Planned detector tests for FLASH dosimetry at PITZ

PITZ Physics Seminar 24.02.2022

Felix Riemer
Ph.D. student (Detector development)

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

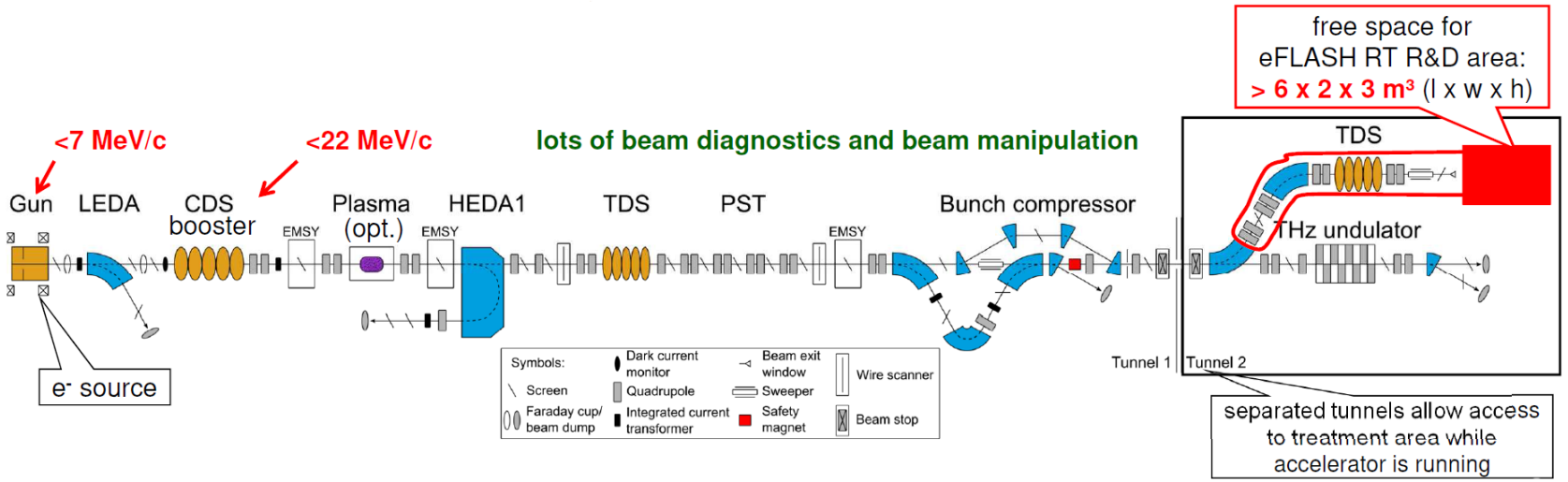
Motivation

About FLASH radiation therapy

- New method for cancer treatment
- Treatment with short and high intensity pulses
- High dose rates (> 40 Gy/s):
  Better tissue sparing than conventional radiation therapy (few Gy/min)
- AND equal eradication of tumors

About PITZ for FLASH

- PITZ has unique beam parameters
- Parameters are extremely flexible (bunch charge, bunches per train etc.)
- Dosimetry is challenging



