Radiation Hard Optical Fibres for LHC

» Project Status and Outlook «

Topics

- Foreword: Recapitulation of project definition / aim
- Estimations for first year
- Current project status
- Future possibilities

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Recap of project definition / aim

- Offer by INT, accepted by CERN:
  - *Aim of project:*

    doped Draka Fibre Technology G652.D fibres will be confirmed and extended to measurements under different conditions (see below). To identify the best possible alternative, a comparative study will be conducted with fibres of other manufacturers and newly developed fibres from Draka.

  - *Extension of phase 3:*

    On basis of the results for three different dose rates, it will be tried to develop a model that allows a realistic extrapolation of the results to other dose rates, with a special emphasis on lower dose rates, including annealing.

- Reorientation after meeting September 2005:

  1. Continuation of the tests but with a re-orientation.
  2. Emphasis on dose rate dependency and annealing respecting as much as possible the future LHC machine cycles (anneal 3 times).

  ← New experimental task

- No new need for direct modelling, but required input data!

Approach defined in the project

- Assumptions
  - *Best fibre in ^{60}Co also (one of the) best in mixed field*
  - *Dose rate dependence very important factor*
  - *Best fibre for mean dose rate also (one of the) best in application*
- "Model" presented by Fraunhofer INT
  - *Extrapolation to lower dose rates for comparing fibres*
  - *No predictive ambition*
- Origin of misunderstanding
  - *Fraunhofer INT showed dose and days in figures*
- Lesson learned during project
  - *Radiation environment very complex*

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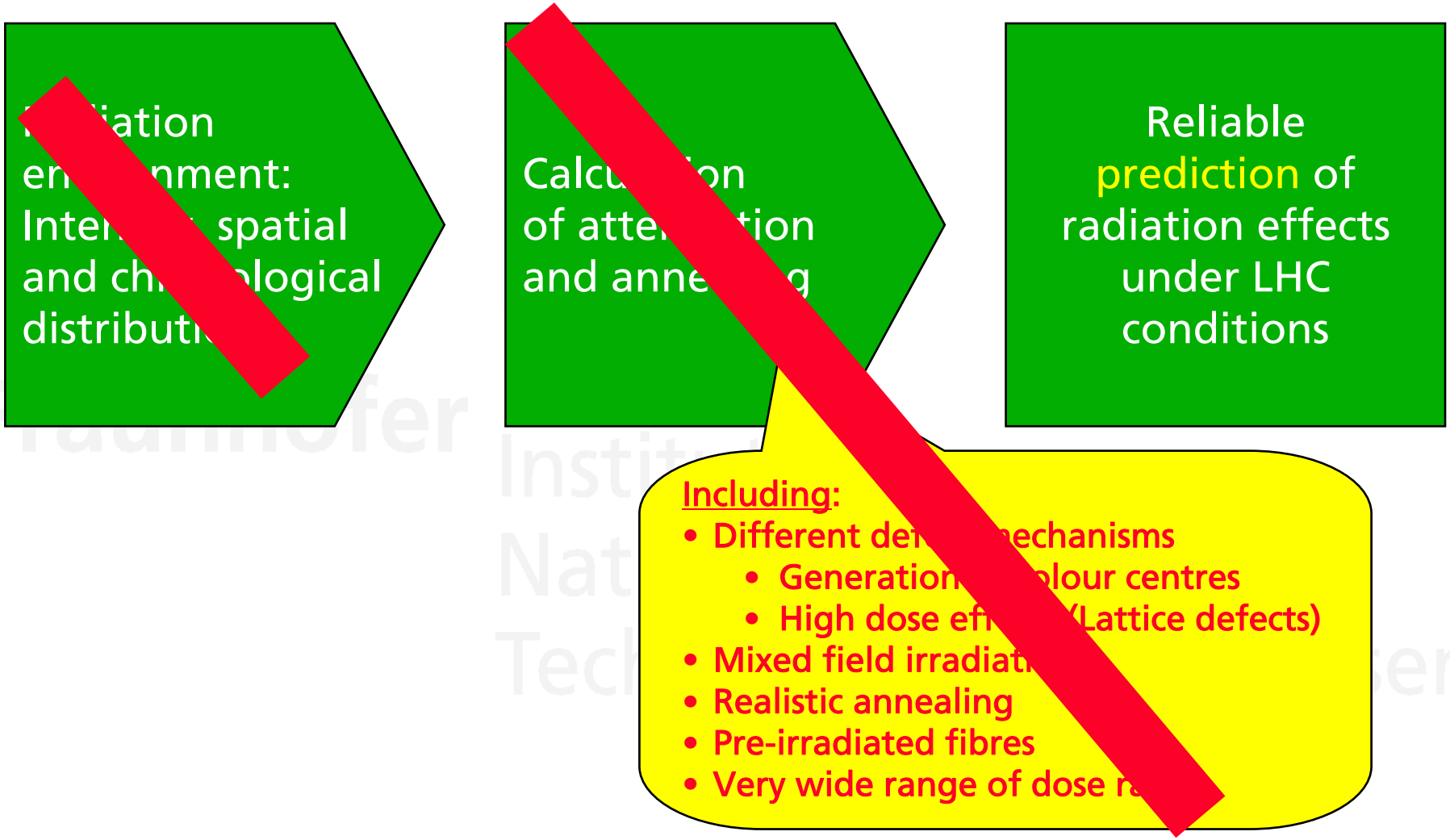
How to predict the radiation induced attenuation?



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How to estimate the radiation induced attenuation?

Radiation environment: Intensity, spatial and chronological distribution

Theoretical calculation of attenuation and annealing

Possible estimation of radiation effects under LHC conditions

Including:
- All defect mechanisms
  - Generation
  - High dose
- Mixed field irradiation
- Pre-irradiation

Experimental simulation

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Summary of aims and questions

- Between CERN and INT it was agreed to answer the following:
  - *Are the measurements done by CERN for Draka 445755 giving a realistic estimation of the losses? NO!*
  - *Are there fibres which can be operated reasonable at IR3 and IR7? YES!*
  - *What are the best suited fibres?*
    Several candidates with better performance identified!

