

Gaseous Detectors for Beam Diagnostics at GSI and FAIR

01.12.2023, M. Schwickert

- # and FAIR

What is „Beam Diagnostics“?

Beam Diagnostics is the „nervous system“ of accelerators.

- **Measurement of the ion beam with adequate detector systems,**
- detection **along entire accelerating structures and beamlines,**
- processing and **provision of all beam parameters**
- for effective **operation, trouble shooting** and **optimization** of the accelerators.
- Important: permanent **upgrades of detector systems,** often at the limit of what is technically feasible



Simon Van der Meer
CERN accelerator scientist and
beam diagnostic expert
noble prize for physics 1984
(Photo: Cern Courier, June 2011)

General Structure of Beam Diagnostic Systems

Accelerator Tunnel



Detection

- Detectors and actuators along the beamlines
- Signal pick-up and shaping
- Pre-amplification of analogue signals
- Transport to electronic rooms

Electronic Rooms



Signal Processing

- Analogue signal pre-processing
- Control of detectors and digitization (ADCs...)
- Data pre-processing
- Feed-in to accelerator control system

Main Control Room



Display and Archiving

- PC Terminals for graphical visualization of measurement data
- Digitale control of detectors
- Evaluation of measurement results
- Further data processing, evaluation and storage

Overview of Beam Diagnostic Detector Systems

- | | |
|--------------------------------|-----------------------------------|
| ▪ AC Transformer | ▪ Macropulse Selector |
| ▪ Beam Induced Fluorescence | ▪ Multi Wire Proportional Chamber |
| ▪ Beam Loss Monitor | ▪ Phase Probes |
| ▪ Beam Position Monitor | ▪ Plastic Scintillator |
| ▪ Base-band Tune Measurement | ▪ Profile Grid/SEM Grid |
| ▪ Bunch Structure Monitor | ▪ Quadrupolar Pick-Up |
| ▪ Collimator | ▪ Resonant Transformer |
| ▪ Cryogenic Current Comparator | ▪ Schottky Diagnostics |
| ▪ DC Transformer | ▪ Scintillating Screen |
| ▪ DC Transformer Novel Type | ▪ Secondary Electron Monitor |
| ▪ Emittance Measurement System | ▪ Slit Pair / Scraper / Iris |
| ▪ Faraday Cup / Beam Stopper | ▪ Tune Measurement / BTF |
| ▪ Fast Current Transformer | ▪ Transmission Interlock System |
| ▪ Ionization Chamber | ▪ Closed Orbit Feedback |
| ▪ Ionization Profile Monitor | ▪ ... |

- BEA-Team is responsible for 45+ different detector types
- BEA operates distributed detector infrastructure
 - pressurized-air drives
 - stepper motor drives
 - high-voltage supplies
 - detector gas
- Synoptic BEA systems
 - **LASSIE** (particle counters and many different signal sources)
 - **MAPS** (online transmission control in Unilac)
 - **UNIMON** (RF monitoring tool for Unilac)

Beam Diagnostics is a Cross-Sectional System

- 45+ Detector types at GSI

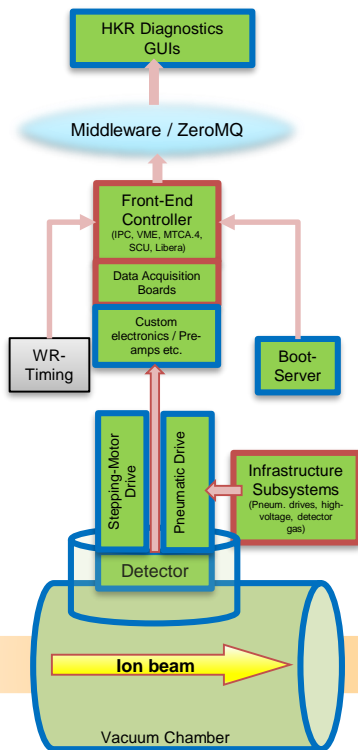
Unit numbers at GSI:

- 573 Diagnostic components
- 257 Stepping motor drives
- 352 Pneumatic drives
- 174 HV channels

FAIR (ES + FS*):

- 561 Diagnostic components
- 54 Stepping motor drives
- 147 Pneumatic drives
- 560 HV channels

*ES: Early Science
FS: First Science



... along the accelerator chain...

