Solid-State Cameras for LHC instrumentation

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and thanks to G.Berger (LLN), R.Brun (PSI)

Different applications- different cameras

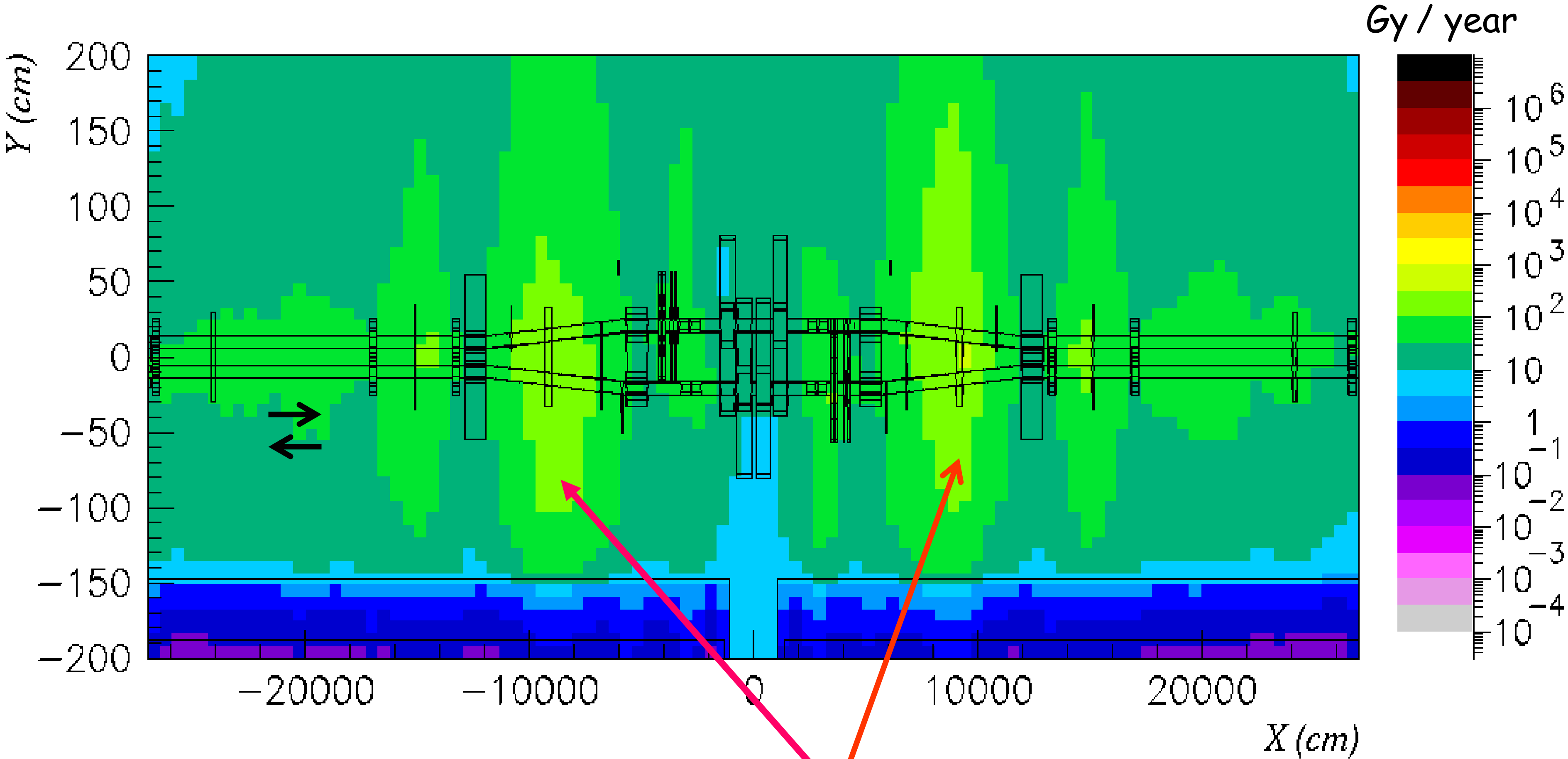
- Low light - intensified
- Fast framing (11kHz)
- High Radiation

  -but we want to use commercially available equipment wherever possible…

…and different environments

- LHC Beam dumps
- CNGS target
- Sensitive equipment in IP4- a “nice clean area”…but it isn’t

IP4 Dose Estimation



Synchrotron light telescope positions: dose ~ 380 Gy/year

The telescopes are used to image synchrotron light from the beam to record transverse profiles

Each one will have

- **a video camera**
- **a fast framing camera (11kHz, for turn by turn profiles)**
- **a low light camera**

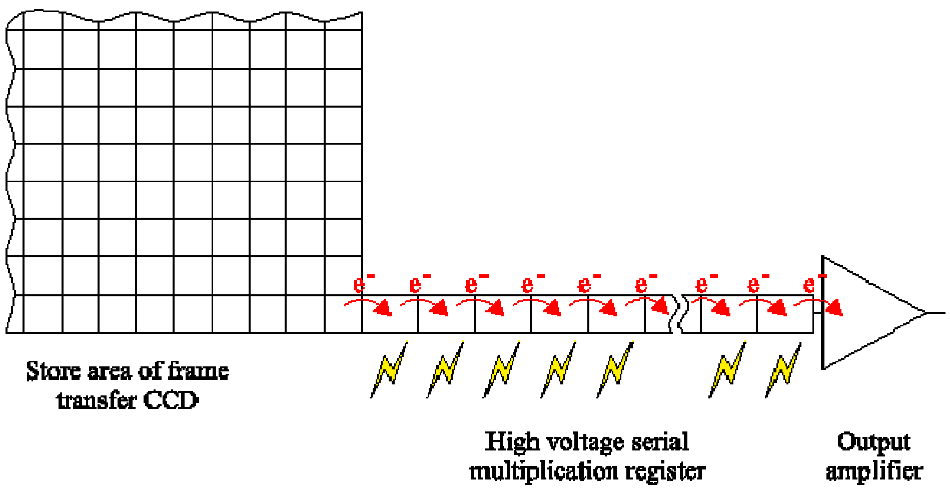
The cameras and some of the acquisition electronics must be in the tunnel

We must use commercially available equipment to control costs:
- these devices are not designed or tested for radiation resistance

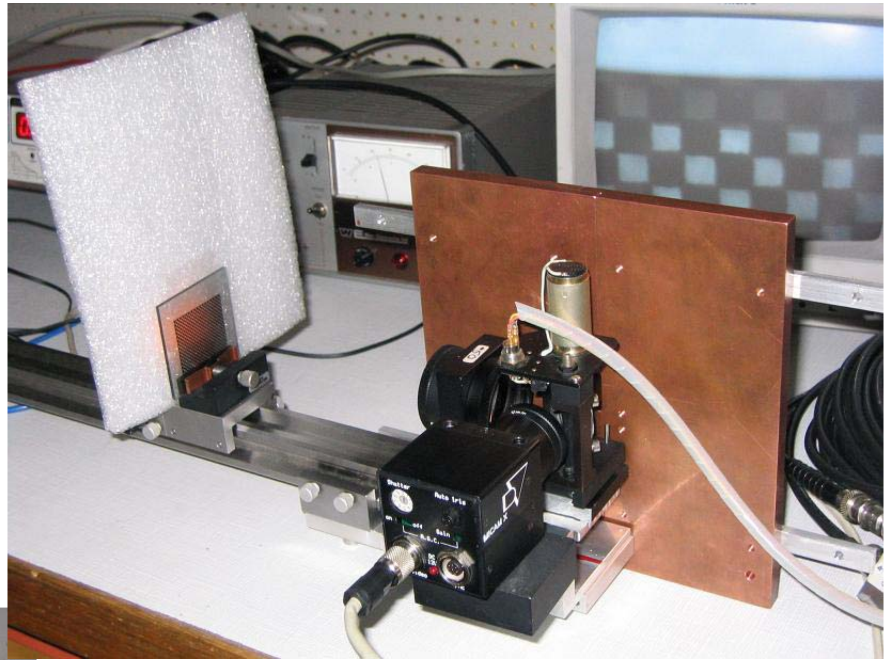
Our first test is to determine the lifetime of a commercial low light camera,
- we choose the E2V electron multiplying CCD and test at PSI