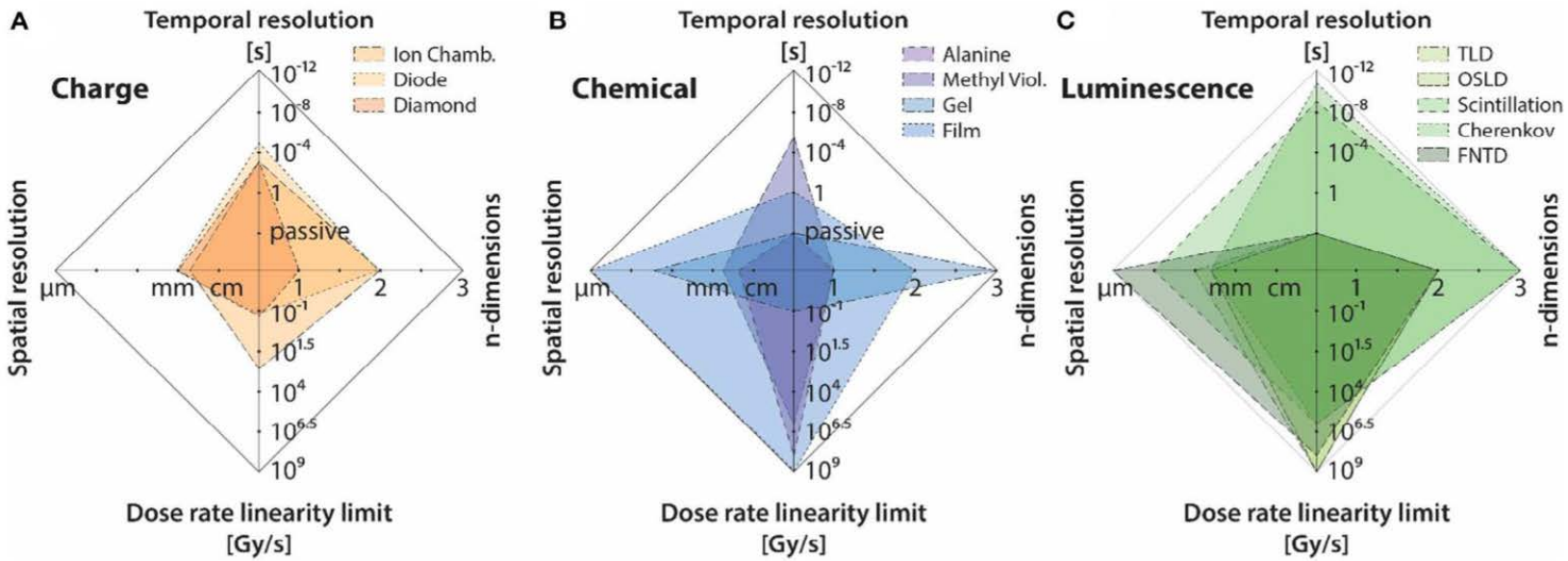
Two examples:

Single bunch: ~9 Gy/cm³

Options @PITZ:	low dose case	high dose case
Bunch charge [pC]	0.1	5 000
Single bunch OR train	single bunch	1ms train (1MHz)
RF pulse rep. rate	1Hz	10Hz
Bunch length [ps]	<1	~30
Dose | Dose rate **per bunch** [Gy | Gy/s]	0.02 | >2E+10	1000 | 4E+13
Dose | Dose rate **per train(ms)** [Gy | Gy/s]	0.02 | 20	1E+6 | 1E+9
Dose **per second** [Gy/s]	0.02	1E+7

Challenges of FLASH dosimetry: 3 critical parameters

- Temporal resolution: very fast time resolution (at least bunch-train level) and readout is needed
- Spatial resolution: imaging of dose distribution is needed (at least mm resolution)
- Dose rate linearity: dose rate linearity for very high dose rates is needed for PITZ

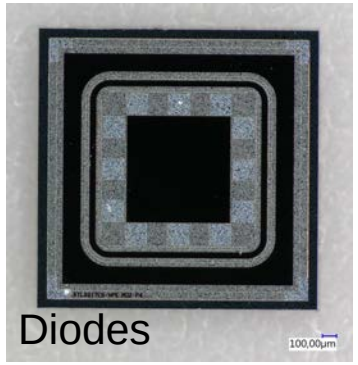


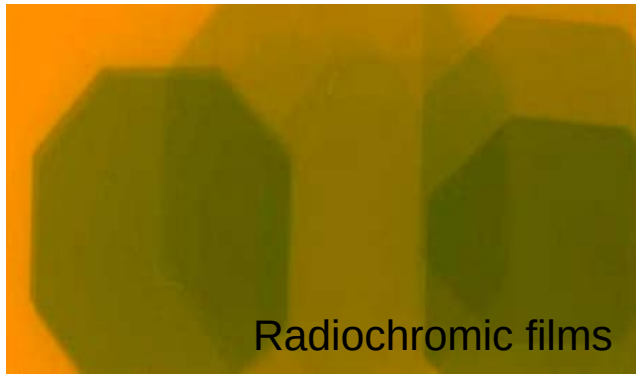
There is no perfect dosimeter for FLASH available now.