Mechanics

- Vacuum Chamber
- Detector
- Pneumatic Drive
- Stepper Motor Drive

Electronics

- Analog detector electronics & pre-amp
- Custom connector boxes / signal shaping
- Commercial data acquisition boards
- Industrial front-end controllers

Software

- Full vertical SW stack: drivers, FESA classes, graphical user interfaces, boot server

Subsystems

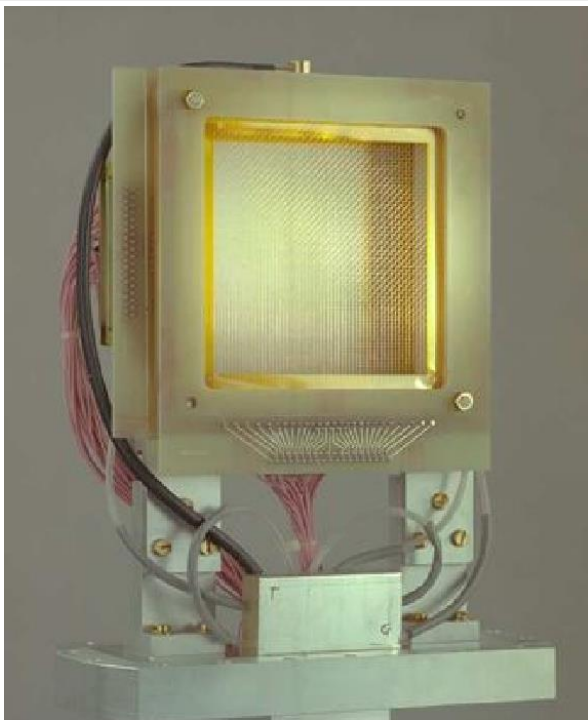
- Pneumatic Drive Control
- Stepper Motor Control
- High-Voltage Supply
- Detector Gas Supply
- Unbreakable / Clean Power Supply



From ion sources...

... to experiments.

Multi Wire Proportional Chambers @ GSI



Ar/CO₂ 80/20 @ 1 atm., cont. flow

Nr	Position in Beschleuniger	Kommentar: MWPC Ausführung
1	GTE5DGCG	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
2	GTE5DGAG	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
3	GTE5DGBG	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
4	GTE5DGDG	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
5	GTH1DG2G	Profilgitter mit Gasverstärkung, (T-DG 080) 61*61*1.5 mm, Ab
6	GTH1DG4G	Profilgitter mit Gasverstärkung, (T-DG 080) 61*61*1.5 mm, Ab
7	GTH4DG4G	Profilgitter mit Gasverstärkung, 79*79*1 mm Abfrage (H u. V)
8	GTH4DG5G	Profilgitter mit Gasverstärkung, (T-DG 080) 61*61*1.5 mm, Ab
9	GTT1DG1G	PG gasverstärkt, 45 x 45 x 1 mm(ULD 05) Auswertung H und V:
10	GTT1DG6G	Profilgitter mit Gasverstärkung, (F2)(B-PF 01) 61*61*1.5 mm
11	GHADDG1G	Profilgitter mit Gasverstärkung, (T-DL 140) (F4) 61*61*1.5mm
12	GTH4DG7G	Profilgitter mit Gasverstärkung, (T-DG 080) 61*61*1.5 mm, Ab
13	GHHDDG2G	Profilgitter mit Gasverstärkung, 61*61*1.5mm, Abfrage H u.V
14	GHHDDG3G	Profilgitter mit Gasverstärkung, 61*61*1.5mm, Abfrage H u.V
15	GHTADG2G	Profilgitter mit Gasverstärkung (T-DG-080) 61*61*1.5mm, Abfr
16	GHTADG4G	Profilgitter mit Gasverstärkung (T-DG-080) 61*61*1.5mm, Abfr
17	GHTCDG2G	Profilgitter mit Gasverstärkung [BPF01] 61*61*1.5mm, Abfrage
18	GHTPDG1G	Profilgitter mit Gasverstärkung, (T-DG 080) 61*61*1.5mm, Abf
19	GHTMDG1G	Profilgitter, 63/63 * 1,5mm m. Gasverstärkung(BPF080)
20	GHTMDG2G	Profilgitter, 63/63 * 1,5mm mit Gasverstärkung
21	GHTMDG3G	Profilgitter, 63/63 * 1,5mm mit Gasverstärkung
22	GHTMDG4G	Profilgitter, 63/63 * 1,5mm mit Gasverstärkung
23	GHTMDG5G	Profilgitter, 31/31 * 1,5mm mit Gasverstärkung an Luft
24	GHTMDG6G	Profilgitter, 31/31 * 1,5mm mit Gasverstärkung an Luft
25	GHADDG4G	Profilgitter mit Gasverstärkung, an Luft 61*61*1.5mm, Abfrag
26	GE01DG3G	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
27	GE02DG3G	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm
28	GECEDG1G	PG gasverstärkt, hor.: 52 x 2 mm, vert.: 28 x 2 mm

