Radiation Levels in the CLIC Tunnel

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Overview

- Radiation and damage / detriment
- What levels are “safe” ?
- A Toy Model of CLIC
- Results
  - Absorbed dose to magnet coils
  - Hadron fluence
  - Dose equivalent rates in shutdown
- Conclusions and Outlook

Radiation damage and detriment

- Above certain limits, ionising radiation
  - damages materials,
  - leads to errors in semiconductor devices
  - can have long-term health effects on exposed humans.
- Which levels of exposure to ionising radiation can be considered safe ?

Material Damage

- Magnet coils:
  - epoxy becomes brittle
  - insulation may break down
- Critical quantity *absorbed Dose D* . SI-Unit: J/Kg, special name: Gray (Gy)
- From past experience, a dose of several MGy over the lifetime of a magnet is acceptable
- Guideline for CLIC:
  D < 1 MGy/ year

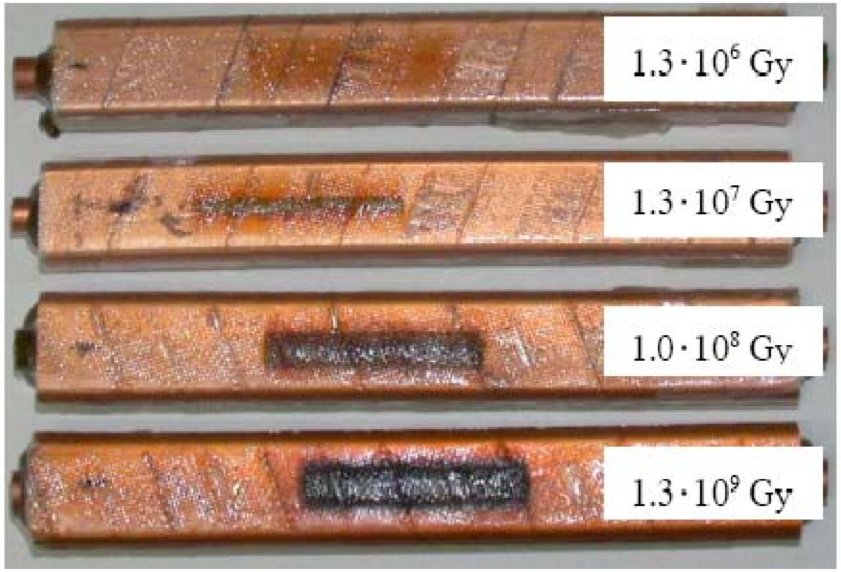
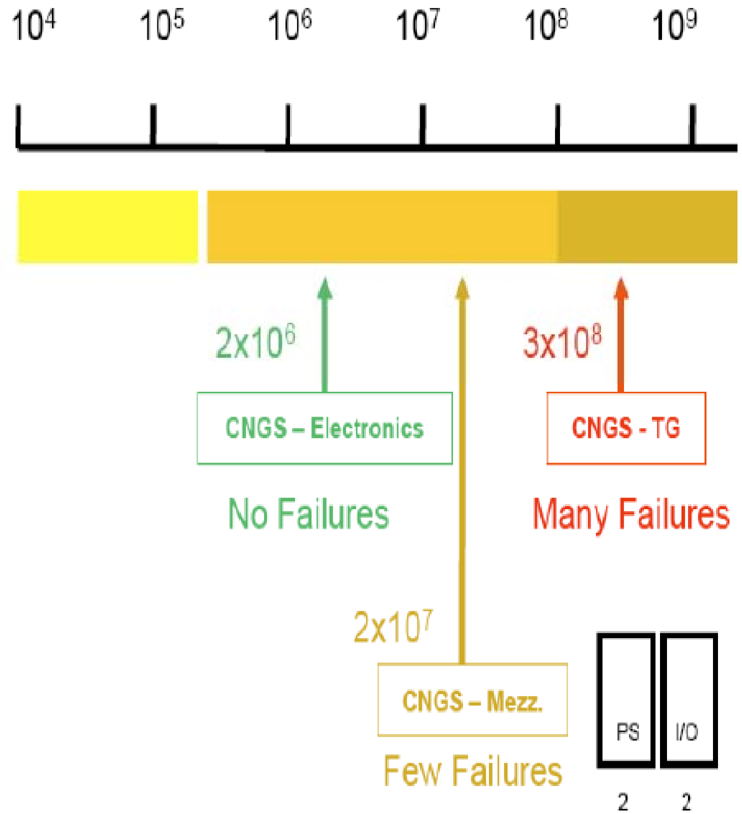


Figure 3: Test pieces after irradiation.