Within 3 Months!
(June to Septem.)

- Questions which can/should be asked after this project:
  - *How long might the fibres be operational at LHC?*
    - Radiation environment has to be defined, e.g. first year, worst case.
  - *As a consequence of this: What is the best solution?*
    - Balance between costs and advantages.

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Estimations for first year

- LHC project note 375 (Lamont):
  - *Proton losses: 1.3 · 10^{15} to 5.2 · 10^{15} per year (in IR3 and IR7)*
- Radiation levels in the UJ33 tunnel (Kurochkin):
  - *Annual doses for IR3: 1000 - 1300 Gy*
  - ⇨*Annual doses for IR7: 2500 - 4200 Gy*
- Constraints (Wijnands):
  - *Exposed length: ~ 300 m*
  - *Acceptable attenuation: ~ 8 dB*
  - ⇨*Maximal attenuation: ~25 dB/km*
- Question for first year (conservative):
  - *Induced attenuation after 5000 Gy below 15 dB/km?*

First year estimations

- Assumed first year LHC operation conditions:
  - *Dose:*
    5000 Gy
  - *Mean dose rate:*
    2 mGy/s (corresponding to ~30 days exposition)
  - *Maximum tolerable attenuation:*
    15 dB/km

Source / Fibre	Draka Predictions	Fraunhofer-INT "Model" (2005)	Fraunhofer-INT "Model" (2006)
Draka 445744	< 7 dB/km	< 5 dB/km	< 5 dB/km
Draka/CERN#4	< 5 dB/km	< 5 dB/km	< 3 dB/km

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First year summary

- All estimations show for assumed first year conditions:
  - *Draka 445755 and Draka/CERN #4 below thresholds*
  - *No distinct difference between two Draka products except for different time/dose dependence*

- Very positive factors:
  - *The attenuation can (and will?) be constantly monitored*
  - *Fibre optic dosimetry could give dose distribution (chronological and spatial)*
  - *Suggestion: Using this input to adjust estimations*

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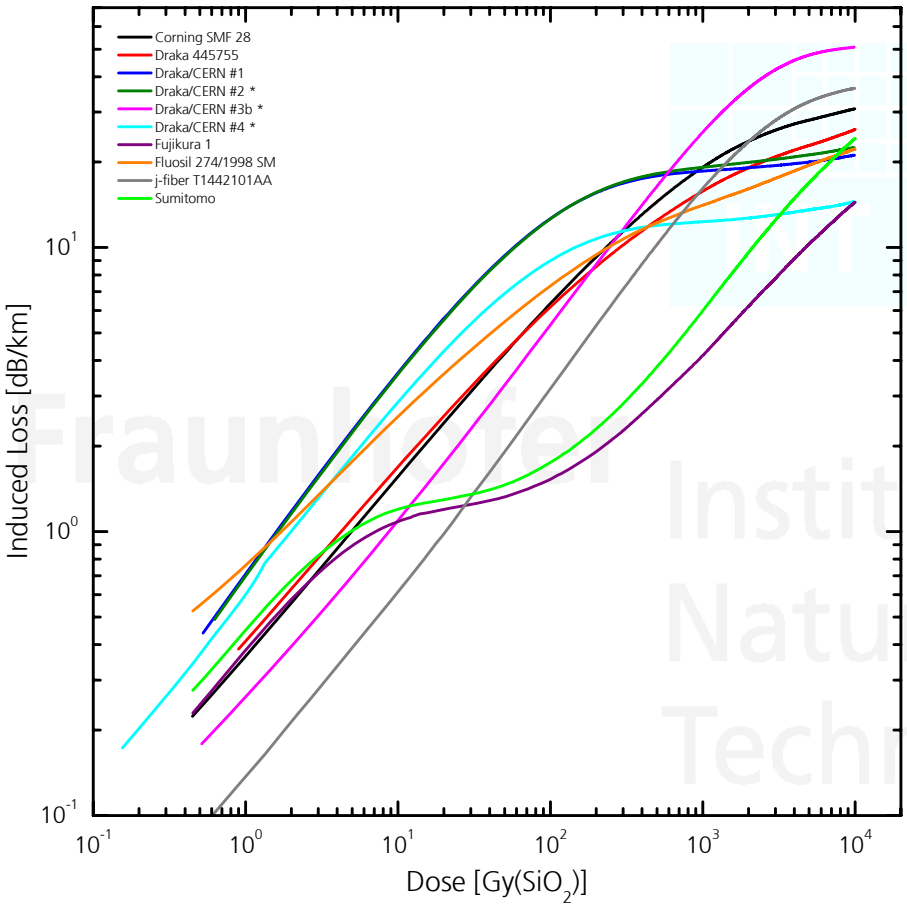
Current status