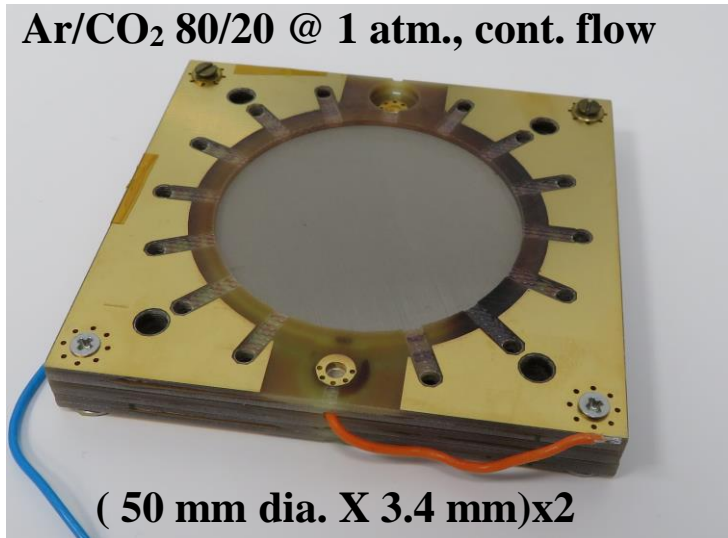
For more details: B.Walasek@gsi.de

Ionization Chambers and Proportional Counters

Beam intensity measurements

Ionization Chambers

Ar/CO₂ 80/20 @ 1 atm., cont. flow



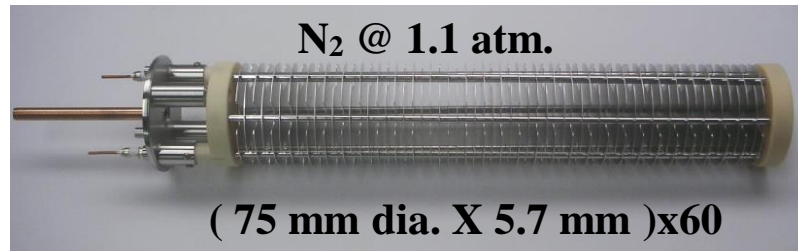
(50 mm dia. X 3.4 mm)x2

Developed and build by B. Voss(GSI)

Beam loss measurements

Ionization Chambers

N₂ @ 1.1 atm.