K. Tsumaki et al., EPAC 2004

“Single event error” SEE

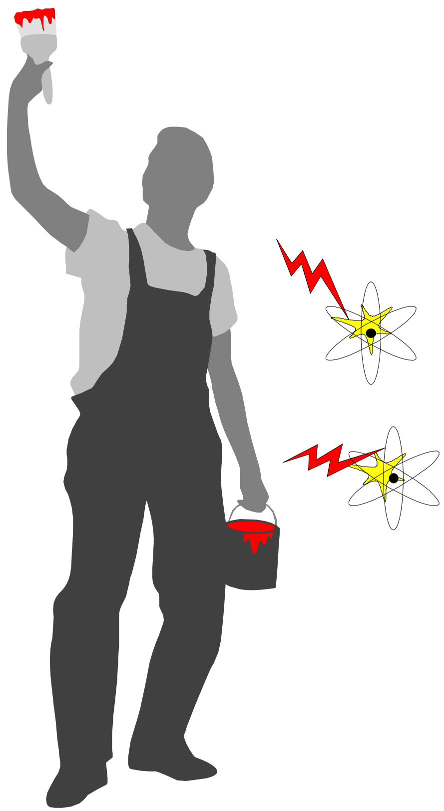
- SEU: ionising radiation changes the content of a elementary memory cell of a digital processor, spuriously or permanently.
- The critical quantity is fluence of hadrons with $E > 20$ MeV, Φ_{20} (cm^{-2})
- Experience from CNGS: at $\Phi_{20} = 2\ 10^7$ devices start to show errors
- Guideline for CLIC: $\Phi_{20} < 10^6 \ldots 10^7$/year



