tba
[69] Document title & text, if applicable, the EDMS Doc. Number.
[70] FAIR-QD-DNxx-000, Doc. Types & Naming Convention, EDMS: tba
[71] FAIR-QP-DRxx-000, Document Review and Approval, EDMS: tba

I.1. Technical Guidelines Vacuum

[a] F-TG-V-13.1e Assembly Instructions for Knife-Edge UHV Flanges 20100414.xls
[b] F-TG-V-2.19e Additives for TIG Welding of Stainless Steel 20100512.xls
[c] F-TG-V-2.1e Stainless Steel for Beam Vacuum Chambers 20100617.xls
[d] F-TG-V-2.23e Bolts_Studs_Nuts_Washers for bakeable UHV Components 20100624.xls
[e] F-TG-V-2.24e Materials in UHV 20100512.xls
[f] F-TG-V-2.25e Forged Blanks for Vacuum Applications Mat. 1.4429_ESU 20100512.xls
[g] F-TG-V-2.26e Forged Blanks for Vacuum Applications Mat. 1.4435_ESU 20100512.xls
[h] F-TG-V-2.28e Stainless Steel for Beam Vacuum Chambers at Cryog. Temp. 20100614.xls
[i] F-TG-V-2.36e Bolts_Studs_Nuts_Washers for non-bakeable UHV Components 20100629.xls
[j] F-TG-V-2.37e Bolts_Studs_Nuts_Washers for Cryogenic UHV Components 20100630.xls
[k] F-TG-V-2.3e Copper for Vacuum Applications 20100512.xls
[l] F-TG-V-2.5e Vacuum Firing 20100512.xls
[m] F-TG-V-2.6e Material for bakeable CF-Flanges 20100512.xls
[n] F-TG-V-2.7e Ceramics for Vacuum Applications 20100624.xls
[o] F-TG-V-3.11e Bolts for Use in Vacuum 20100512.xls
[p] F-TG-V-3.17e Design of Thick-Walled Vacuum Chambers 20100624.xls
[q] F-TG-V-3.1e Constructive Design of Welding Seams for Vacuum Chambers 20100510.xls
[r] F-TG-V-3.30e Dimensions for Standard Bellows 20100621.xls
[s] F-TG-V-3.3e Design of O-Ring Grooves 20100624.xls
[t] F-TG-V-3.41e Construction and Mounting of COF gaskets 20100625.xls
[u] F-TG-V-3.42e Copper Gaskets for ConFlat Flanges 20100510.xls
[v] F-TG-V-3.4e Manufacturing of CF-Knife Edge Flanges 20100629.xls
[w] F-TG-V-3.9e Welding of CF-Flanges on Tubes 20100512.xls
[x] F-TG-V-4.1e Bakeout Equipment 20100512.xls
[y] F-TG-V-5.1e Surface Conditions of Vacuum Chambers 20100510.xls
[z] F-TG-V-6.10e Cleaning Assemblies and Sub-Assemblies in Vacuum 20100511.xls
[aa] F-TG-V-6.1e Cleaning of UHV Components Stainless Steel 20100707.xls
[bb] F-TG-V-6.2e Cleaning of Vacuum Components 20100510.xls
[cc] F-TG-V-6.3e Cleaning Procedure for Bellows 20100512.xls
[dd] F-TG-V-6.4e Cleaning of Ceramics for Use in UHV 20100510.xls
[ee] F-TG-V-6.5e Cleaning of Aluminum Components 20100510.xls
[ff] F-TG-V-6.8e Cleaning of Copper Components 20100512.xls
[gg] F-TG-V-6.9e Bakeout Cycle 20100914.xls
[hh] F-TG-V-7.15e Record for FAT Vacuum Components 20100512.xls
[ii] F-TG-V-7.1e Mechanical Acceptance Testfor UHV Components 20100512.xls
[jj] F-TG-V-7.25e Vac. Prop. Acceptance Tests for Cryo Beam Vacuum Comp. 20100630.xls
[kk] F-TG-V-7.2e Vacuum Properties Acceptance Test without Bakeout 2010917.xls
[ll] F-TG-V-7.3e Vacuum Properties Acceptance Test with Bakeout 20100510.xls
[mm] F-TG-V-8.10e Recom. Data Reconciliation of Internals in Vacuum Tanks 20100625.xls
[nn] F-TG-V-8.14e Recom. Guidelin. Purchase of Beam Vac. Chambers SuperFRS 20100914.xls
[oo] F-TG-V-8.15e Recom. Guidelin. Purchase of Beam Vac. Chambers SIS100 20100630.xls
[pp] F-TG-V-8.16e 15e Recom. Guidelin. Purchase of Beam Vac. Chambers PL 20100630.xls
[qq] F-TG-V-8.17e 15e Recom. Guidelin. Purchase of Beam Vac. Chambers HEBT 20100630.xls
[rr] F-TG-V-8.18e 15e Recom. Guidelin. Purchase of Beam Vac. Chambers CR 20100630.xls
[ss] F-TG-V-8.1e 15e Recom. Guidelin. Purchase of Cer. Chamb. wo Bakeout 20100624.xls
[tt] F-TG-V-8.2e 15e Recom. Guidelin. Purch. Beam Vac. Chambers wo Bakeout 20100624.xls
[uu] F-TG-V-8.3e Recom. Guidelin. Purch. Beam Vac. Chambers wo Bakeout 20100624.xls
[vv] F-TG-V-8.6e Recommendation Data Reconciliation of Vacuum Chambers 20100707.xls
[ww] F-TG-V-9.1e Transport and Packaging of Vacuum Components 20100624.xls

III. Document Information

III.1. Distribution, storage and access

The Document is distributed and announced by storing the approved version in the EDMS system.

III.2. Approval and Release Procedure

This document belongs to the approval procedure: FAIR-AL.
The impacted groups are defined as:

Group / Approver	Release/Approval comment

Document History

Version	Date	Description	Author	Review / Approval
0.1	2010-10-26	Draft version	Frank Becker	review comment, approver
0.2	2010-10-29	GSI internal version	Frank Becker	Georg Schepers Beata Walasek-Höhne
1.0				