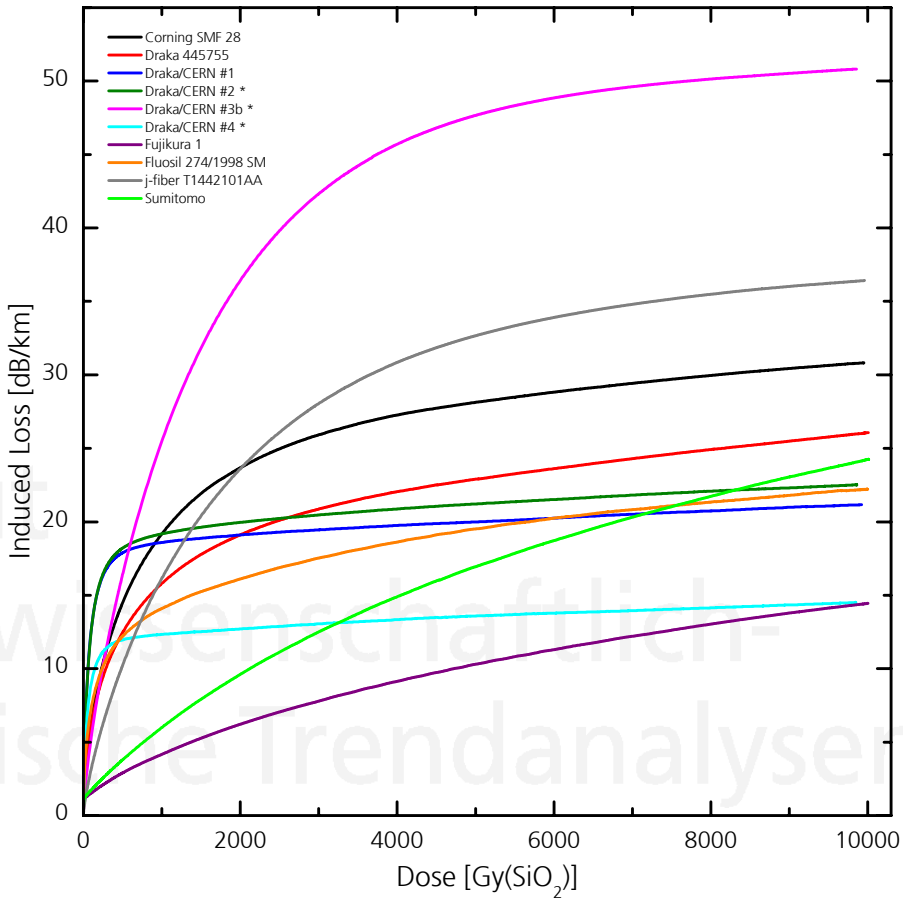
- Measurements for phases 1, 2 and 3 finished
  - *Presented in September 2005 and November 2005*

- Final report for first part in preparation
  - *Some changes in low dose rate extrapolation*

- Additional samples by Draka and Fujikura
  - *Measurements of new Fujikura fibre completed (2005-12-13 to 2006-01-16)*
  - *New sample by Draka arrived last week at INT*
  - *Administrative details for additional samples to be clarified*

Wrap up of results: Screening





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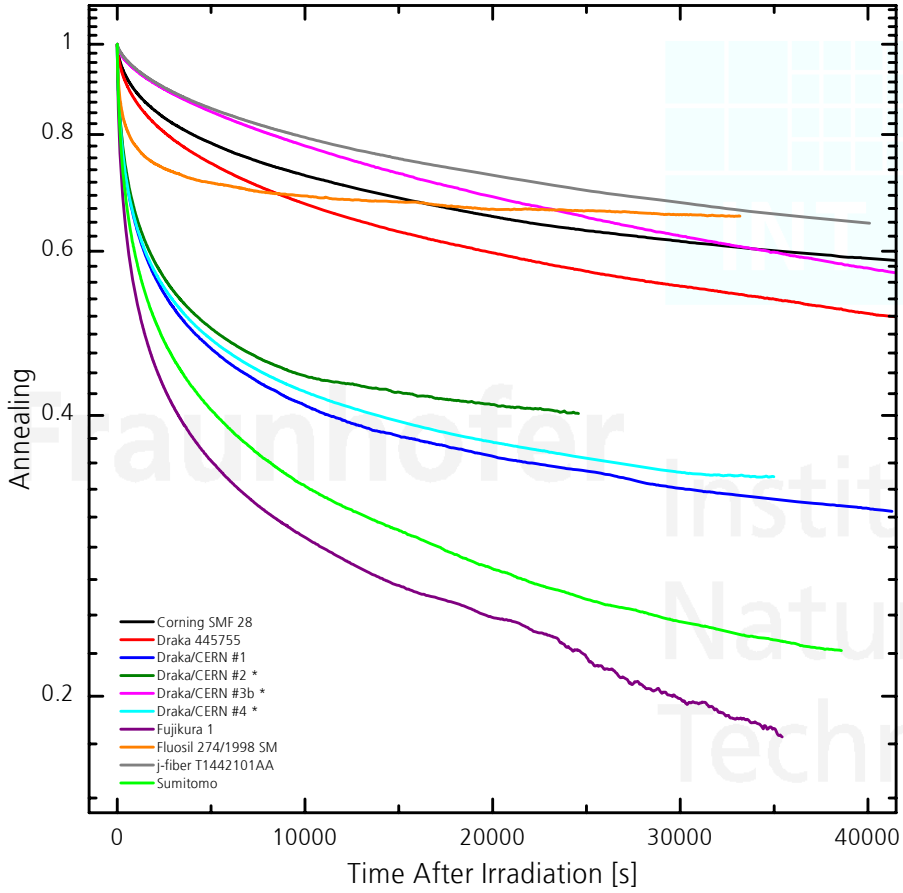
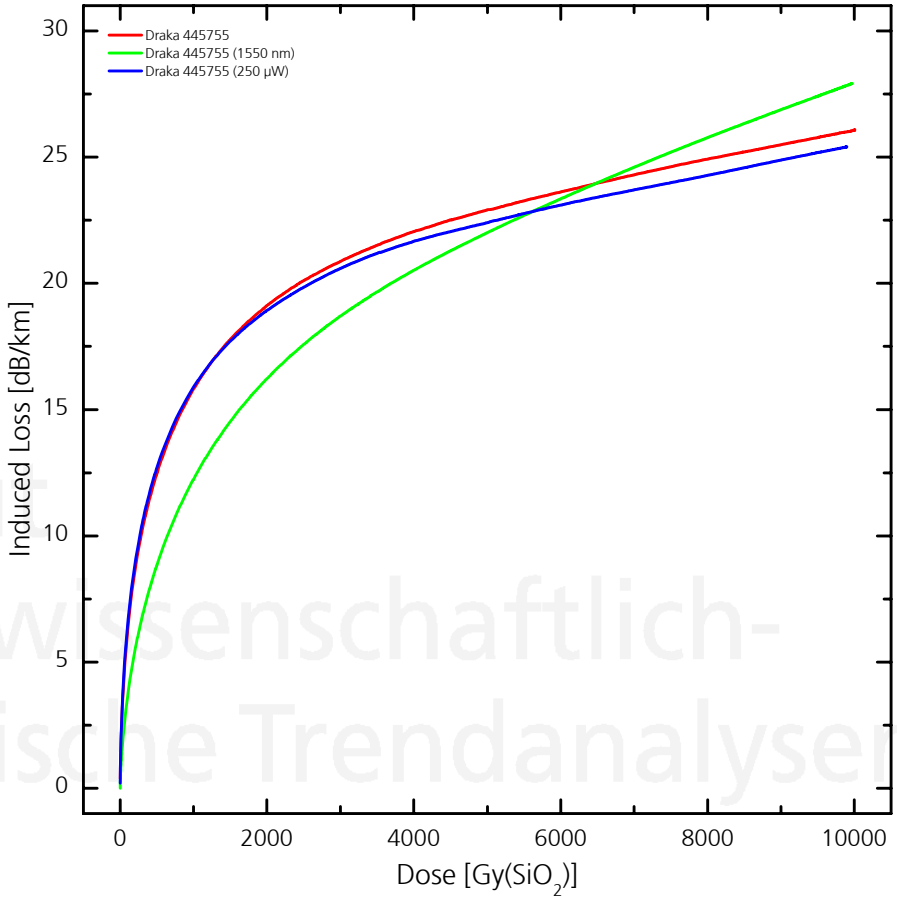
Wrap up of results: Annealing and parameter influence