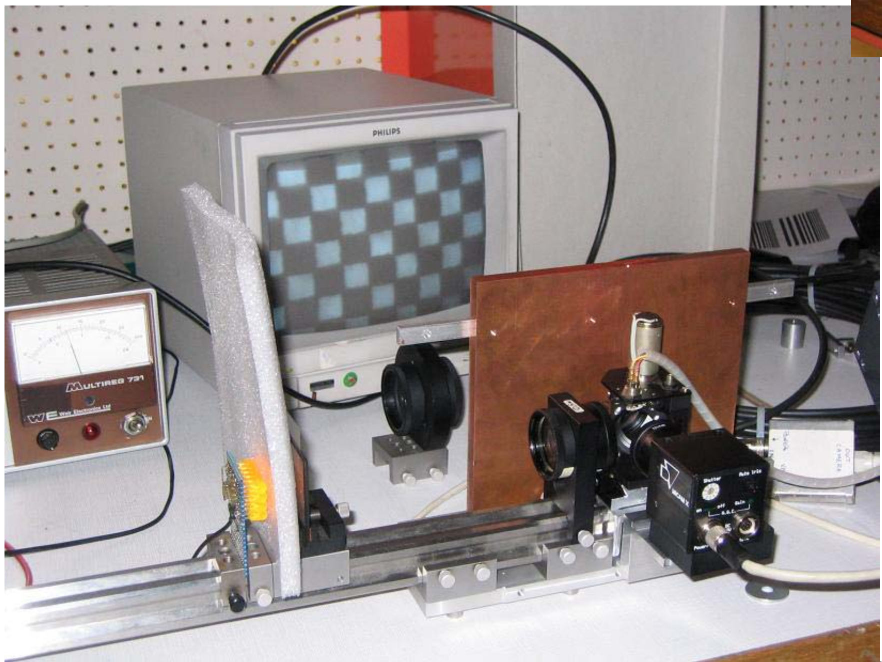
E2V em-CCD at PSI

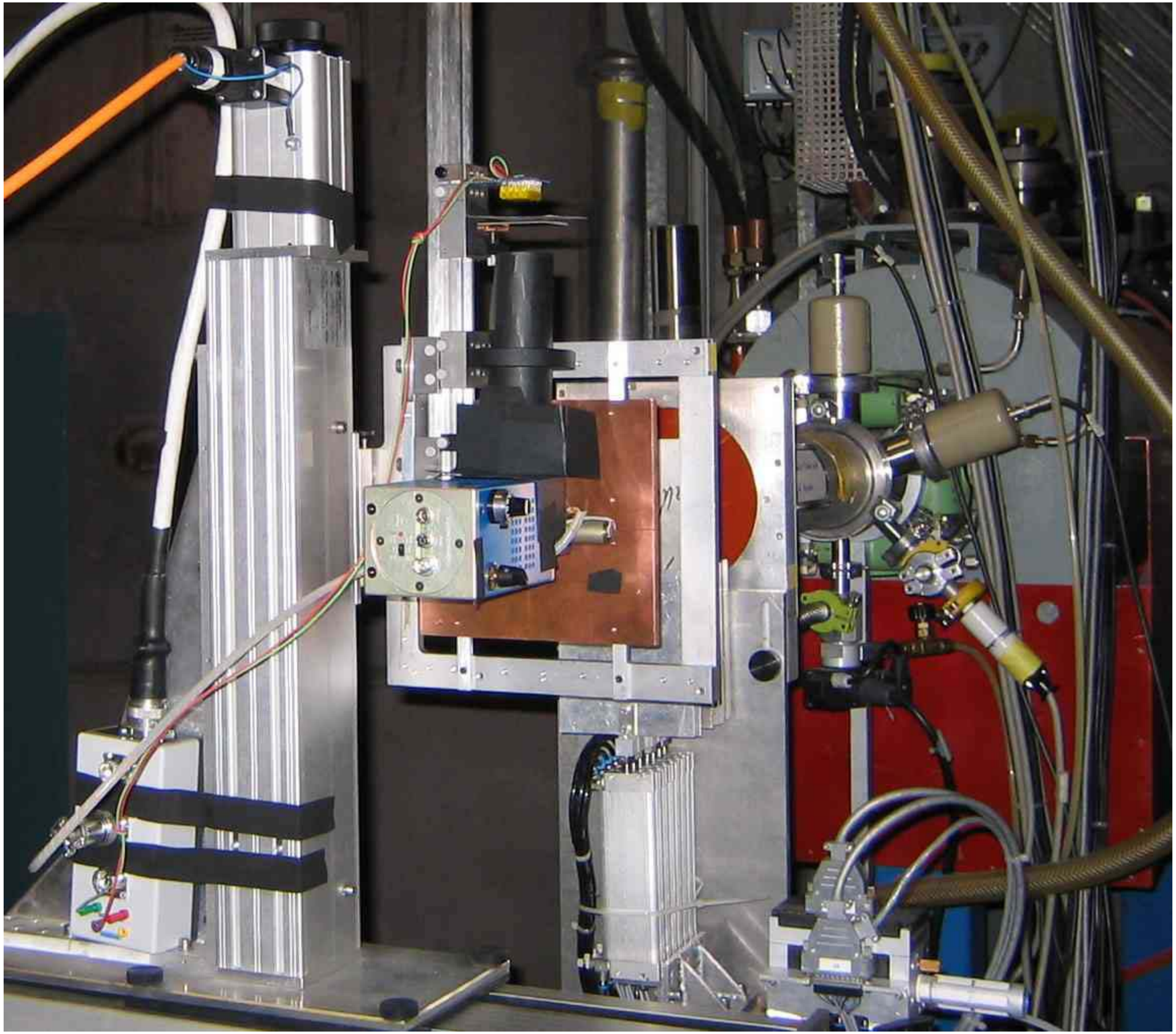
- The CCD chip has 3 areas: sensor, memory and amplifiers
- We irradiate the 3 areas separately
- The camera is powered up during the whole test
- We measure the loss of contrast to determine useful lifetime

