A Photogrammetric Alignment Approach at High-Radiation Areas of FAIR

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Outline

- i3mainz, GSI, FAIR
- RALF – basic concept
- Configuration, optimization
- Camera tests (geometry, radiation)
- Future work

Institute for Spatial Information and Surveying Technology

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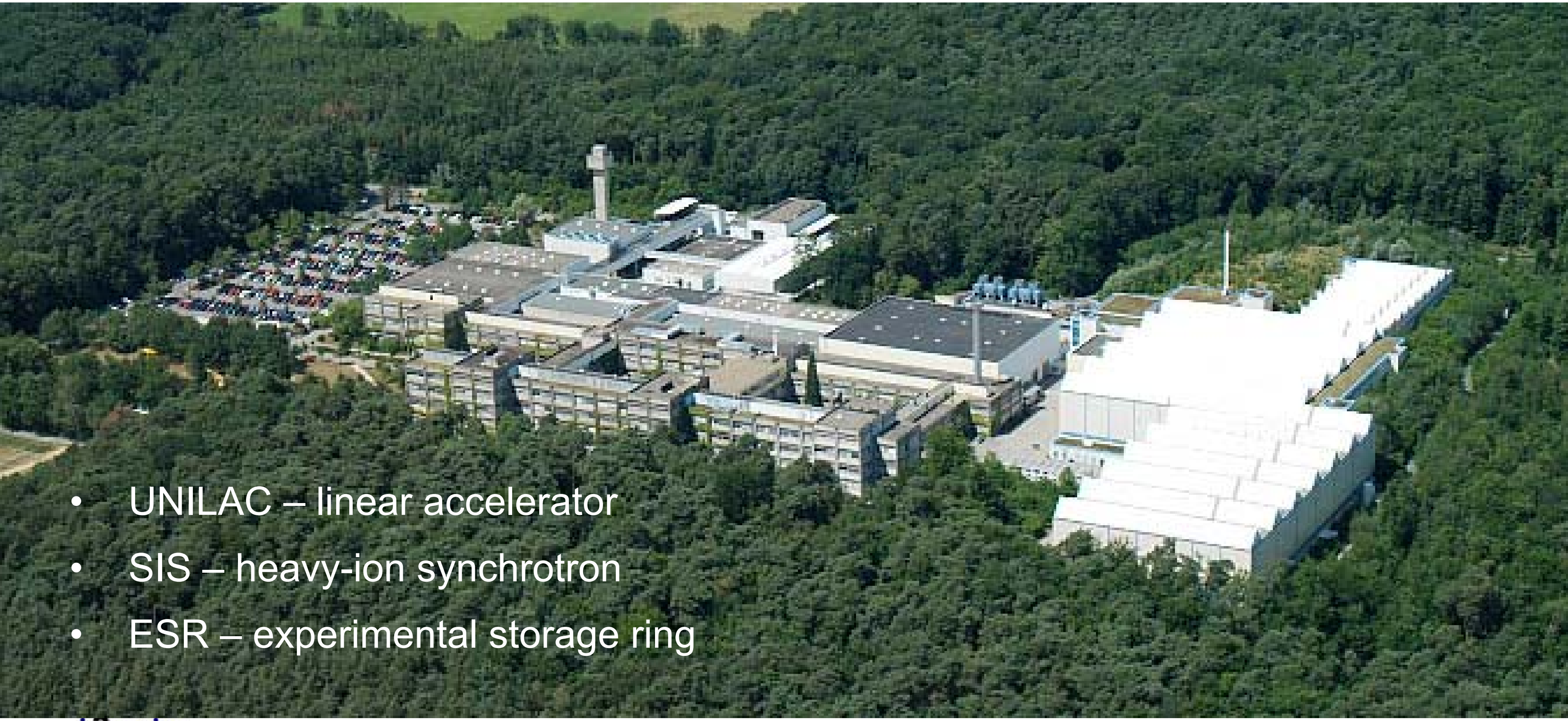
Fachhochschule Mainz

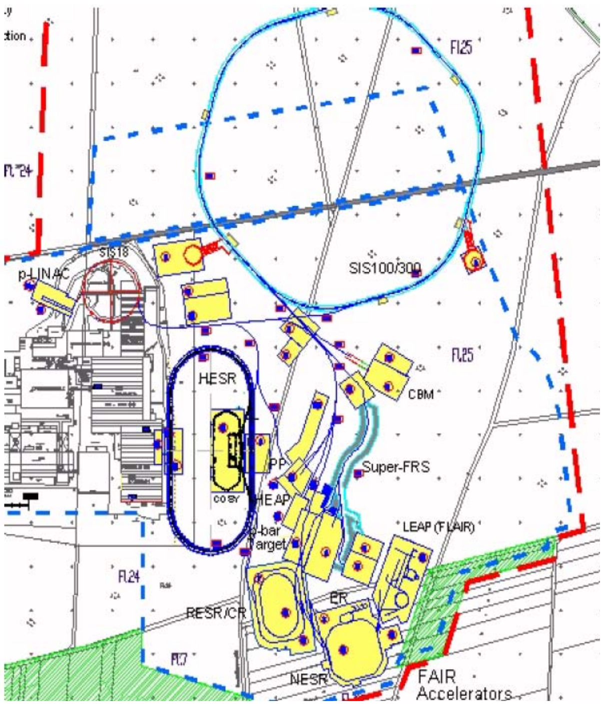
- Research institute within the Fachhochschule (University of Applied Sciences, Mainz)
- Competencies: image processing, photogrammetry, remote sensing, surveying, 3D scanning, visualization, internet development, software engineering
- 18 scientific collaborators, 7 full professors
- http://www.i3mainz.fh-mainz.de
- Cooperation with GSI