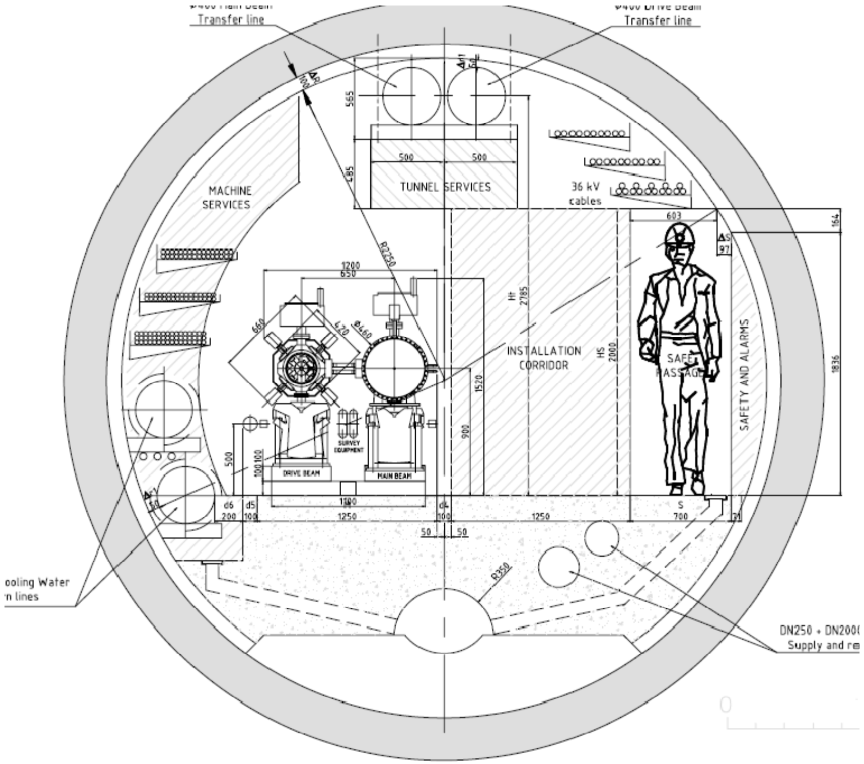
T. Wijnands, TS-LEA

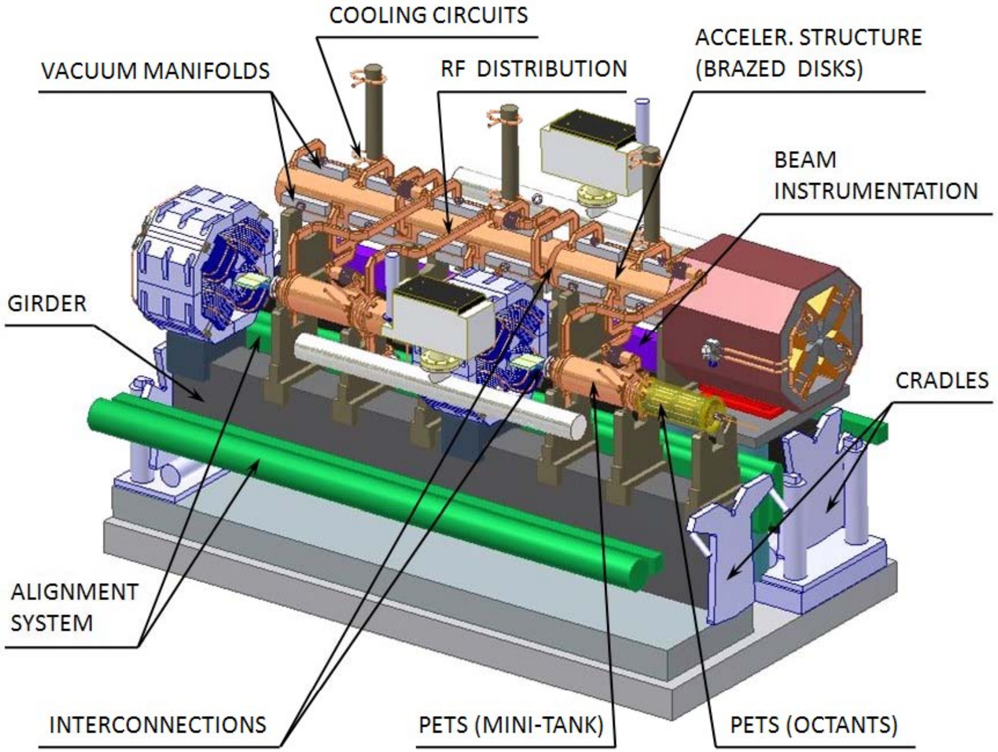
Personal dose

- Exposure to ionising radiation at low levels enhances the risk of contracting cancer.
- The critical quantity is effective dose *E* (Sv) with an annual limit of 20 mSv for radiation workers
- For monitoring purposes *ambient dose equivalent H** (10) is used, among others .
- $H^*(10) > 0.5\ \mu Sv\ h^{-1}$: radiation area
- $H^*(10) < 10\ \mu Sv\ h^{-1}$ allows “hands-on” interventions during intervention times measured in hours or days
- $H^*(10) > 100\ \mu Sv\ h^{-1}$ necessitates detailled optimisation of every intervention and strict control of times