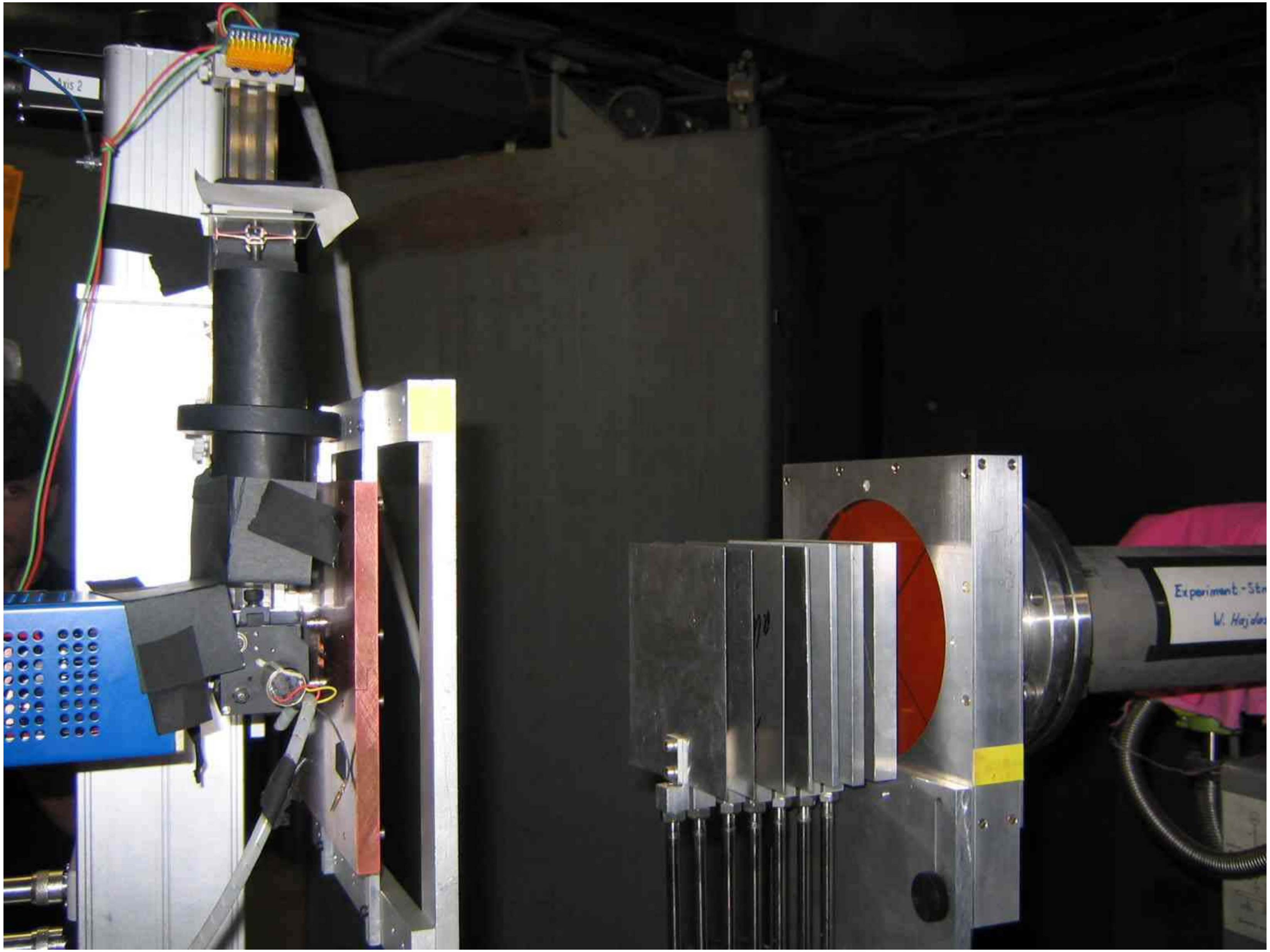


Radiation test E2V camera



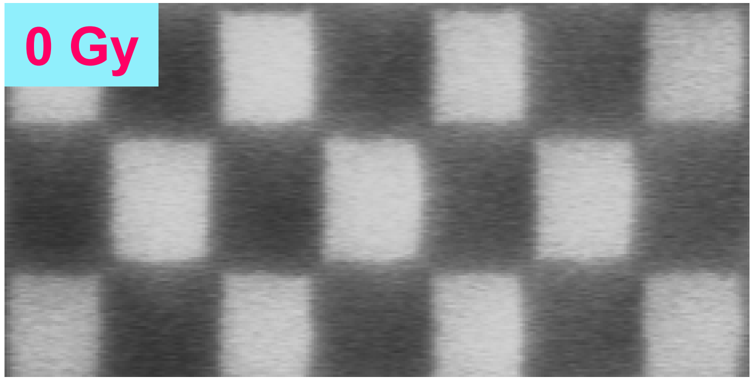


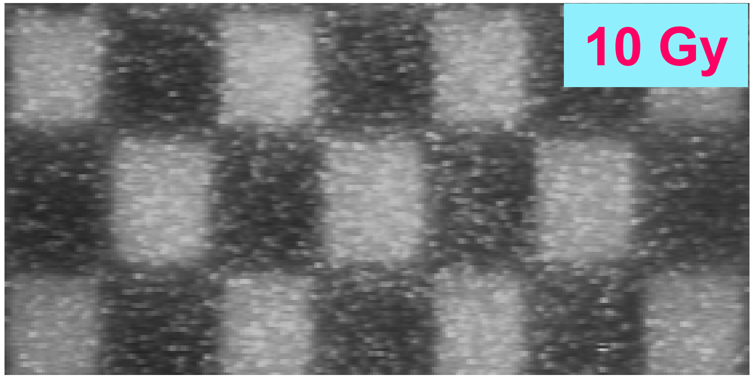


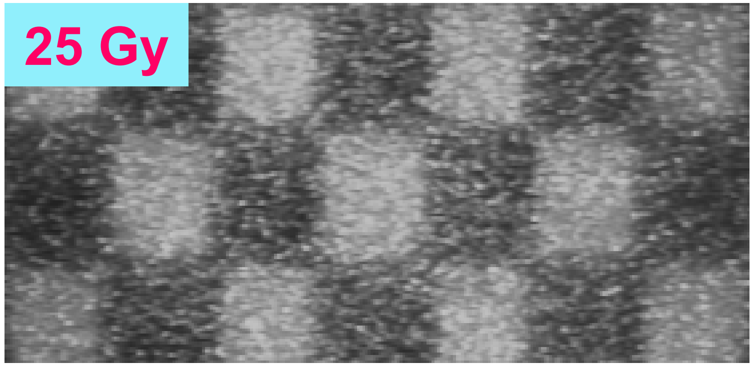


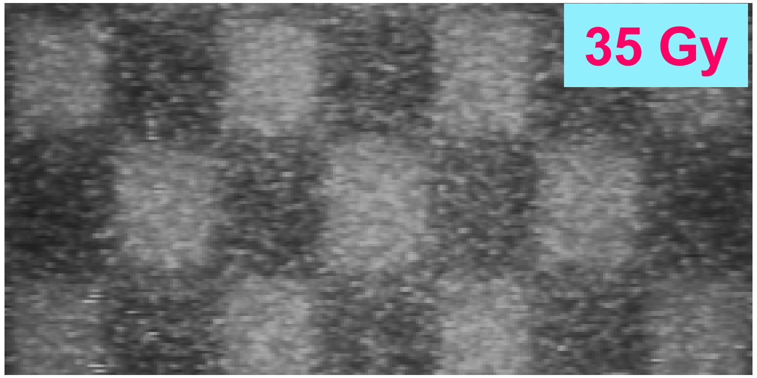
- The irradiation was intended to be in 3 parts: first exposure of the CCD image area, then the image area and the memory section, finally the image, memory and amplifier sections.
- The 1 cm copper shielding could not stop secondary neutrons that were in the beam, so all sections were exposed to some radiation all the time, including the amplifiers.
- The radiation level in the LHC is about 100Gy/year
- These pictures have been converted to JPG format with a loss of resolution, the analysis will be done on the original BMP files