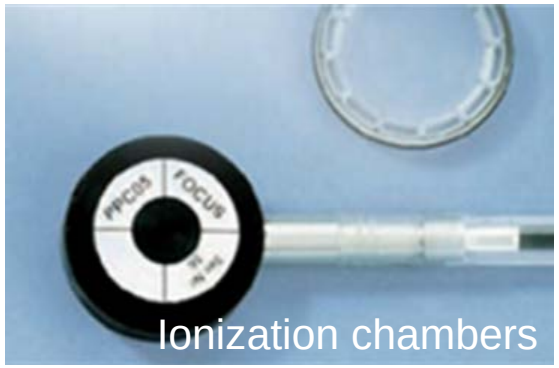
[arXiv:2006.03755 *Dosimetry for FLASH Radiotherapy]*

Dosimeter overview (some examples)

- **Ionization chambers:** limited by ion recombination rate, work up to 300 Gy/s
- **Radiochromic films:** passive measurement to high dose rates of 10^9 Gy/s (6 MeV) and easy readout
- **TLDs and OSLDs:** passive measurement up to 10^9 Gy/s, but readout complicated (external company)
- **Alanine:** often used as reference in current FLASH experiments, tested to very high dose rates of 10^9 Gy/s but readout is complicated (external company)
- **No dosimeter is optimal for FLASH dosimetry at PITZ**
- **To-Do**: Improve existing devices or find new technologies


Diodes

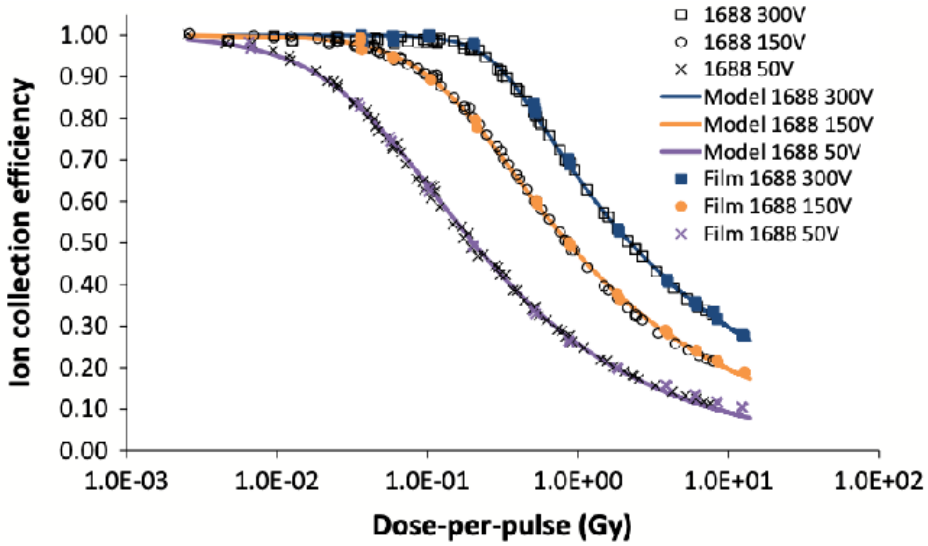

Radiochromic films


Ionization chambers


TLDs

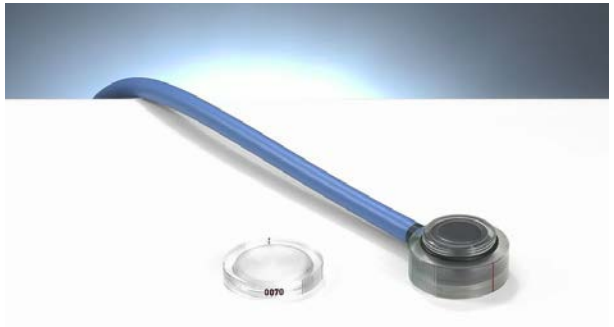
Ionization chambers

- Currently standard device for clinical dosimetry, but show their limits at FLASH dosimetry
- Commercially available and tested
- Problem: Ion recombination rate is dose depended at high dose rates (> 300 Gy/s)
- Some attempts for correction factors were made