GSI – Gesellschaft für Schwerionenforschung



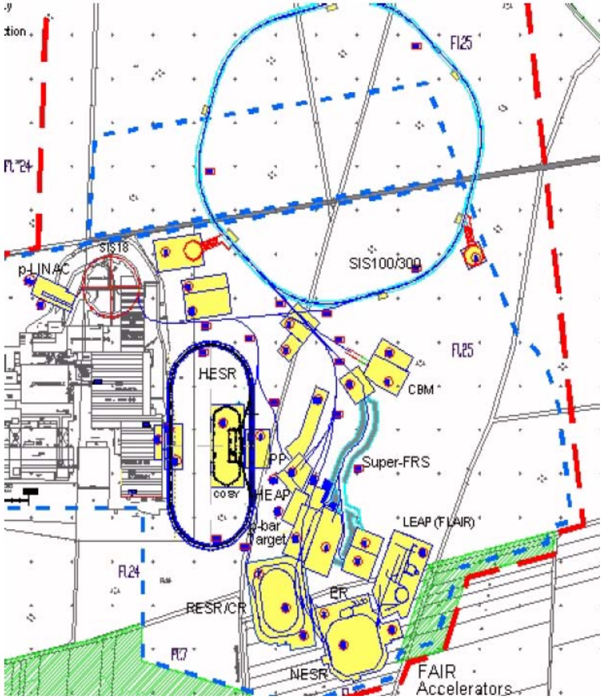
- UNILAC – linear accelerator
- SIS – heavy-ion synchrotron
- ESR – experimental storage ring

FAIR – Facility for Antiproton and Ion Research



- new accelerator facility
- start of construction: fall 2007
- completion: end of 2015
- Double ring synchrotron SIS 100/300: circumference 1100 m
- Diverse new storage rings: CR, HESR, RESR, NESR
- Super-Fragment-Separator

FAIR – Facility for Antiproton and Ion Research



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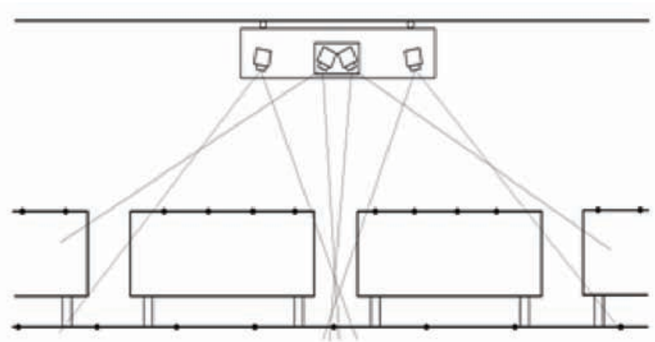
- **Super-Fragment-Separator**

New constraints for accelerator alignment

- No access to accelerator tunnel after commissioning of FAIR due to **high radiation environment** in some areas of Super-FRS
- Accuracy requirements: 0.1 mm
- stretched, non-linear geometry
- Lack of space (iron and concrete shieldings)
- automatic and remote-controlled adjustment of machine geometry (high radiation! huge masses!)

Basic concept (introduced at IWAA 2004)

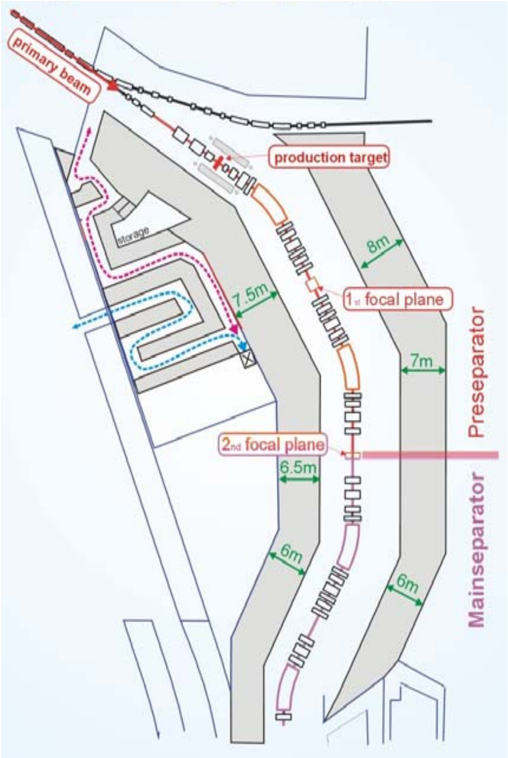
„R A L F“ – Remote ALignment on the Fly



First idea (2004)

- Photogrammetric solution
- Remote-controlled vehicle equipped with digital cameras
- Photogrammetric targets on magnets and in object space
- Automatic target detection, image measurement and bundle adjustment
- Remote-controlled motorized jacks for geometric adjustment of magnets