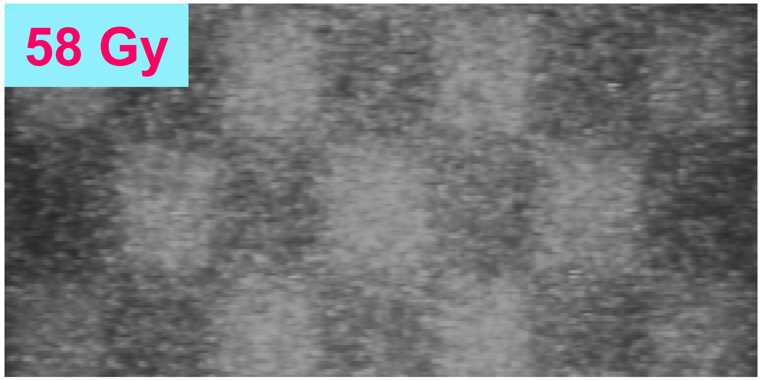
E2V emccd

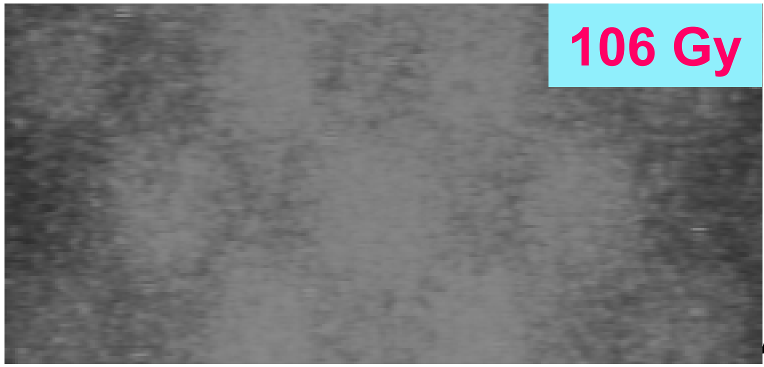


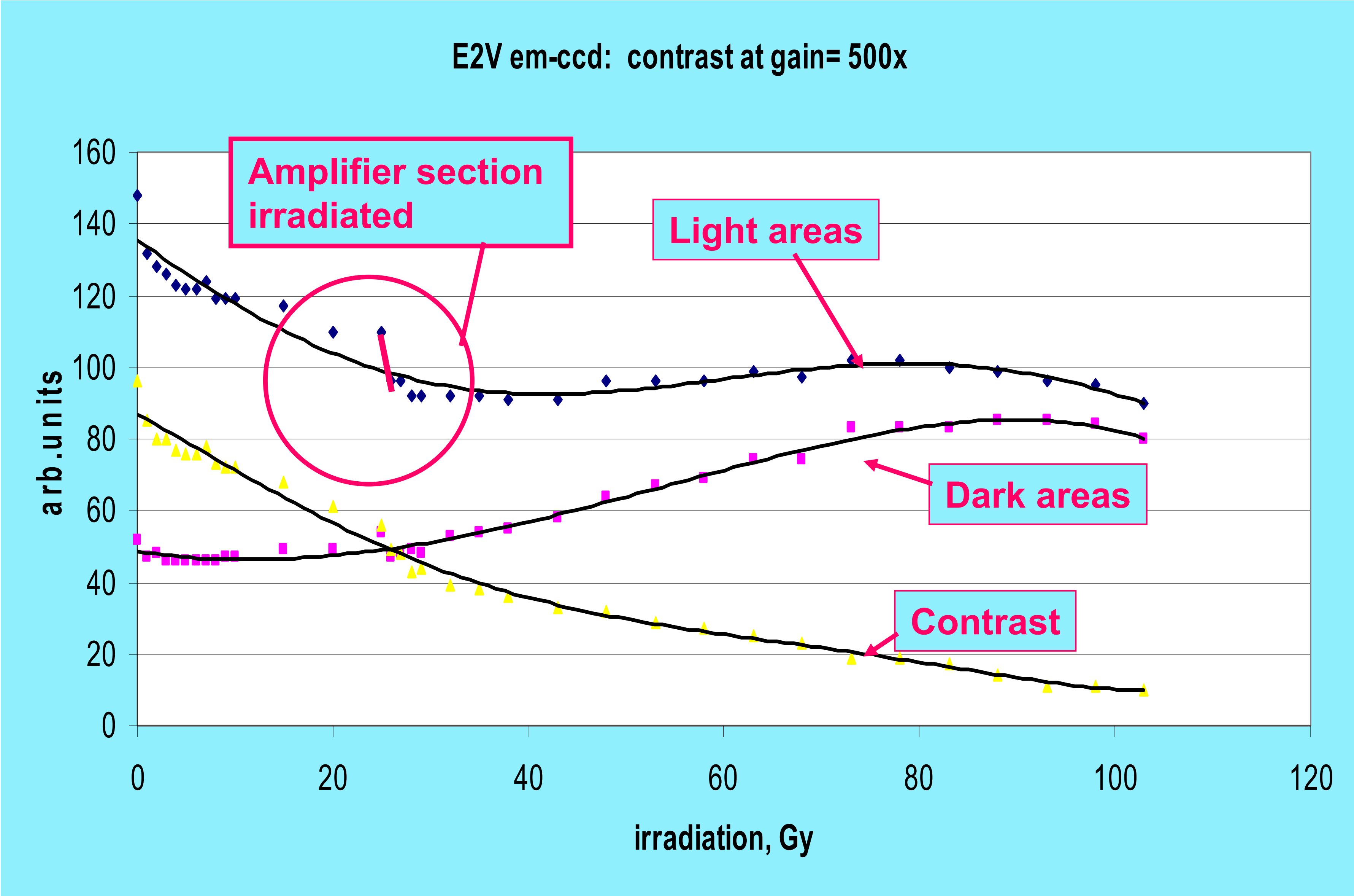











E2V em-ccd: contrast at gain= 500x
Amplifier section irradiated
Light areas
Dark areas
Contrast
arb.units
irradiation, Gy
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120

E2V camera, after irradiation test, gain= 1x

Conclusion e2v l3vision:

- The camera is equipped with internal amplifiers (em-ccd) to give a gain of up to 1000, this has made the unit more sensitive to radiation damage.

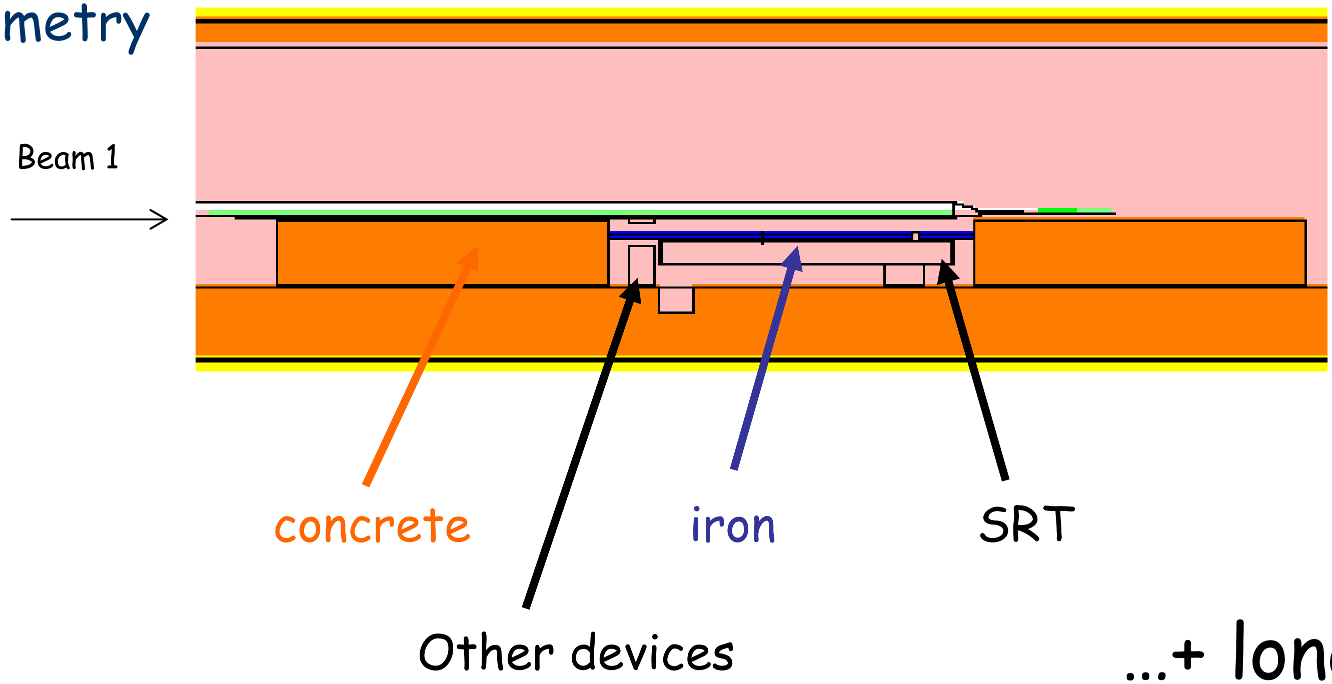
- Even after only 10-20 Gy the level of damaged pixels and the loss of gain made the camera unsuitable for use in the LHC as a measuring instrument (loss of resolution and contrast)