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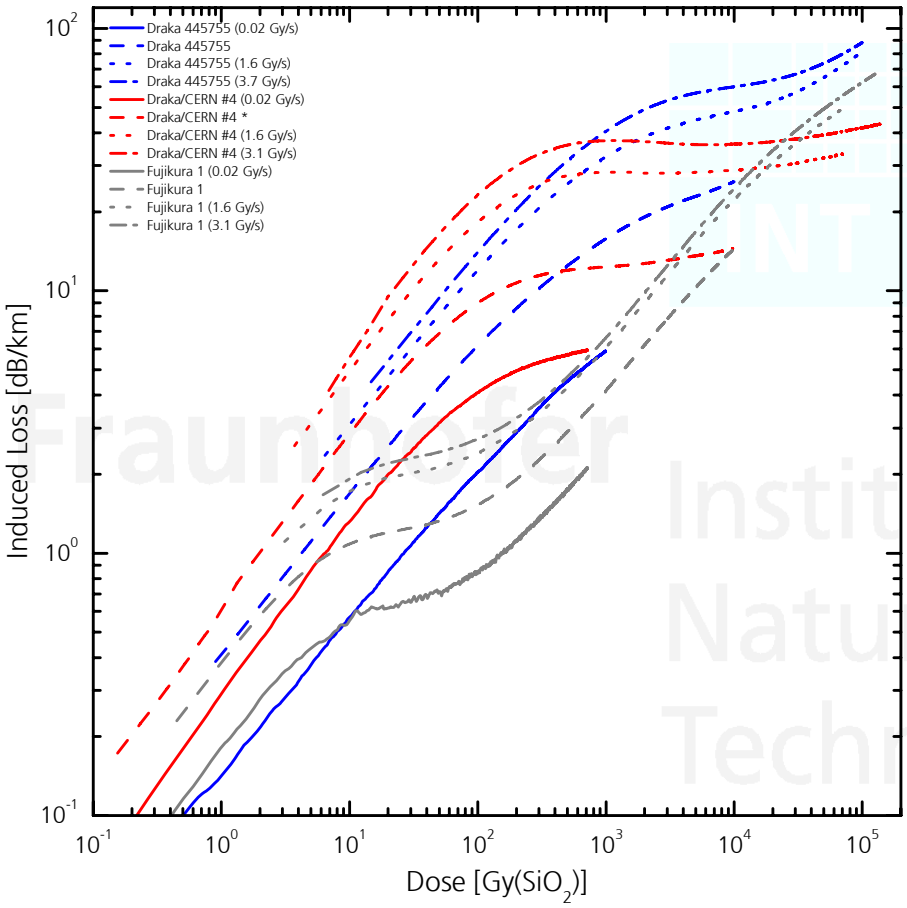
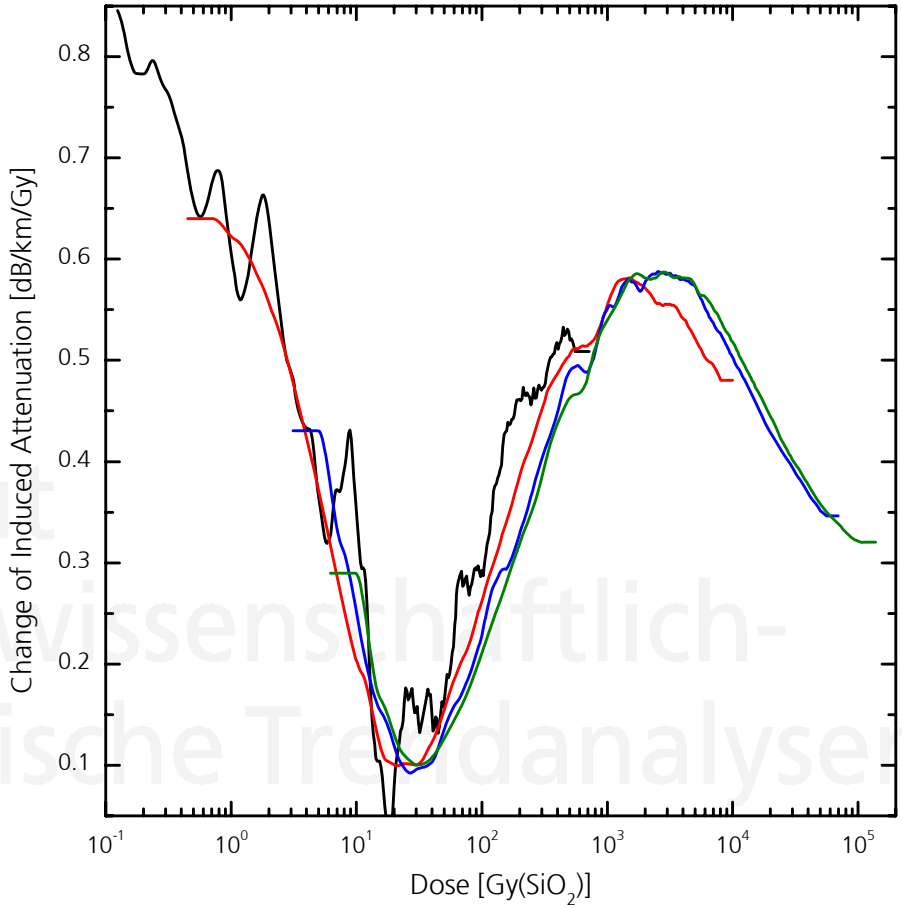
Low dose rate extrapolation: Dose rate dependency