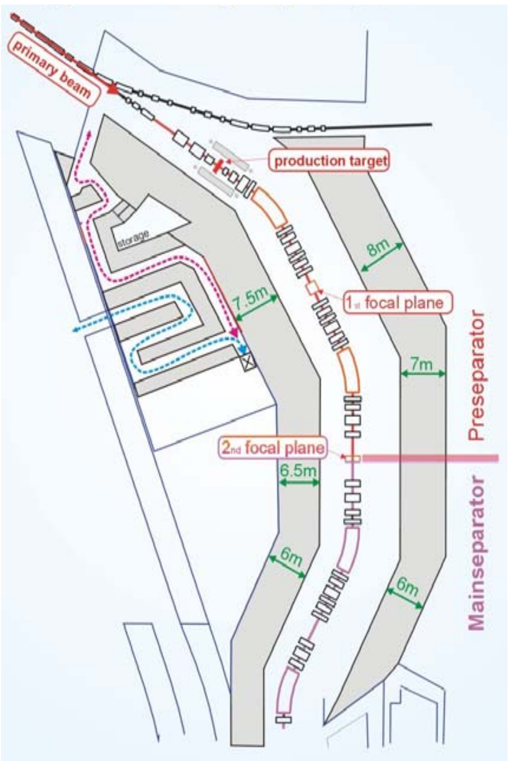
Configuration of RALF



State of 2004

- Environmental conditions changed within last 2 years
- Additional shieldings
- Access to accelerator tunnel impossible!
- A new solution had to be found

Configuration of RALF



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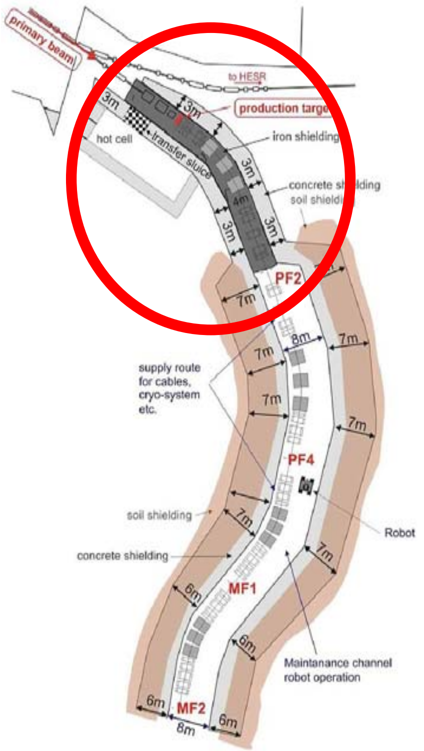

State of 2006

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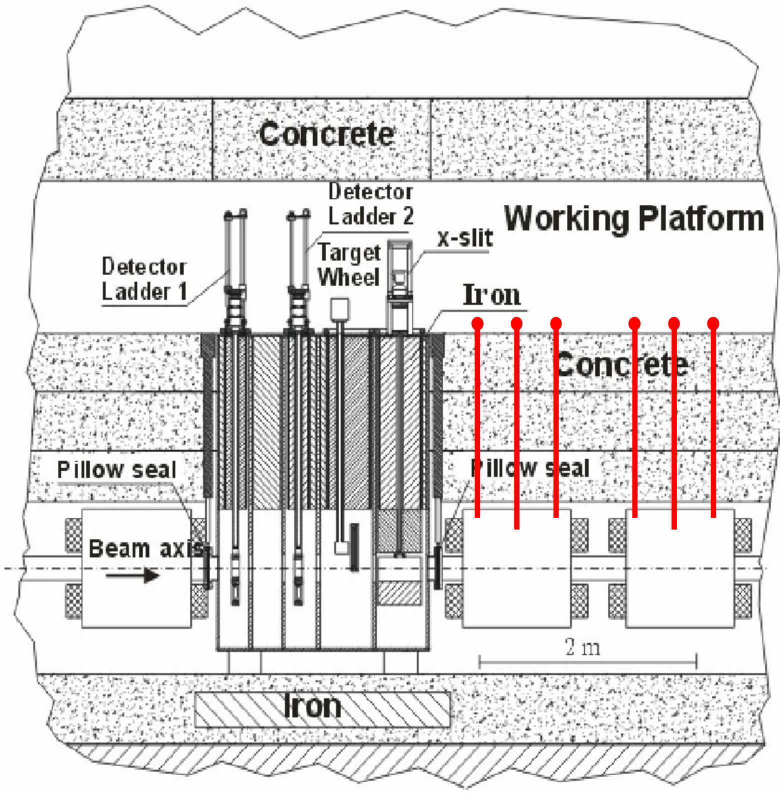
Configuration of RALF