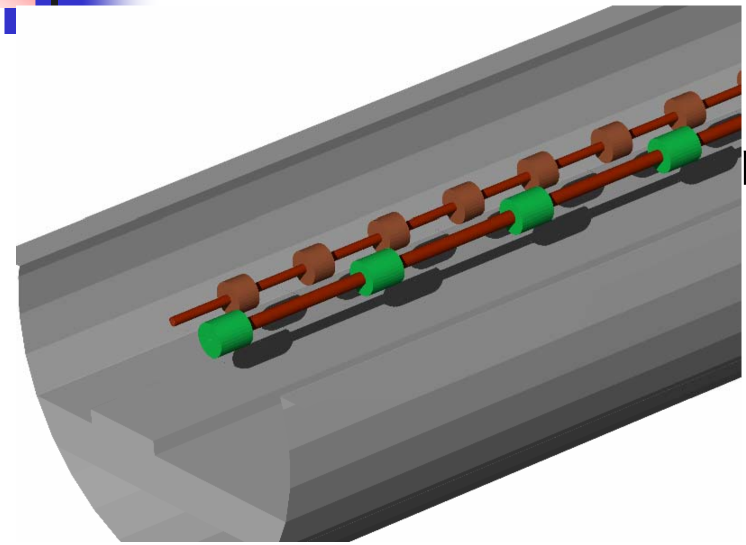
A Toy Model of CLIC





A. Samochkine, CLIC-project

A Toy model of CLIC



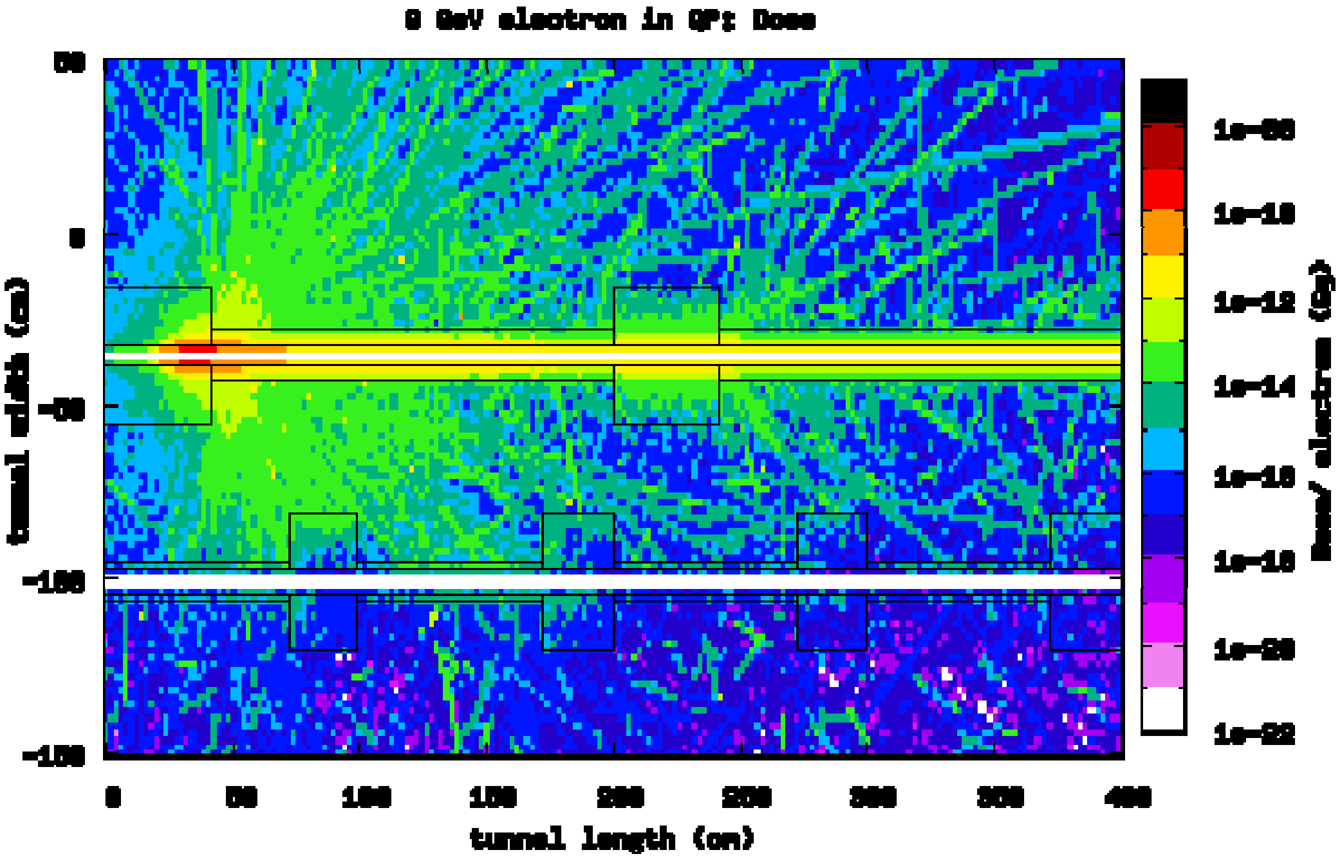
nly walls, floor, quadrupole magnets and PETS/ AS represented. QP-magnets: effective density

Simulation of particle and radiation transport with FLUKA2008

Scoring of absorbed dose and hadron fluence

Tracking of decay radiation from activation products, scoring of ambient dose equivalent for different times after beam-off