2nd approach: change the environment

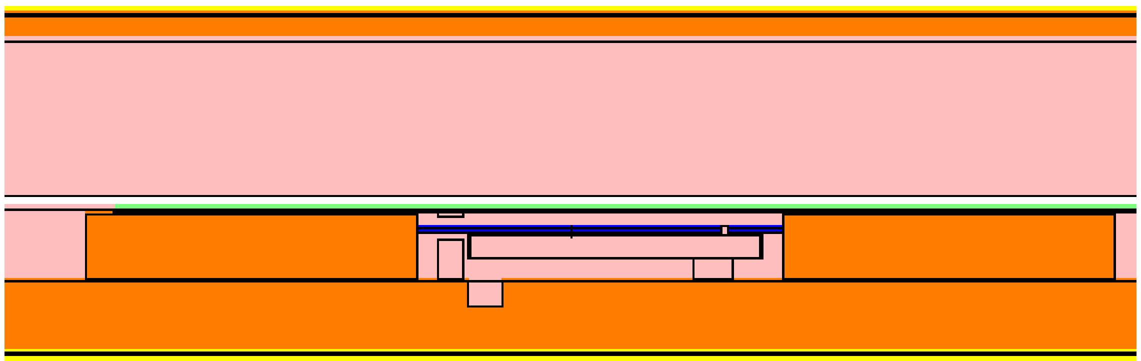
- The equipment is delicate: is it possible to create a safe area in the tunnel?
- Katerina Tsoulou has simulated radiation shielding in the tunnel to achieve an equipment lifetime of a few years

Iron slab 10cm + Two concrete blocks (5m)

Geometry

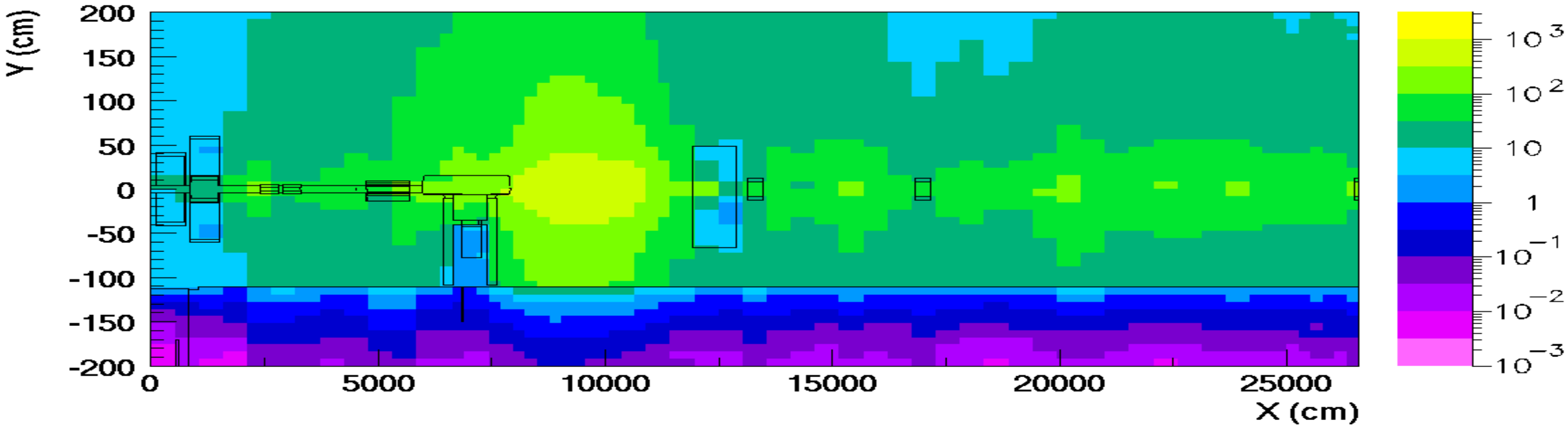


...+ longpipe



Iron blocks (2m) – iron slab (5cm) – 6m longer enlarged pipe

Horizontal cut ±0.25 m from the telescope



SRT fluxes:

1MeVeq(>1MeV) : 1.6×10^{10}

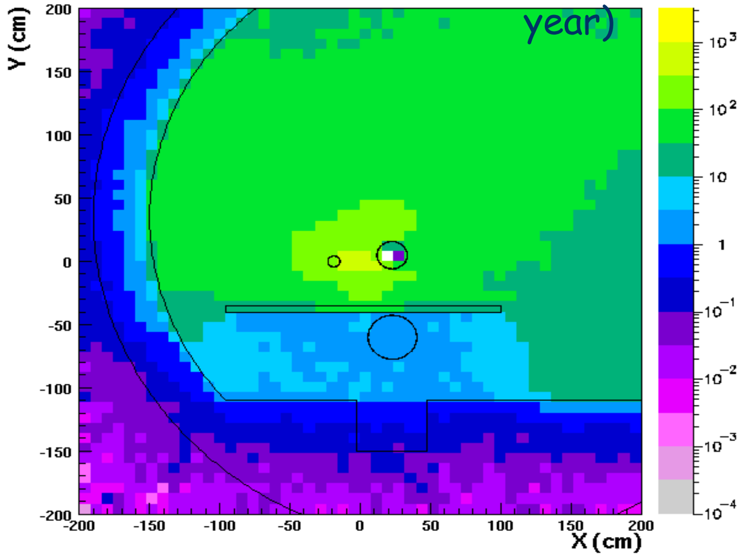
Hadrons>20MeV: 5.0×10^{9}

In the hole:

1MeVeq(>1MeV) : 9.1×10^{9}

Hadrons>20MeV: 2.2×10^{9}

Dose (Gy / year)



SR Telescope - Vcut at 68.5 (±1.5) m

Part 2: cameras for nasty places

- We have a few really horrible applications: LHC beam dumps, CNGS target,….
- The performance requests are higher than in the past: permanent availability, better resolution, reliability, etc.
- The old solutions will not work here: a CCD camera + lead shielding will still have a very short lifetime (poor reliability), and rad-hard vidicons have limited lifetime and resolution.