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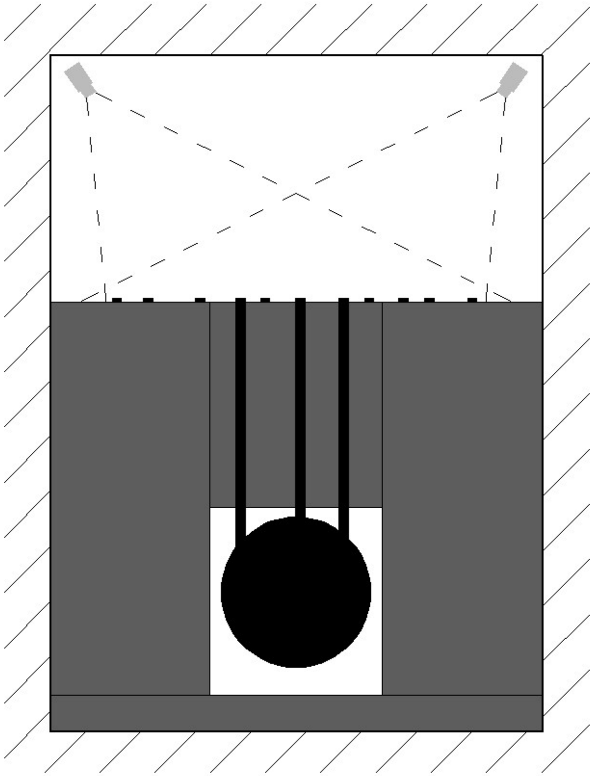
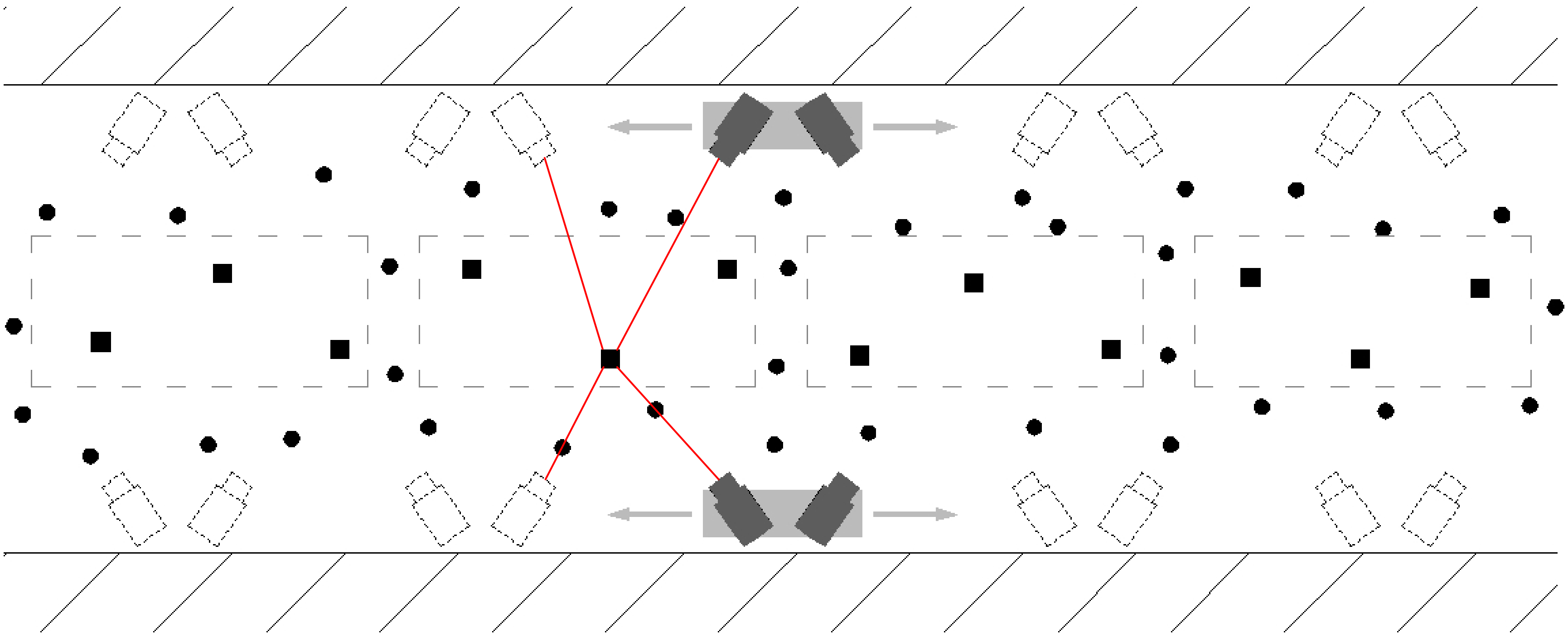
Configuration of RALF