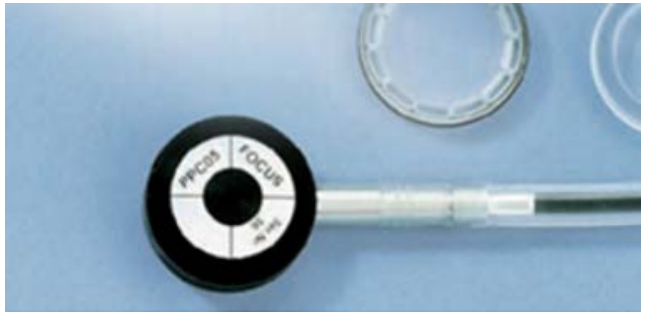


Plans for PITZ:

- Buy two different chambers
- Use them as reference at low dose rates, calibration of other devices
- Possible project:
  Build our own very thin ionization chamber



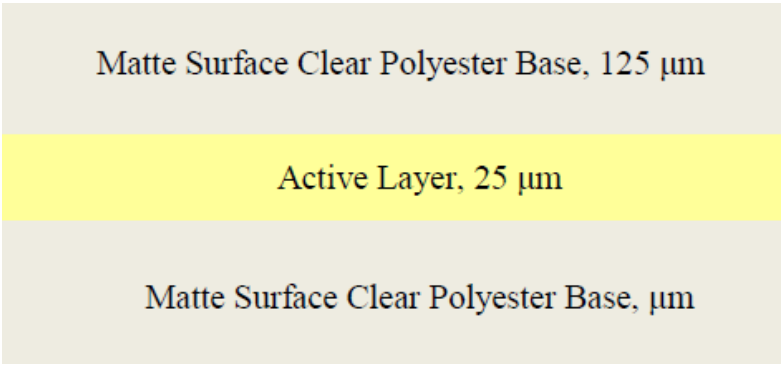
Advanced Markus Chamber (PTW)



PPC05
(IBA Dosimetry)

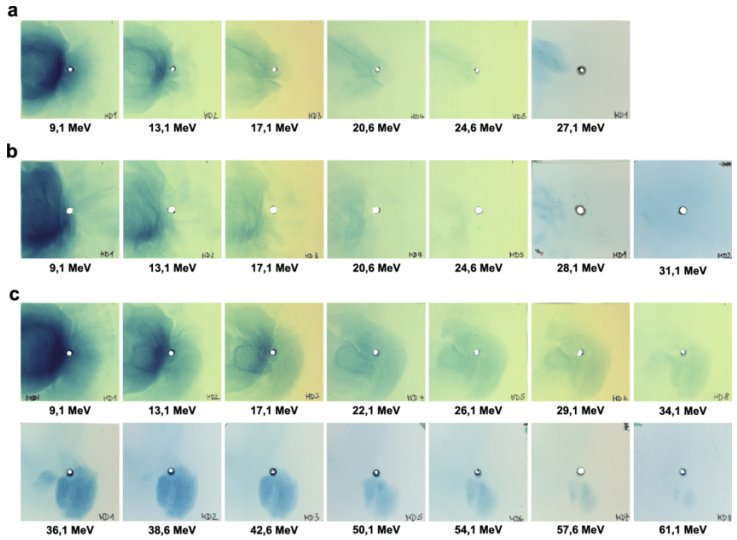
Radiochromic films

- Standard passive dosimeter
- Sandwich layers: Active chemical layer between polyester
- Works comparable to an old camera film
- Readout only after 24h possible
- Limited lifetime (1,5 years)



Plans for PITZ:

- Buy some films and get familiar with the readout
- Can be combined with any other dosimeters (simply tape them on a surface)