- Recently, CID and Active Pixel Detector (APD) sensors have been developed for space applications, where they must survive cosmic radiation…

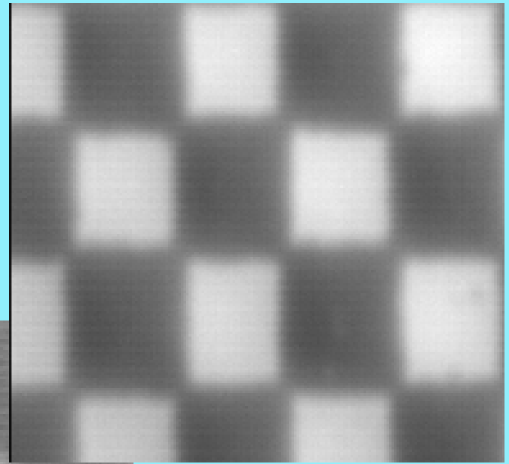
- “Rad” cameras have been tested before, but using easier conditions: gamma radiation, low dose rates, all electrical connections tied to ground…..
- LHC simulation uses 60MeV protons, high flux rate: $7.7\ 10^{8}$ p/ cm^{2} / s

  (new Louvain record = 850mA beam)
- Devices powered up and working during test: found image quality with and without beam to be nearly the same.
- CID process eliminates “blooming” on image: good for local bright areas on dark background

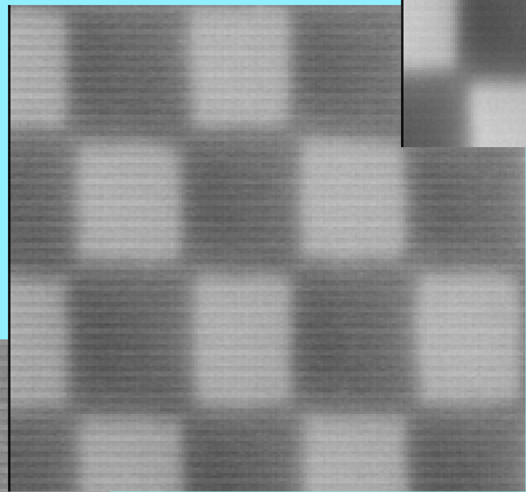
CIDTEC MegaRad camera

CID technology

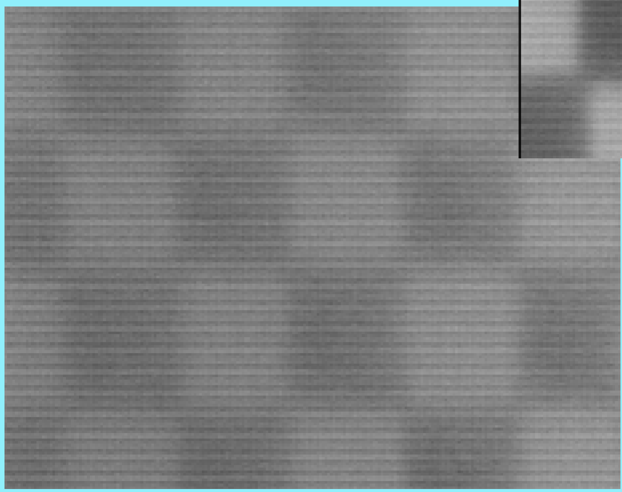
Start: 0 Gy



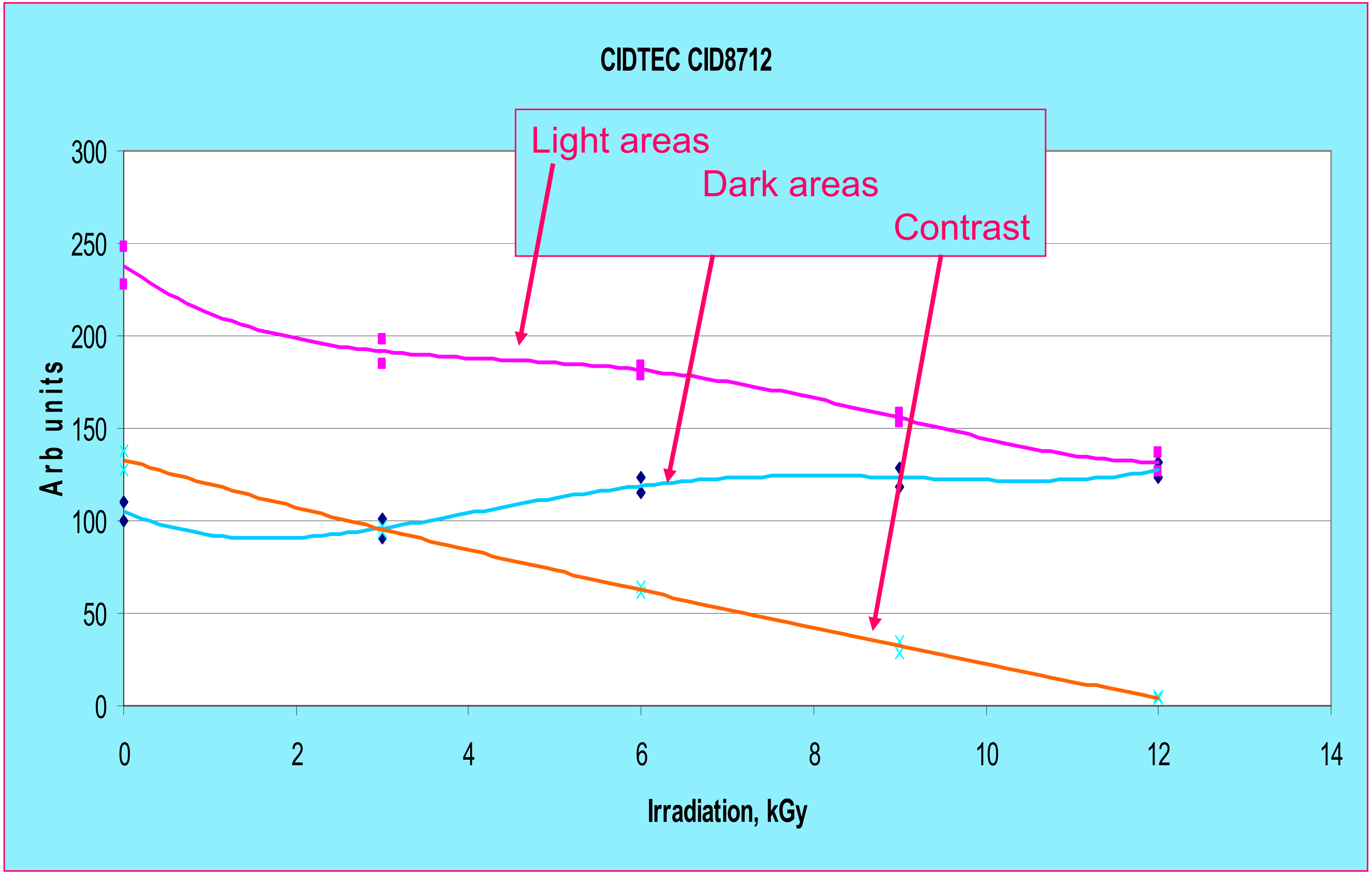
6kGy



12kGy



Variable gain not used in test

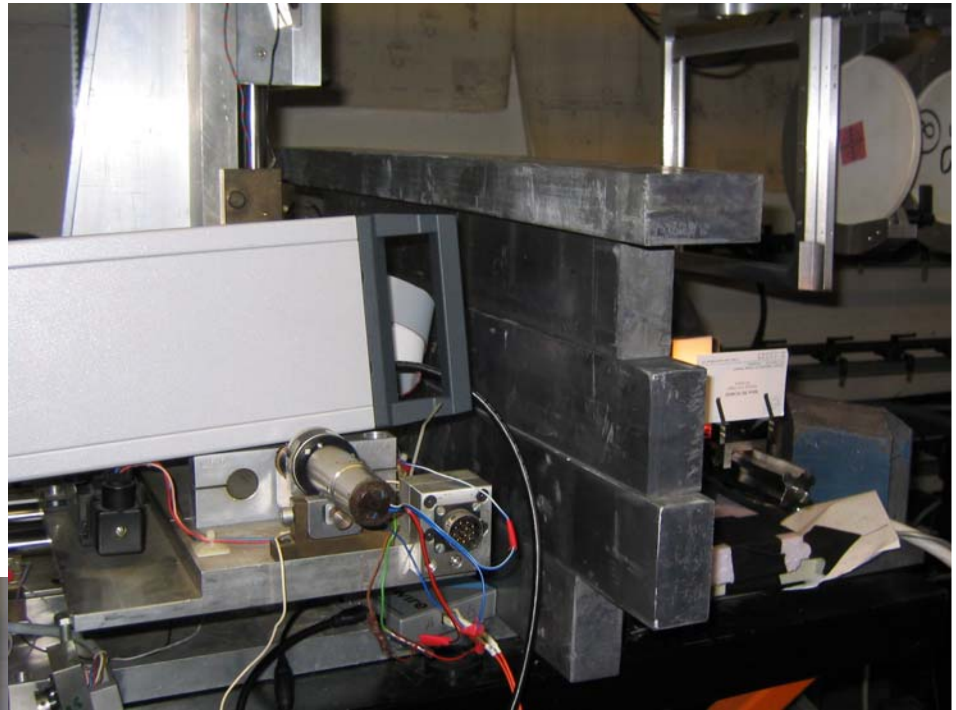

CIDTEC CID8712
Light areas
Dark areas
Contrast
300
250
200
150
100
50
0
Arb units
0
2
4
6
8
10
12
14
Irradiation, kGy