Dose to magnets

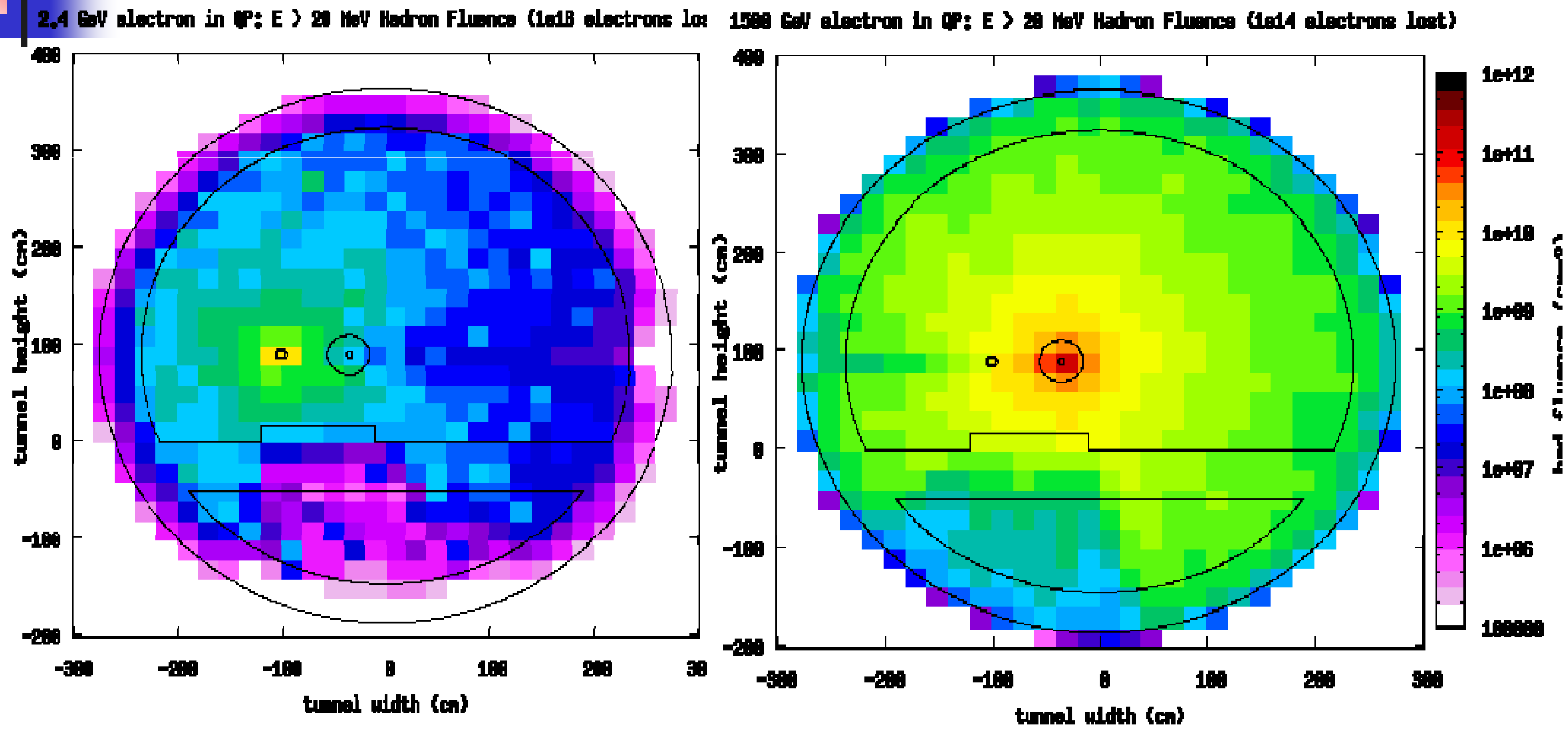


e.g., spatial distribution of *D* for beam loss in main beam QP

How many electrons per MGy ?

	E (GeV)	D_{max} / e^- (Gy)	e^- / MGy	Fraction of beam
Main Beam	1500	8.0 E-09	1.3 E14	1.5 E-07
Main Beam	9	1.2 E-10	8.1 E15	5.0 E-05
Drive Beam	2.4	4.0 E-11	2.5 E16	2.3 E-07
Drive Beam	0.24	7.1 E-12	1.4 E17	1.3 E-06