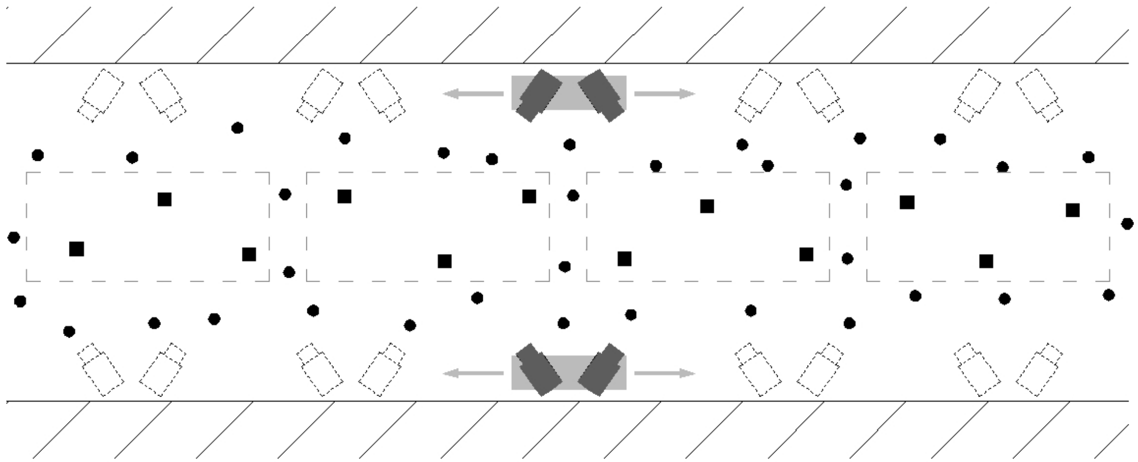


- Dimensions of working platform: approx. 4 m x 1.3 m x 30 m
- Two camera vehicles
- At least three excentric fiducial points per magnet
- Large number of additional tie-points for stable network geometry

Configuration of RALF



Solution



- Four 4Mpixel cameras
- 18 mm lenses
- Assumed image measurement accuracy: 1/25 pixel
- Distance between vehicle positions: 2.5 m
- Approx. 300 tie-points needed on a 30 m working platform

Solution

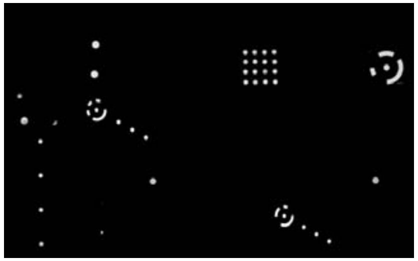
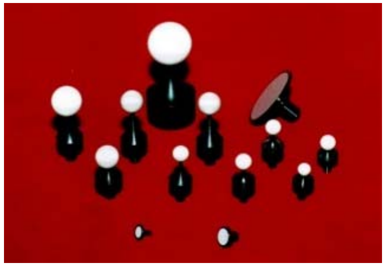
	Longitudinal	Radial	Vertical
RMS	0.18 mm	**0.09 mm**	**0.10 mm**
Max.	0.32 mm	0.21 mm	0.19 mm

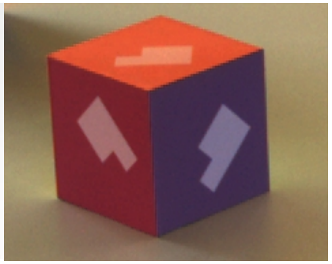
Object point accuracy

- Four 4Mpixel cameras
- 18 mm lenses
- Assumed image measurement accuracy: 1/25 pixel
- Distance between vehicle positions: 2.5 m
- Approx. 300 tie-points needed on a 30 m working platform

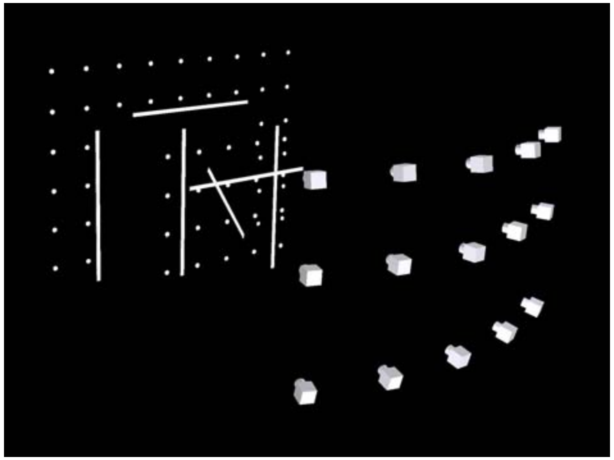
Signaling

- Photogrammetry needs appropriate targets
- Common: white or retro-reflective circular targets on black surface
- Disadvantage: limited viewing angle
- Solution: 3D targets are visible from all sides



Camera tests



- 4-Mpixel cameras needed
- Six different cameras were tested at photogrammetric test field of i3mainz
- 2 color, 4 monochrome
- Results:
  - mono “better” than color
  - CCD “better” than CMOS
  - 1/25 pixel or more is realistic

Camera tests





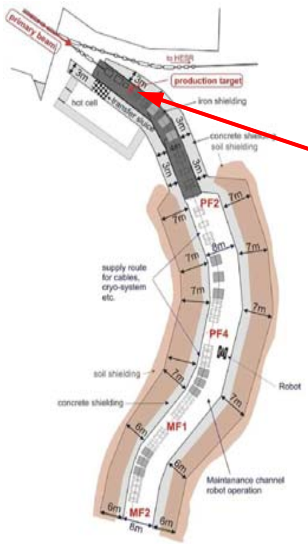

Camera	Mono/Color	Sensor	Image measurement accuracy	RMS of scale distances
Vosskühler VDS CCD-4000C	Color	CCD	1/26 pixel	0.06 mm
SVS-Vistek SVS4021	Color	CCD	1/18 pixel	0.14 mm
SVS-Vistek SVS4020MSCL	Mono	CCD	1/27 pixel	0.06 mm
SVS-Vistek SVS4021	Mono	CCD	1/31 pixel	0.09 mm
AVT PIKE F421B	Mono	CCD	1/33 pixel	0.09 mm
Teli CSB4000F	Mono	CMOS	1/15 pixel	0.09 mm