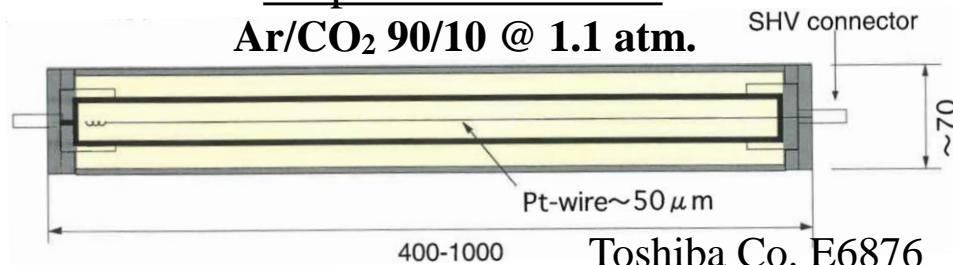


(75 mm dia. X 5.7 mm)x60

Developed and build: CERN+ Protvino, Russia

Proportional counter

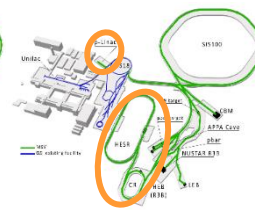
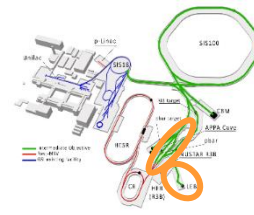
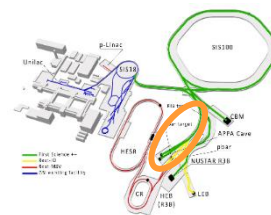
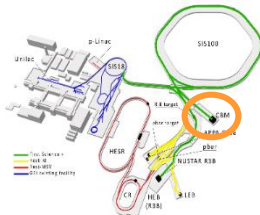
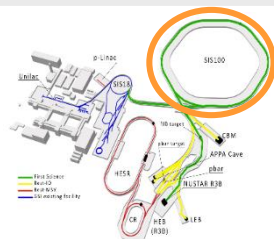
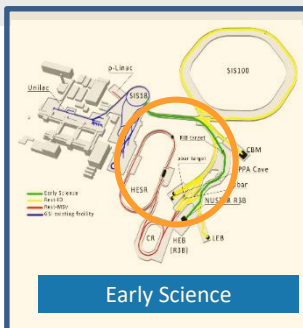
Ar/CO₂ 90/10 @ 1.1 atm.



Detector readout: IFC, H. Reeg, DIPAC99, Chester, p. 147 (1999)

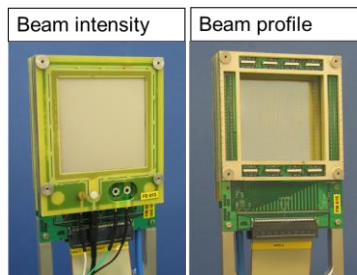
For more details: P.Boutachkov@gsi.de

BEA Equipment for Early Science (ES)

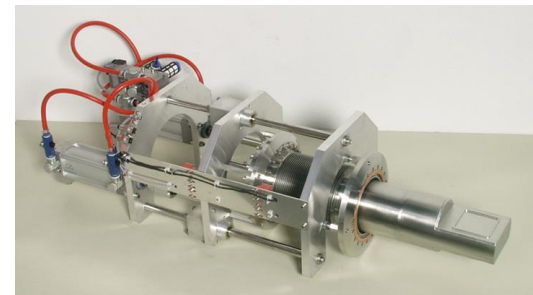


Detector	No. of pcs.	Status
BPM	7	4 pcs. already available
BPM (short)	2	2 pcs. available
MWPC + Ionization Chamber	12	Drives manufactured, detectors in production @ DTL
PDC	6	Drives manufactured, detectors in production
PG 1 (1.8 mm)	9	accomplished
PG 2 (1.2 mm)	3	accomplished
RT	6	accomplished
FCT	2	accomplished
IPM	4	Vacuum chambers: 2x FoS in Sept. 2023, Series X+Y in Dec. 23, Series X in Feb.24
SCR LT1 (120 mm)	4	accomplished
SCR LT2 (100 mm)	1	accomplished

GSI-In-Kind for FAIR:
total 40 pcs. MWPC/IC
detectors to be built by
GSI Detector Laboratory