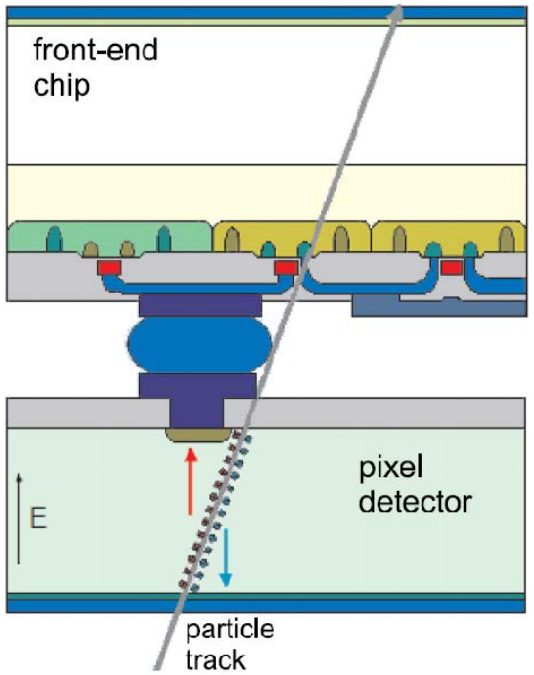


Silicon pixel sensors

Stolen from high energy physics experiments

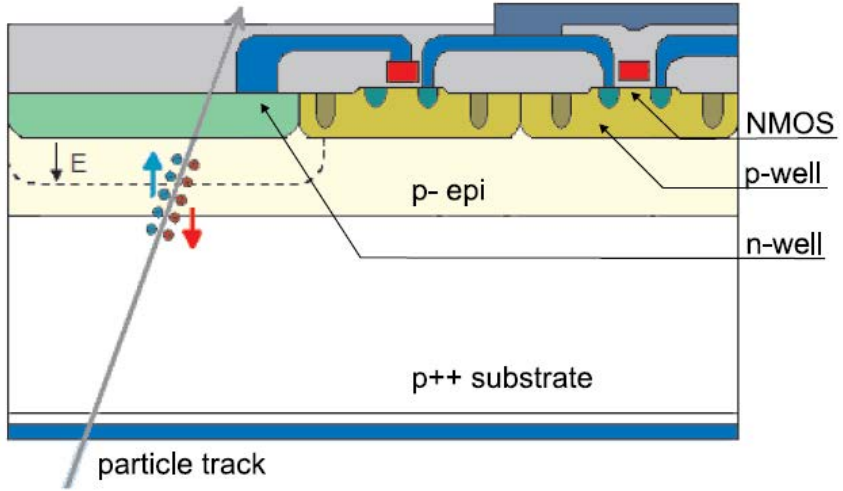
Hybrid Pixels

- Charge collected by drift
- Large signal, radiation hard and fast
- Standard technology for the field



Monolithic Active Pixels (MAPs)

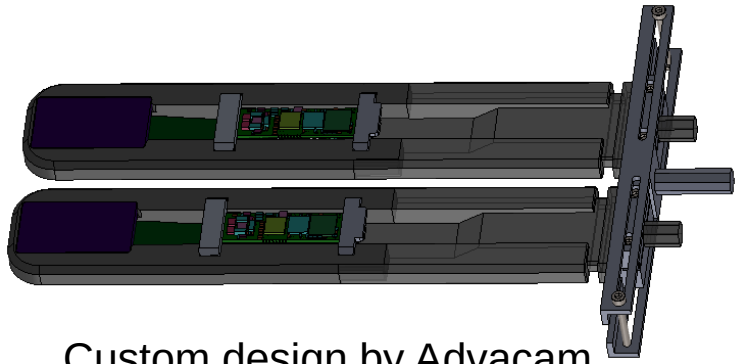
- Charge collection by diffusion
- Small signal, moderate radiation hard
- Slower than Hybrid Pixels
- New technology in the field



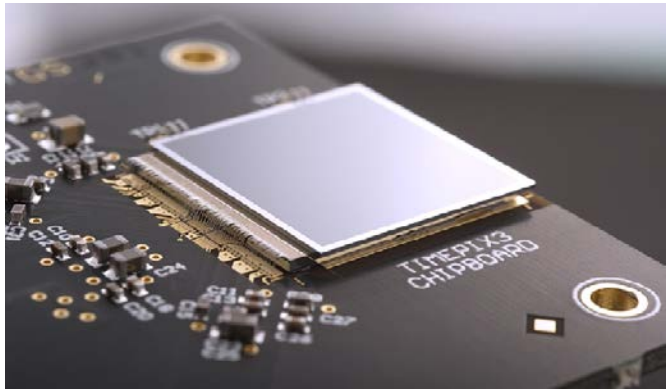
Hybrid sensor: Timepix 3 & 4

Timepix 3:

- Particle tracking/counting detector chip
- Company Advacam will visit us and do experiments with their custom designed Timepix 3



Custom design by Advacam



Timepix 3 (naked chip)

Timepix 4:

- There might be a chance to get one (DESY is an active collaborator of the Timepix 4 development)

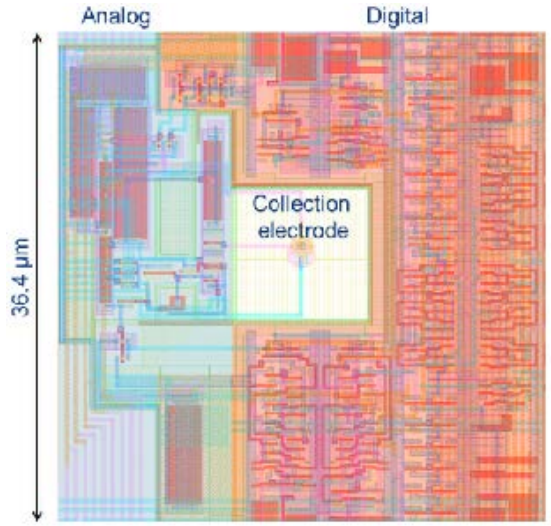
			Timepix3 (2013)	Timepix4 (2019/20)
Technology			IBM 130 nm – 8 metal	TSMC 65 nm – 10 metal
Pixel size			55 x 55 µm	55 x 55 µm
Pixel arrangement 3.5 x			3-side buttable 256 x 256	4-side buttable (TSV) 512 x 448
Sensitive area			1.98 cm^2	6.94 cm^2
Readout modes	Data driven (tracking)	Mode	ToT and TOA	
		Event packet	48-bit	64-bit
		Max rate 8 x	< 43 Mhits/cm^2/s	357.6 Mhits/cm^2/s
		Pix rate equiv.	1.3 kHz/pix average	10.8 kHz/pix average
	Frame Based (imaging)	Mode	Count: 10 bit + iToT	Count: 8 or 16 bit CRW
		Frame	Zero suppressed (with pix addr)	Full frame (no pix addr)
		Max count rate 10 x	82 Ghits/cm^2/s	~ 800 Ghits/cm^2/s
		Max frame rate	N/A (worst case: 0.8ms readout)	80 kHz CRW
TOT energy resolution 2 x			< 2 keV	< 1 keV
Time resolution 8 x			1.56 ns	~ 200 ps
Readout bandwidth 32 x			≤ 5.12 Gbps (8 x 640 Mbps)	≤163.8 Gbps (16 x 10.2 Gbps)
Target minimum threshold			< 500 e^-	< 500 e^-

Timepix 3 vs. Timepix 4

Silicon MAPs @DESY

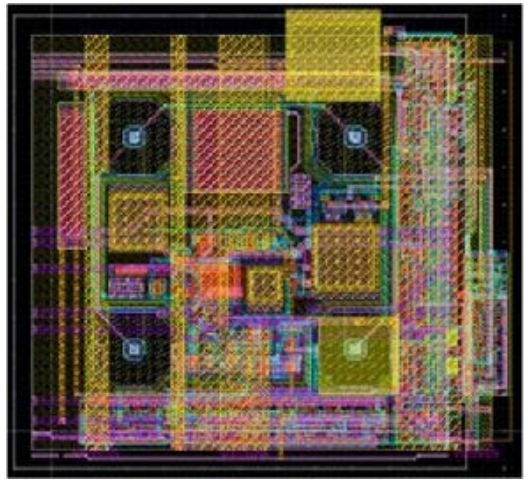
MALTA

- Pixel sensor for particle tracking
- Very radiation hard
- Adjustable thresholds
- Active development at DESY Zeuthen



DECAL

- Reconfigurable strip or pad
- Used for calorimetry
- Active development at HU Berlin



Thank you!