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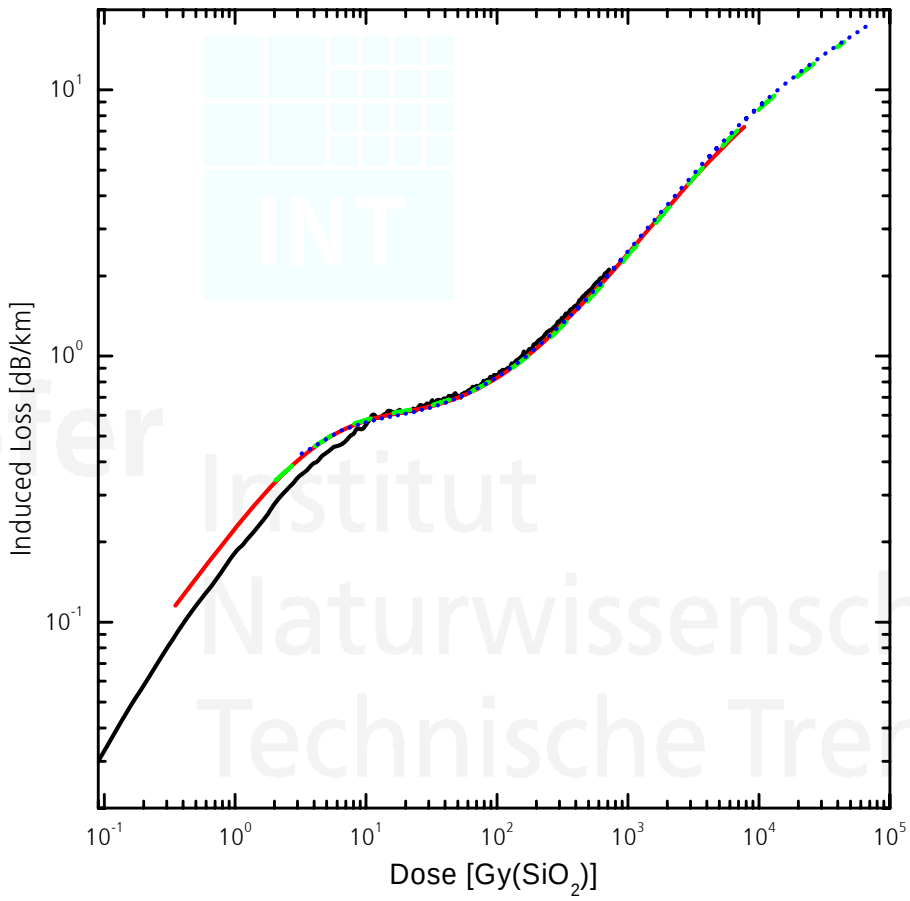
Low dose rate extrapolation: Shifting result