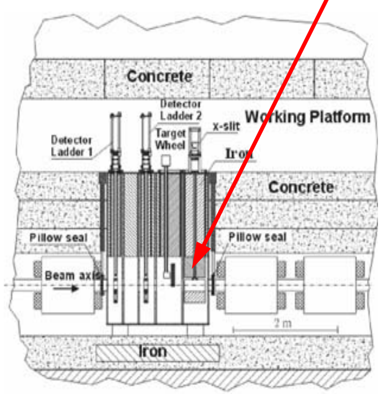
Radiation tests

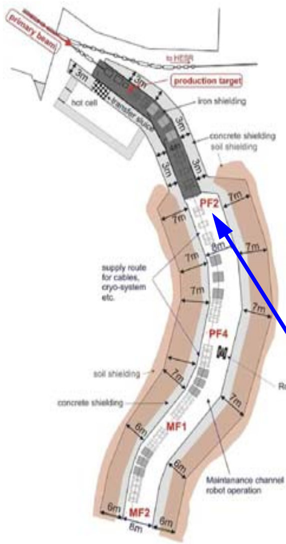
- Image sensor (CCD) = measurement instrument
- Sensitive to electromagnetic radiation (e.g. visible light)
- This includes gamma radiation!
- Particle radiation (alpha, beta, **neutrons**)!
- Radiation can influence the image quality and/or damage the camera sensor permanently
- Influence on photogrammetry (sub-pixel measurement accuracy)?

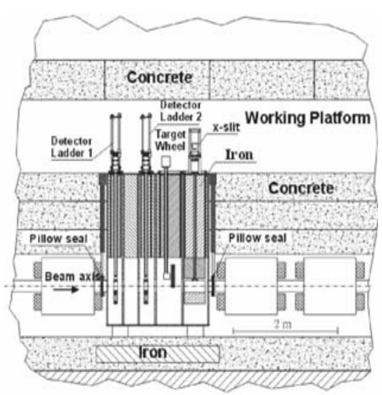
Radiation conditions at FAIR

- Heavy neutron production during beam time (up to 100 Sv/h) at target area









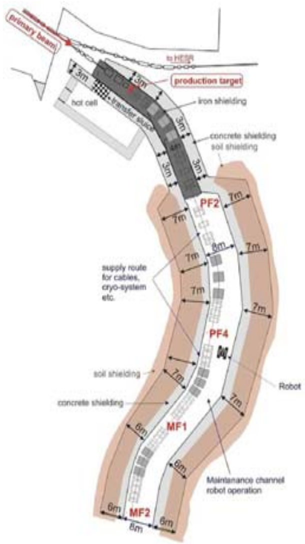
Radiation conditions at FAIR

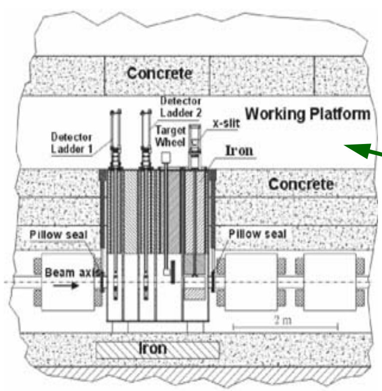
- Heavy neutron production during beam time (up to 100 Sv/h) at target area
- Neutron radiation leads to activation of beam line parts

➔ radioactive environment, even when accelerator is shut down

- Up to 10 mSv/h expected at end of iron shielding

Radiation conditions at FAIR





- Heavy neutron production during beam time (up to 100 Sv/h) at target area
- Neutron radiation leads to activation of beam line parts

➔ radioactive environment, even when accelerator is shut down

- Up to 10 mSv/h expected at PF2
- Some µSv/h on working platform

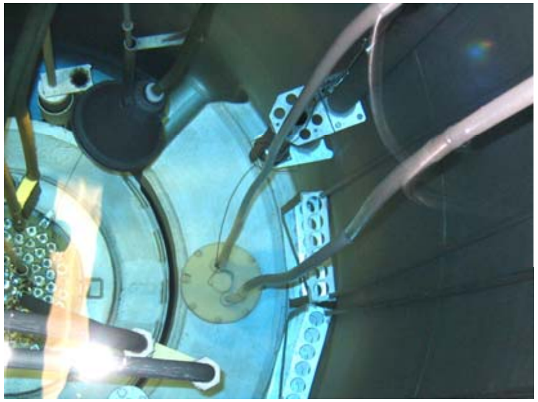
Neutrons

- Single neutrons of few eV can damage CCD chip permanently!
- CCD degradation leads to increased dark current and “hot pixels”

➔ Cameras have to be protected during beam from any neutron radiation!