Hadron Fluence



drive beam, 2.4 GeV

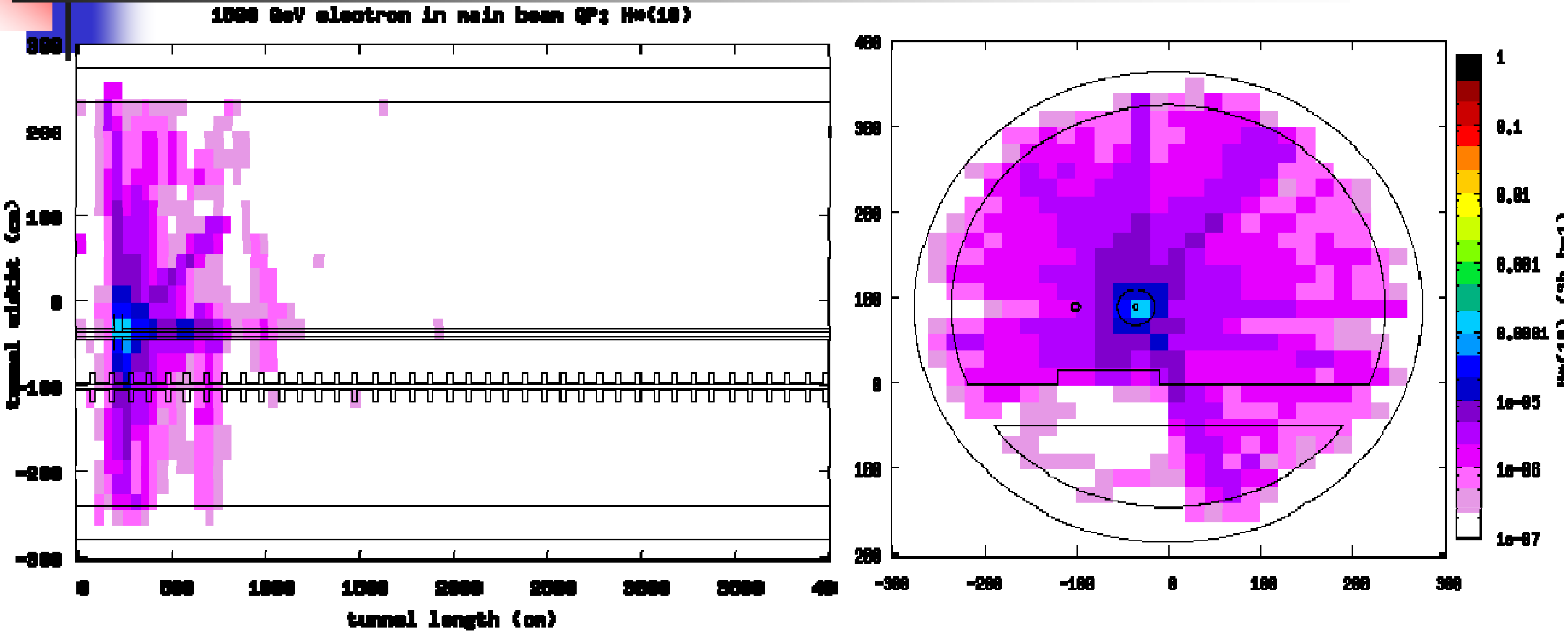
main beam, 1.5 TeV

annual fluence $\Phi_{20}(cm^{-2})$

Hadron fluence on tunnel wall

	E (GeV)	e^{-}_{loss}/ year	Φ_{20} ($cm^{-2}\ y^{-1}$)	Consequence for electronics
Main Beam	1500	1 E14	1 E09	Unacceptably high failure rate
Main Beam	9	1 E15	5 E07	More failures per year
Drive Beam	2.4	1 E16	1 E07	Few failures per year
Drive Beam	0.24	1 E17	5 E06	Few failures over lifetime

Ambient Dose equivalent rates



e.g. *H** (10) for beam loss in main beam quadrupole,
1 E14 electrons lost per year, 1 week into shutdown

Conclusions

- Ionising radiation levels must be controlled by control and reduction of beam loss
- Fractional beam loss levels for limiting dose to magnets to $D < 1$ MGy y^{-1} are challenging, but achievable.
- At these levels, standard electronics in the tunnel suffers high failure rate due to SEE
- First calculations indicate that at these levels, ambient dose rate during the shutdown require standard intervention practice, and little or no remote handling gear.

Outlook

- In the CLIC accelerator tunnel, additional estimations are required for:
  - Ambient dose equivalent rates
  - Drive beam dumps
- Other areas of interest:
  - Drive beam accelerator complex
  - Positron source
  - Final focussing, IP and post-IP beamlines
- All estimates can become more detailed in parallel with accelerator planning
- Must be updated upon design changes.