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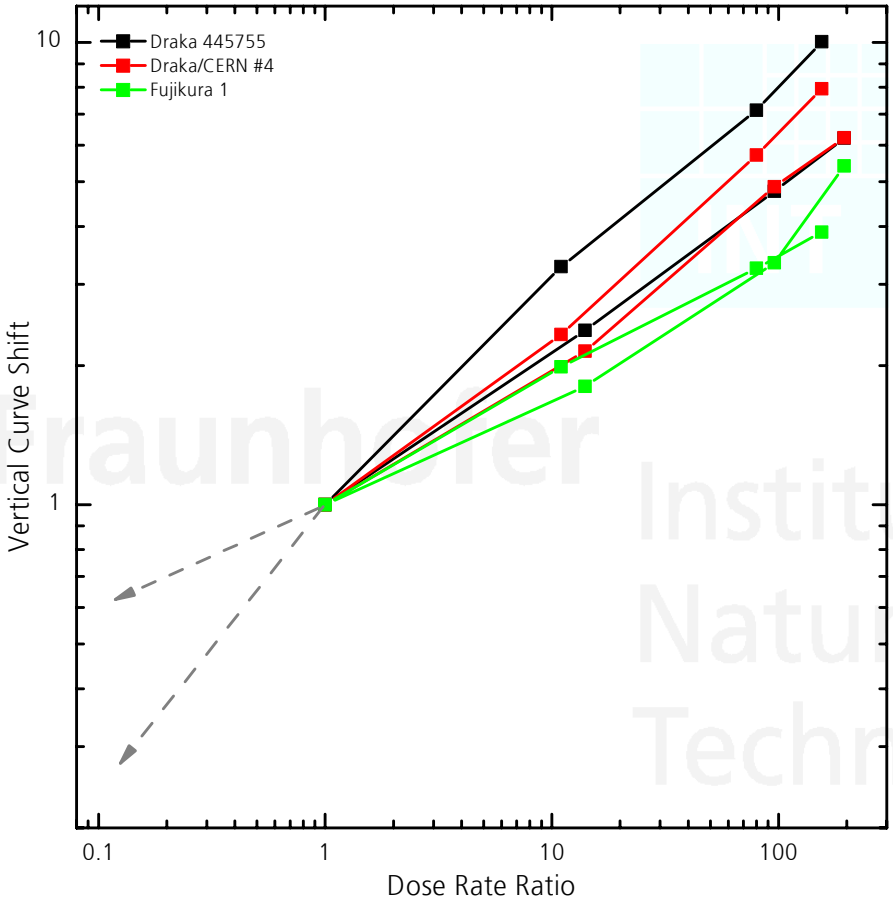
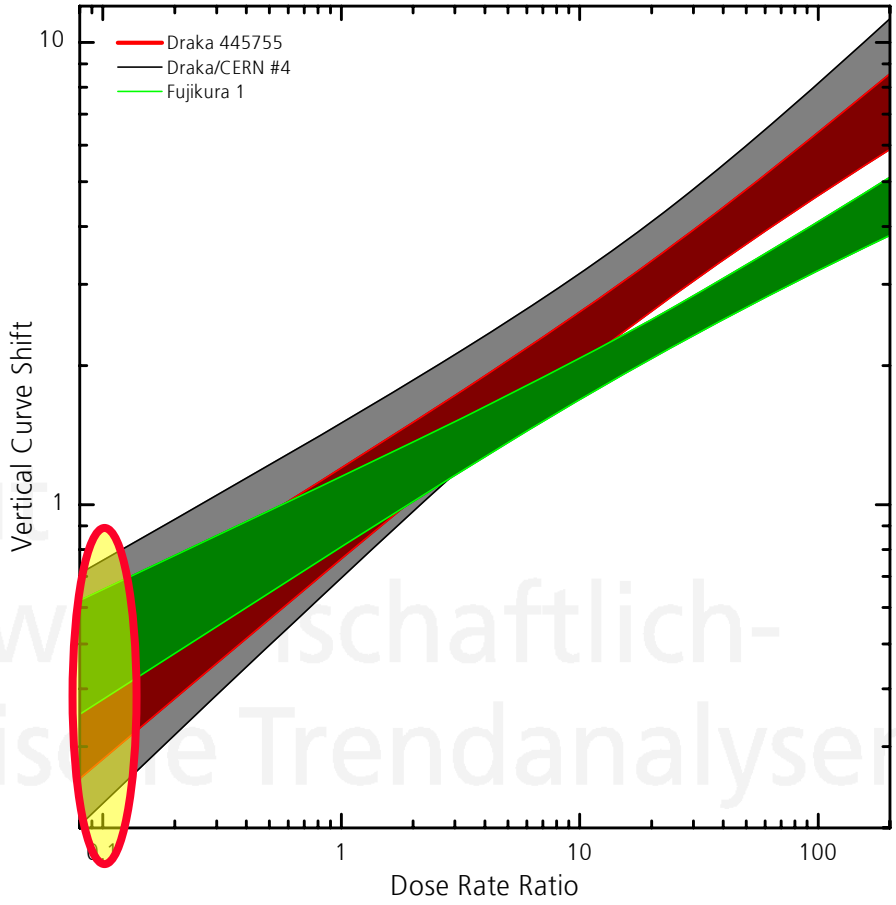
Low dose rate extrapolation: Vertical shift factors





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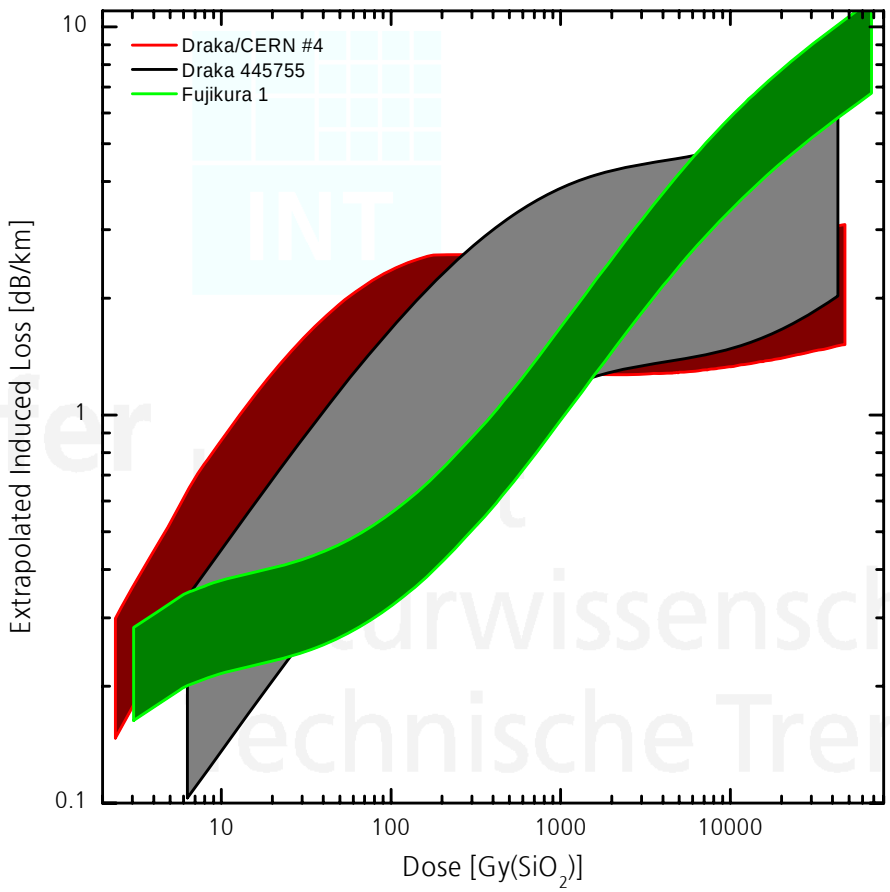
Low dose rate extrapolation