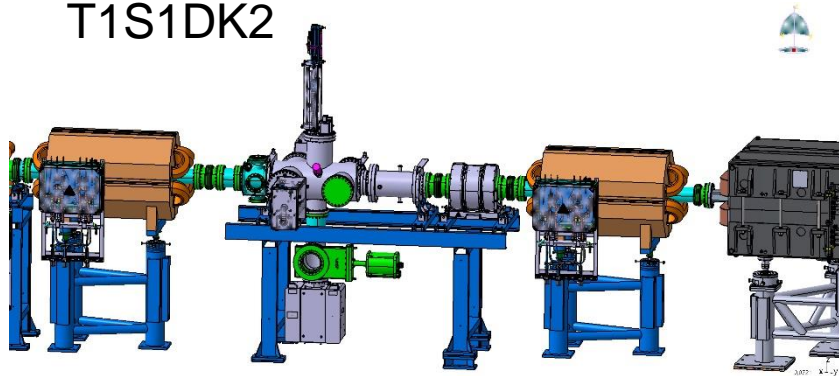


Pneumatic drive with cylindrical housing for gas detectors
(foil window: 50µm stainless steel)

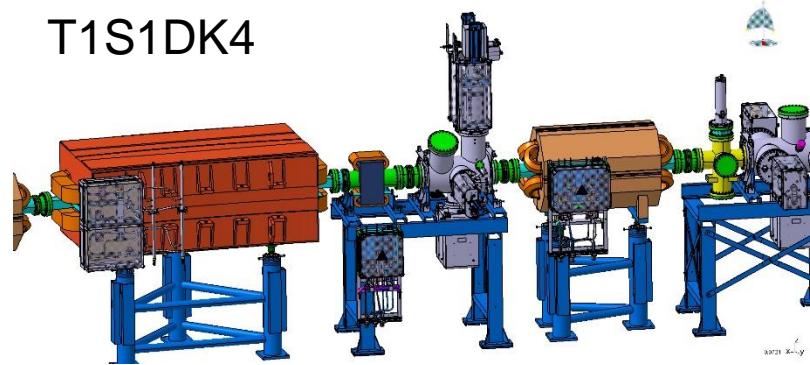


Example of BEA Assemblies for FAIR Early Science

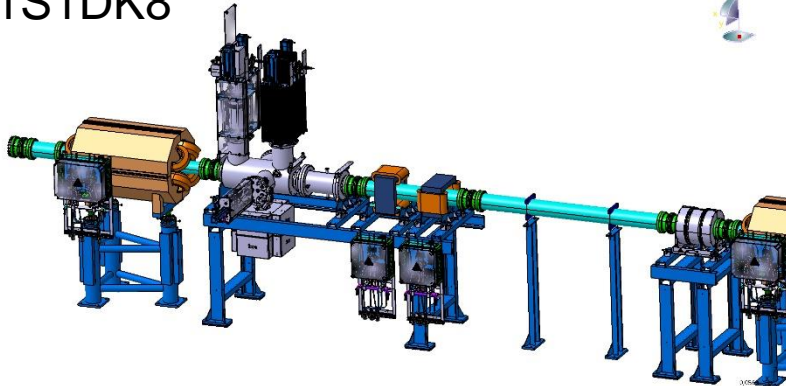
T1S1DK2



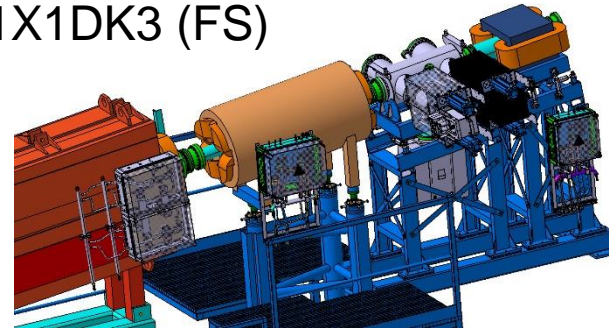
T1S1DK4



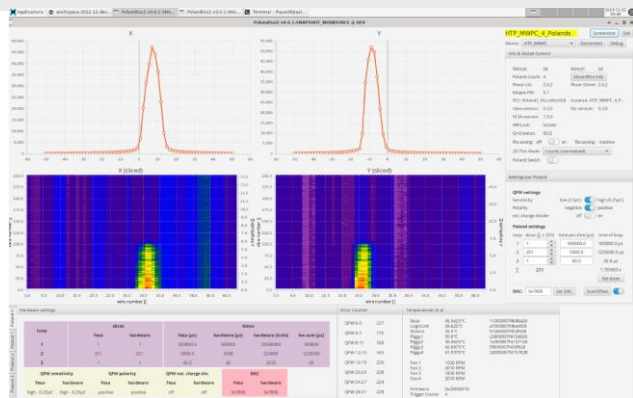
T1S1DK8



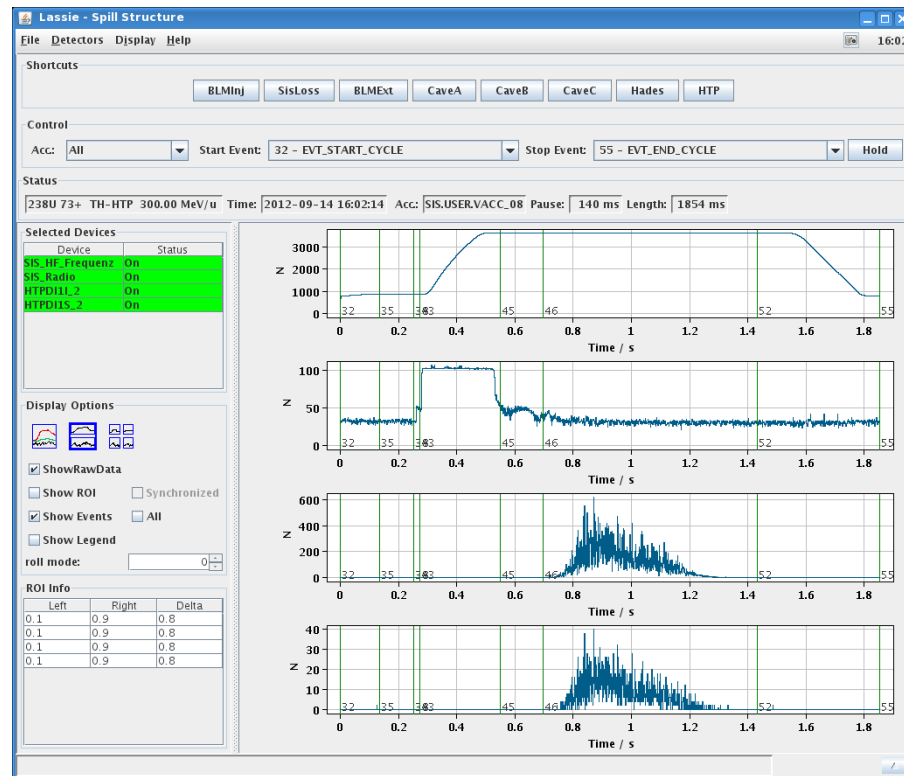
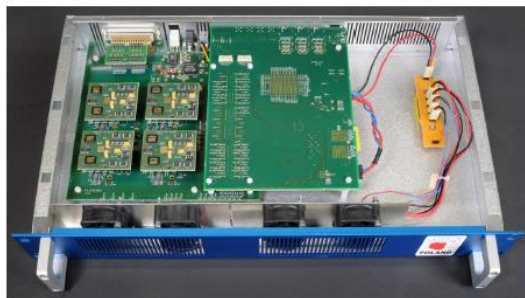
T1X1DK3 (FS)



Example Measurements / Electronics



MWPC readout: POLAND electronics
 → **designed+produced by GSI EEL Dptm.**



- Beam Diagnostics Department (BEA) requires long-term availability of gaseous detectors built by Detector Laboratory (DTL)
- Presently very few spare detectors available, reproduction necessary
- Top priority: completion of GSI in-kind delivery of 40 pcs. MWPC/IC detectors

- to be discussed:
 - future scenarios for service, maintenance reproduction of DTL detectors (GSI / FAIR)
→ availability of experts, knowledge, infrastructure (tools, eg. winding machine)
 - common detector developments of DTL, BEAand experiment collaborations (?)
 - GSI internal issues:
 - support by BEA team for test and data acquisition equipment
 - documentation of the existing detectors
 - future of detector gas supply system