Gamma

Test scenario 1

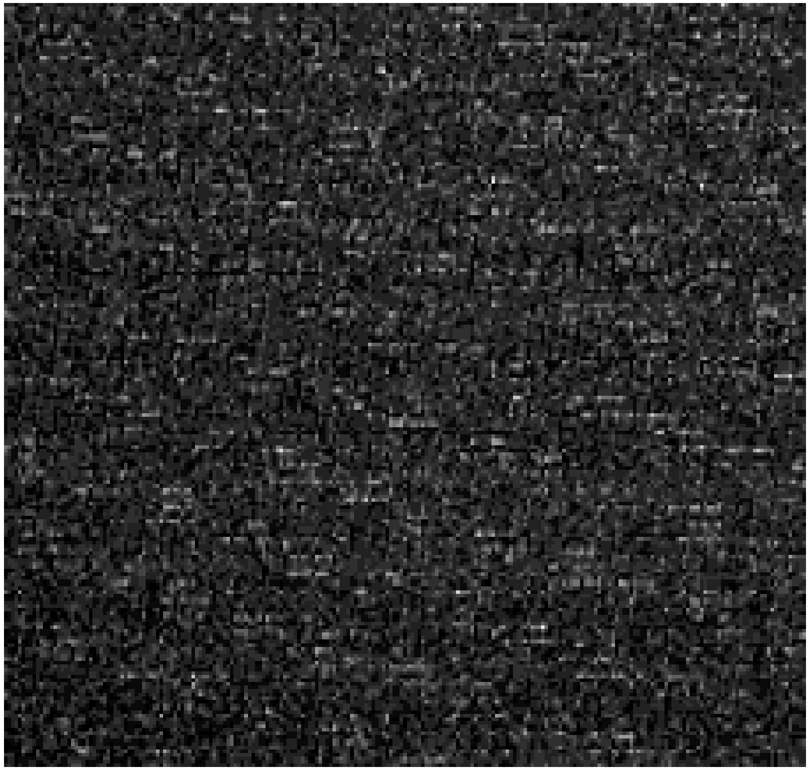


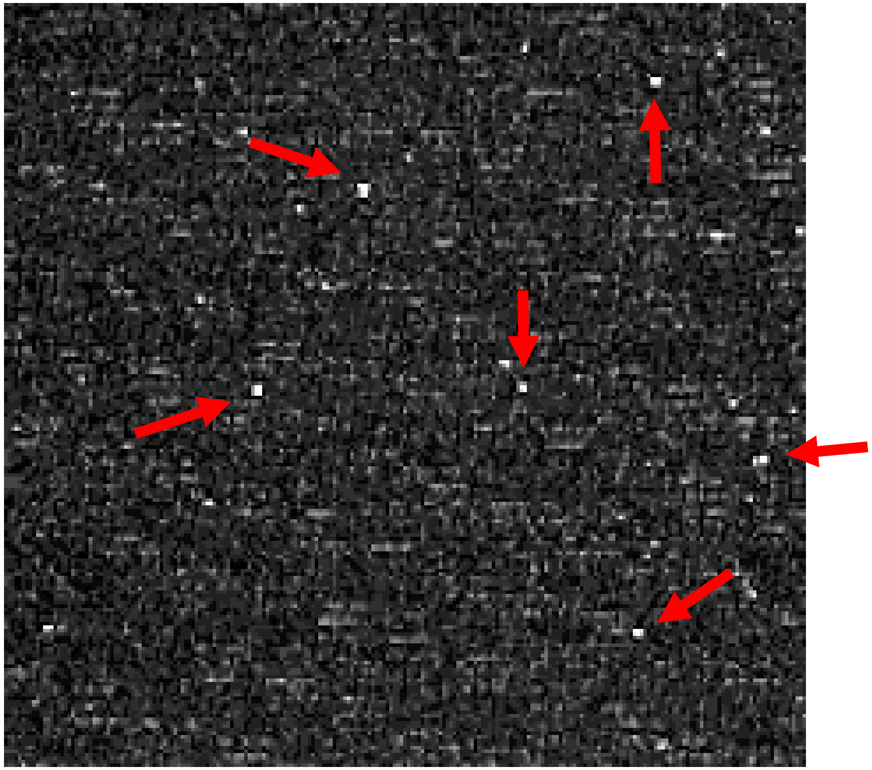
- Gamma irradiation with up to 100 mSv/h
- Closed lens cap

Results:

- Slight increase of noise

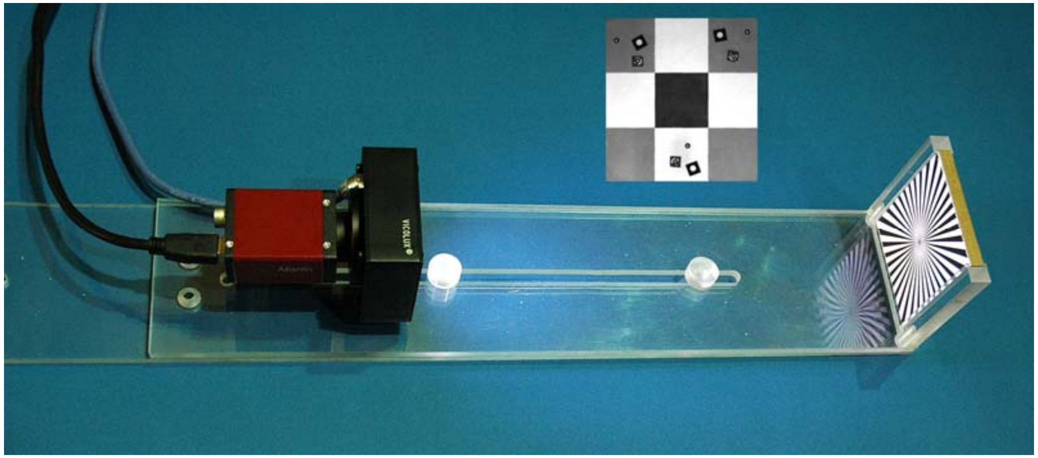
Dose rate (mSv/h)	Mean gray value	Std. dev.	Max. gray value	No. of gray values >0
0	0.00	0.06	18	898
5	0.00	0.09	34	1602
10	0.00	0.10	48	1172
20	0.00	0.10	41	1393
60	0.00	0.14	50	2011
100	0.00	0.15	47	2836