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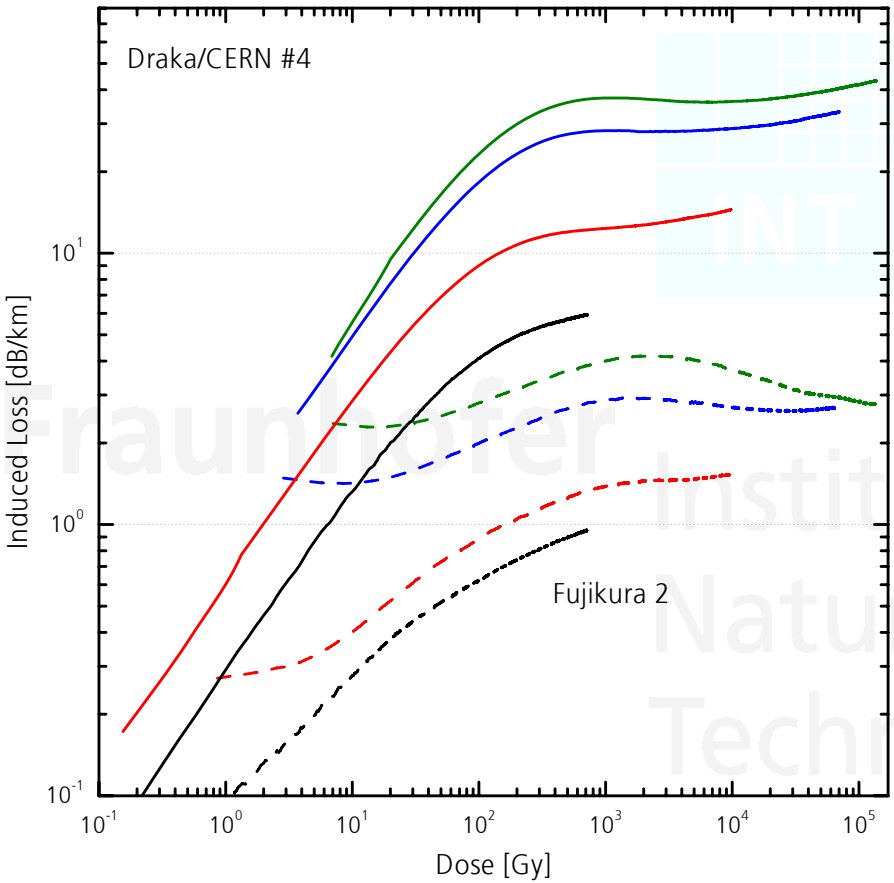
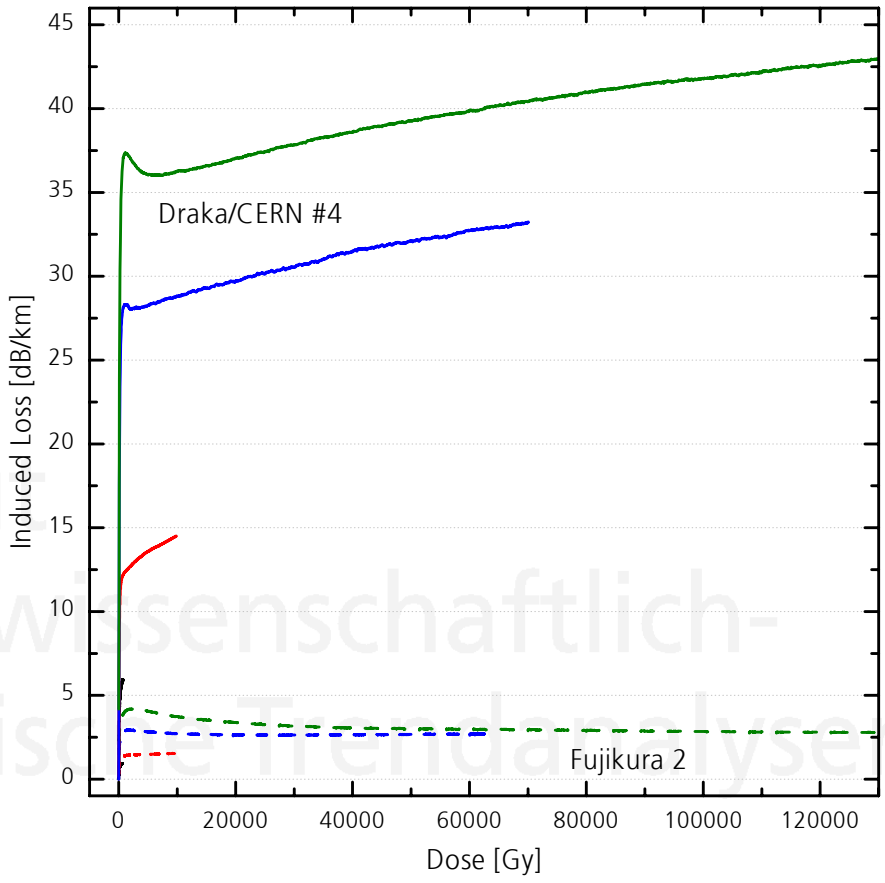
Results for sample Fujikura 2 compared to Draka/CERN #4