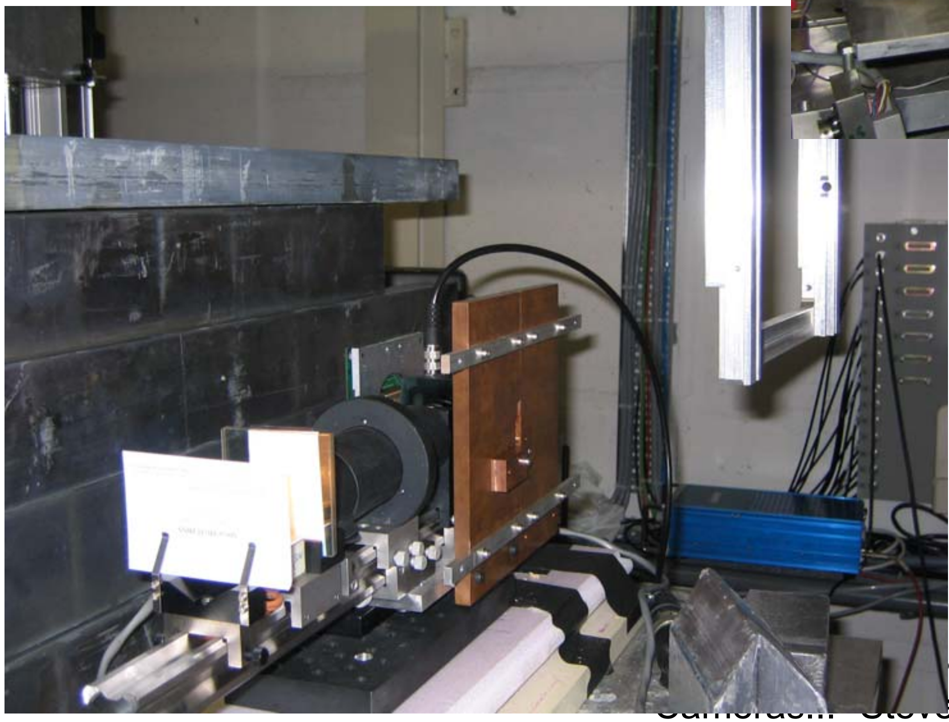
Fill Factory

Star 250

Test setup

APD technology





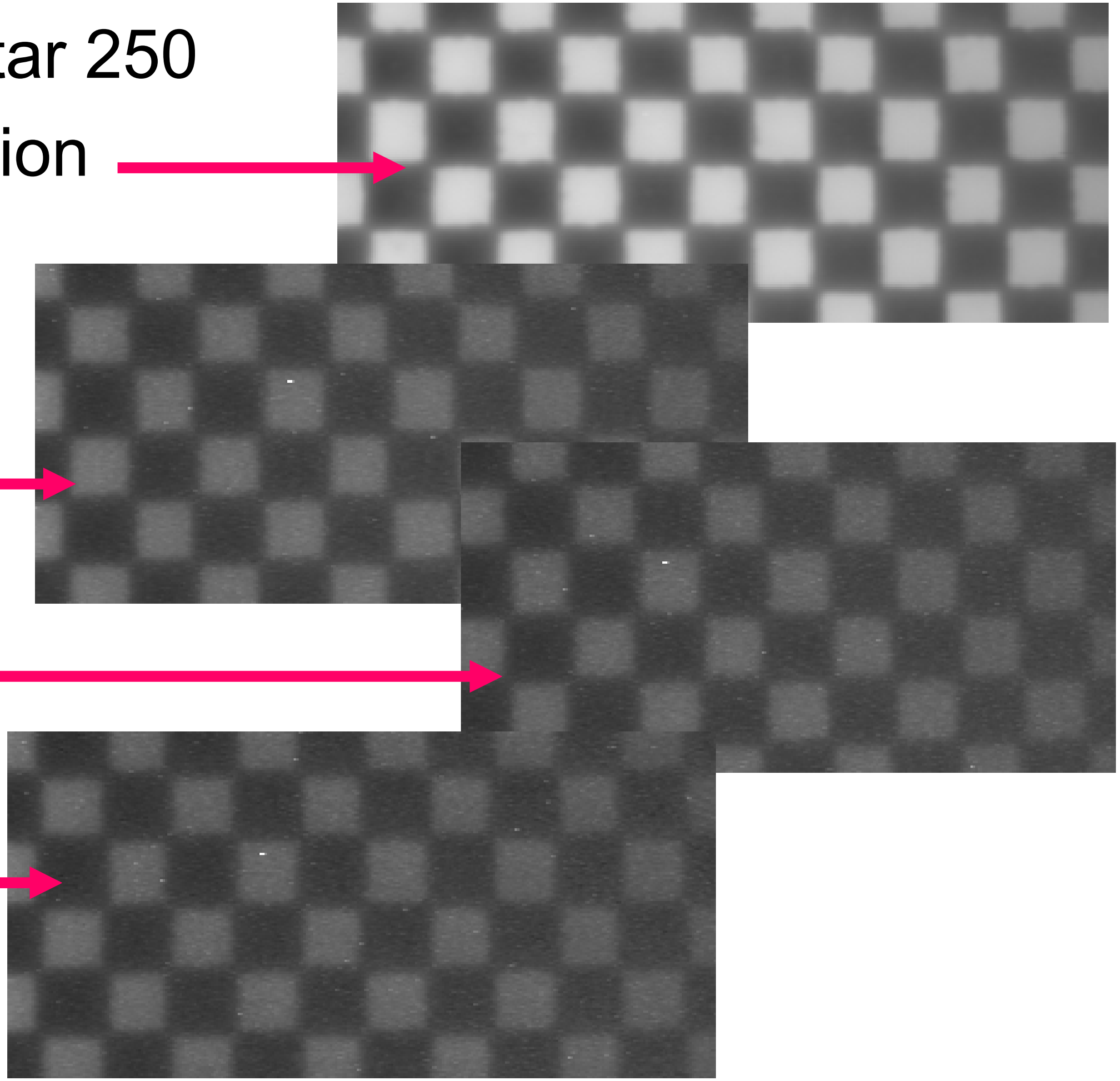
Fill Factory Star 250

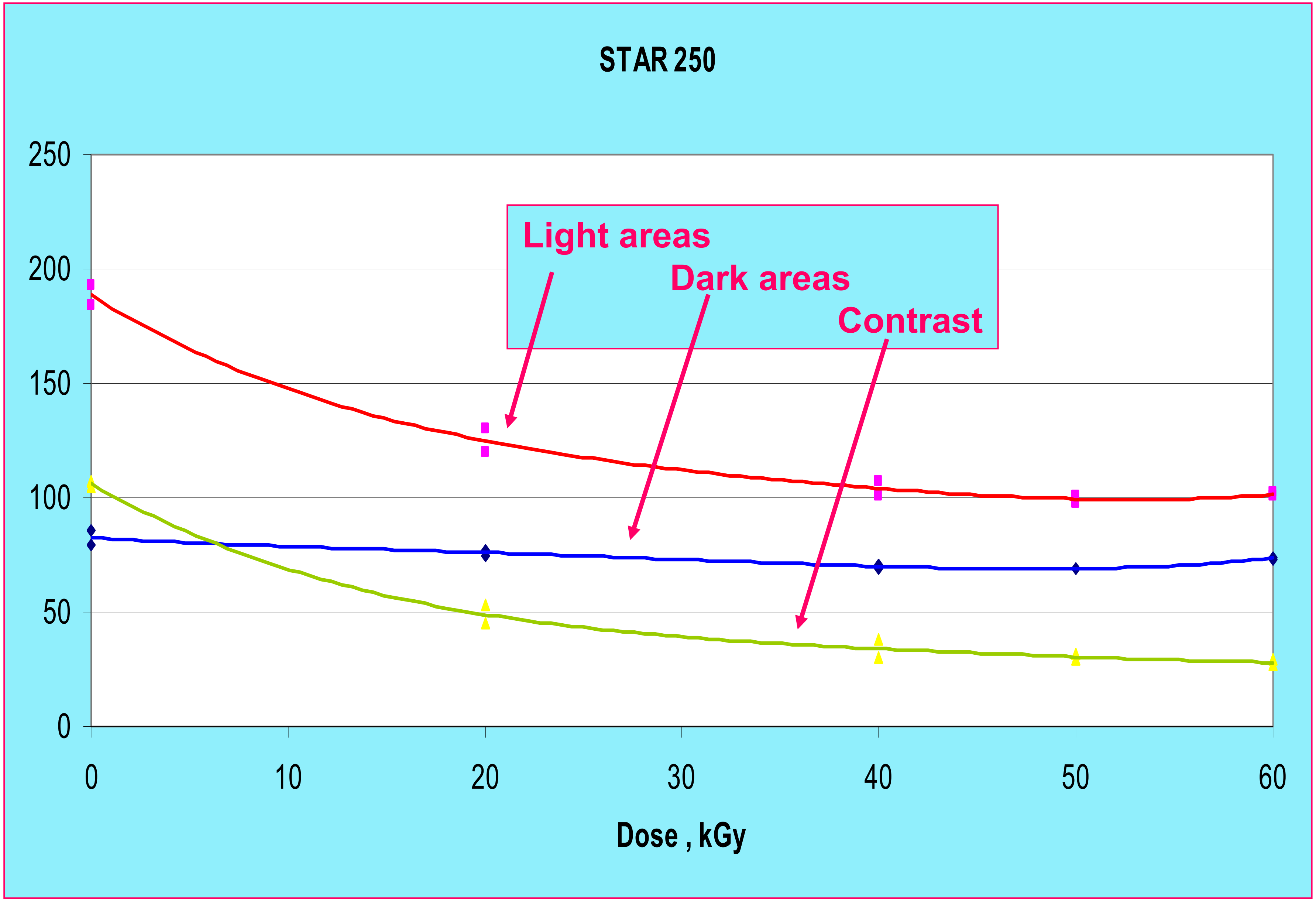
Before irradiation

4MRad

5MRad

6MRad




STAR 250
250
200
150
100
50
0
0
10
20
30
40
50
60
Dose , kGy
Light areas
Dark areas
Contrast

Fill Factory

Star 250

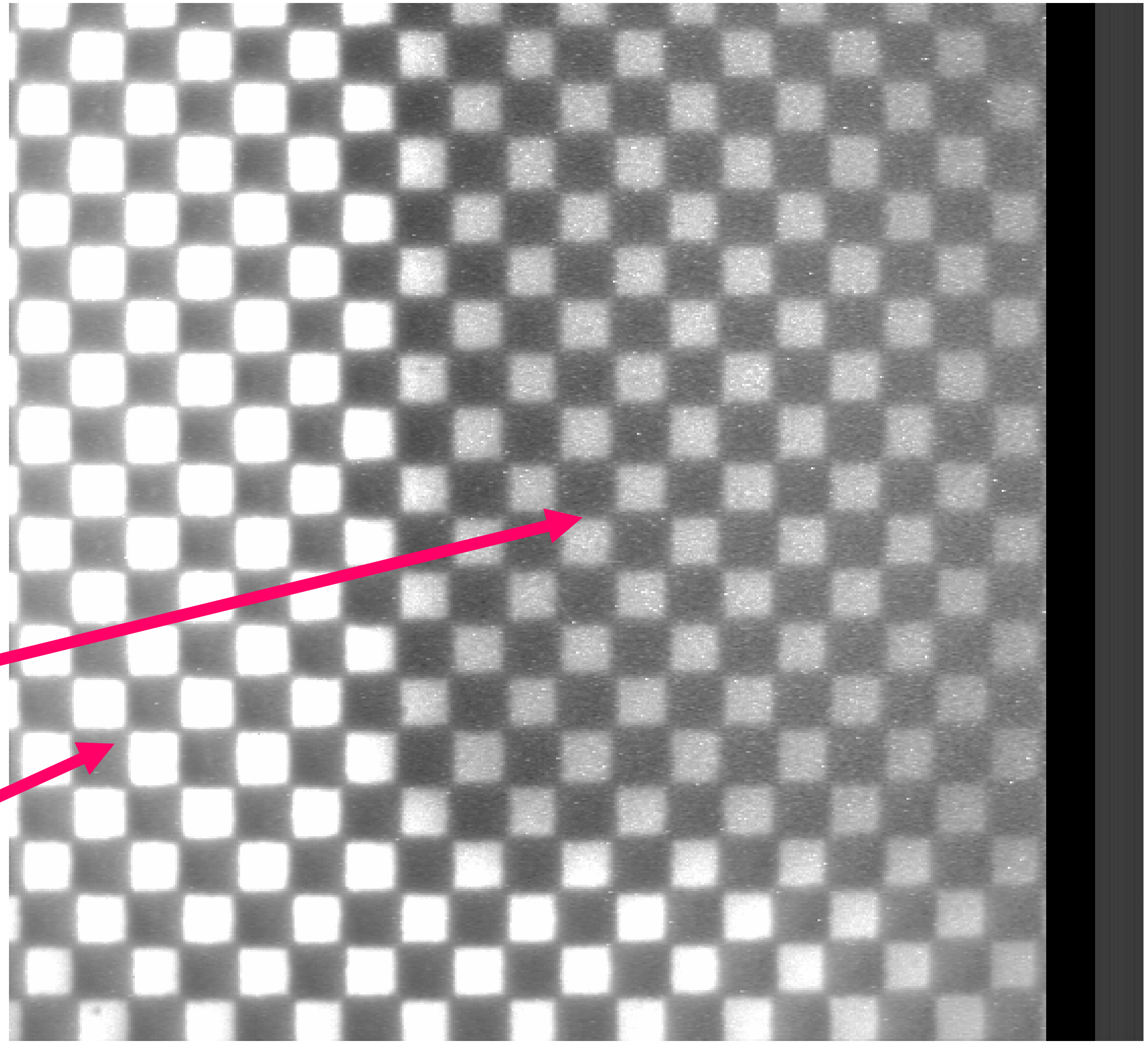
Test point 4

6 MRad

Gain and offset changed

Irradiated area

Screened area



Conclusion

- For sensitive equipment even 15Gy will affect performance
- It is possible to create shielded areas in IP4
- New radiation tolerant cameras are appearing in the marketplace
- In development now: lower noise, higher dynamic range devices in APD
- We now have choices of cameras/cost for different radiation areas
- Dump and Target areas can be better instrumented and operated with lower personnel doses than before