- Note: radiation 10 x higher than expected at Super-FRS!
- Image histogram has been stretched

Test scenario 2



- Gamma irradiation with up to 10 mSv/h
- Targets: Siemens star, gray pattern, photogrammetric targets

Results:

- No influence on resolution or image measurement accuracy could be detected!

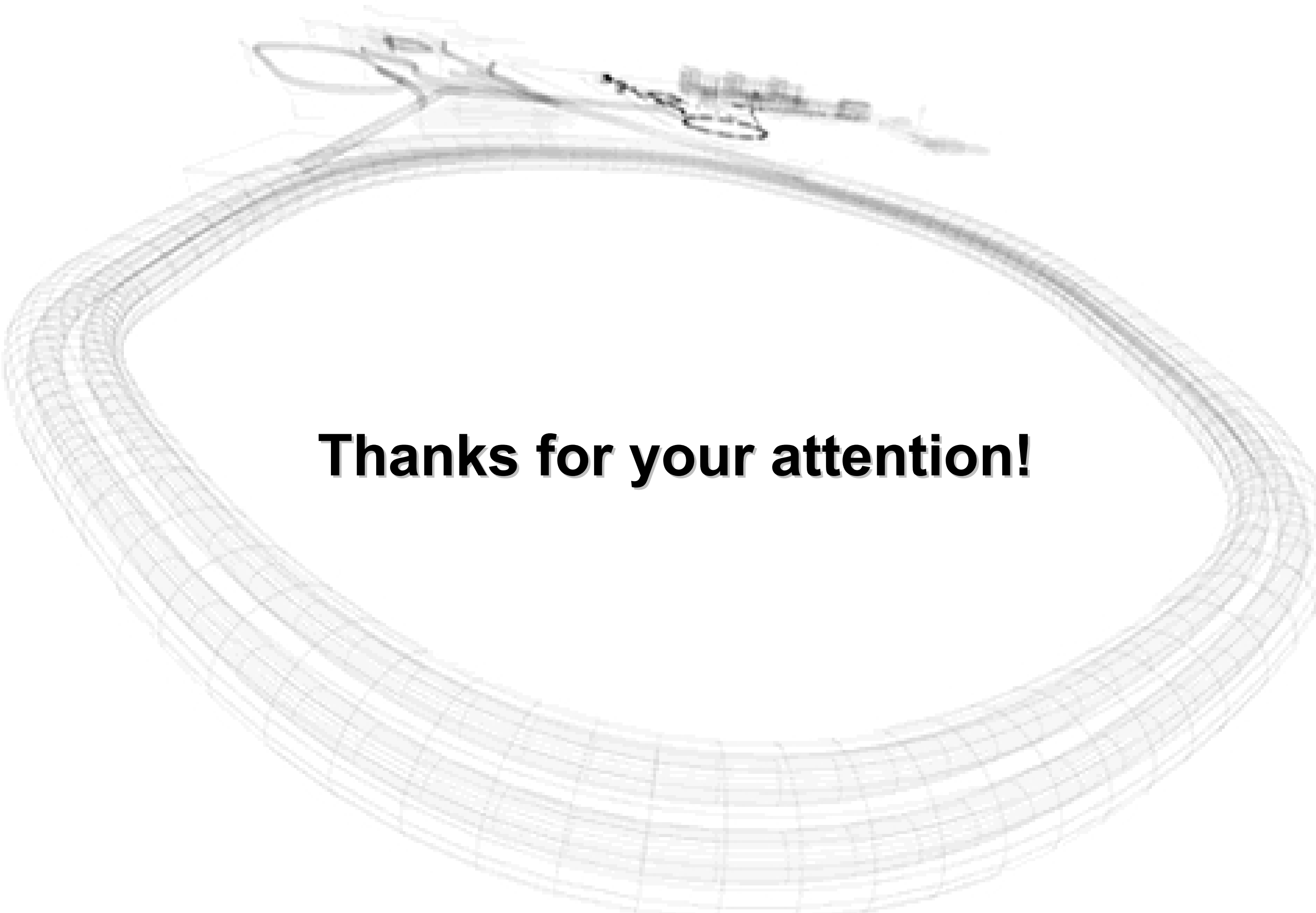
Future work

- Test installation
- Remote-controlled adjustment of accelerator components
- Design, mounting and actuation of camera vehicle
- Data transfer
- Fiducialization of excentric targets
- Illumination/Signaling

Test installation

AVT Pike 421B

- To be built up within next months
- Two 4 Mpixel cameras
- Copy of working platform at scale 1:1
- Confirmation of simulations
- Test of targets, illumination, data transfer …



Thanks for your attention!