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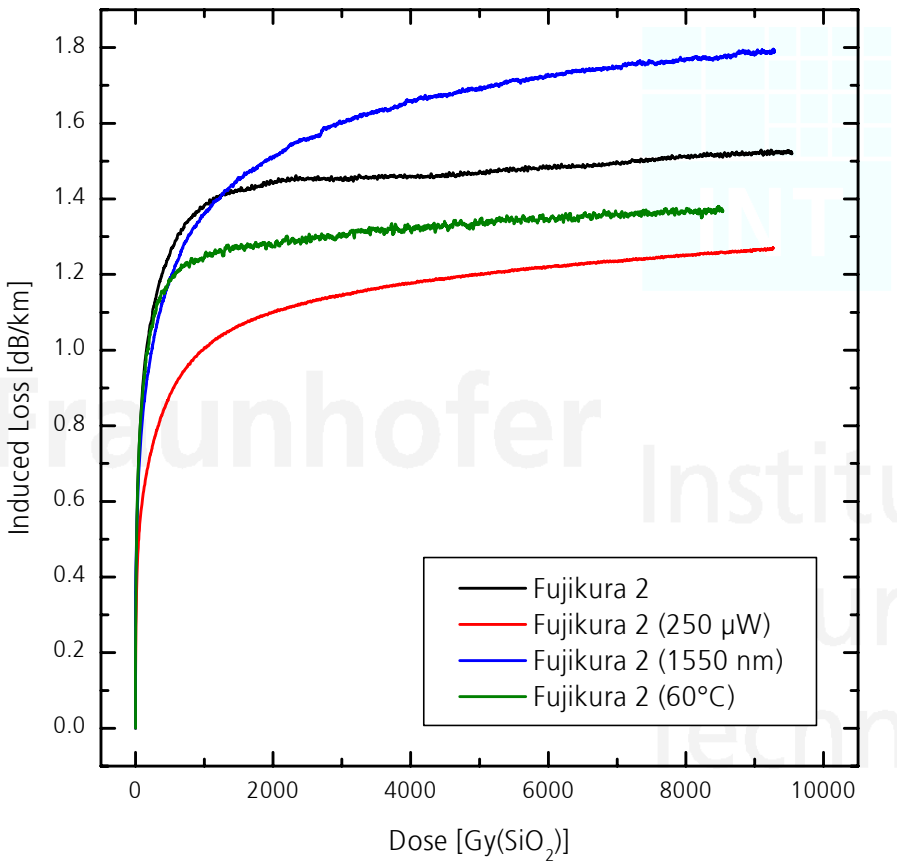
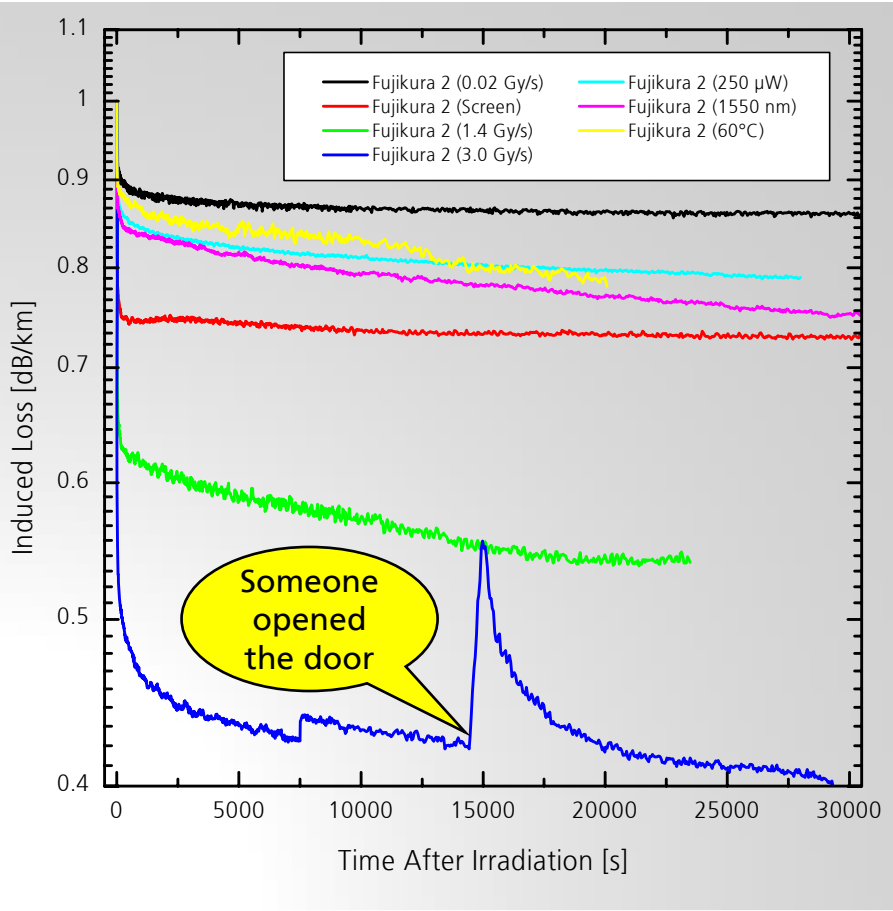
Parameter influences and annealing of Fujikura 2





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Future possibilities - Questions for motivation

- What are the main alternatives now?
  - *Install now the definite fibre without future exchange*
    - What input data would we need to decide this?
    - What output data would we need?
    - What precision/reliability would we need (safety margin)?
    - What time would be left to take the decision?
  - *Install now an transitory fibre and maybe change it in the future*
    - What time frame has to be taken into account (foreseeable occasion)?
    - What radiation environment is to be expected?
    - What would be a break-even time for the subsequent change?
    - Could we use this time to establish more realistic estimations?

Future possibilities

- Additional ^{60}Co testing for communication fibres
- Calibration of P-doped fibre for dosimetry purposes
- Additional testing in mixed field
- Maybe other fibre optic radiation sensing options

Additional ^{60}Co testing for communication fibres

- Verification of low dose rate extrapolations (TK1000 facility)
  - *If for more reliable decision needed other dose rates can be realised at the "strong" source*
  - *For irradiations up to some days*
- Interruptive irradiation up to high total dose (TK1000 facility)
  - *For some days one could do other tests with interrupting irradiation with special consideration of LHC conditions (1. Year?)*
- Long term irradiation at very low dose rate (TK100 facility)
  - *Lower dose rates (from 0.01 Gy/s to 0.1 mGy/s) over longer times possible at weaker source (lower costs, no interference)*
- Interruptive irradiation for long time (TK100 facility)
  - *Very realistic simulation of interrupted irradiation over weeks*

Calibration of P-doped fibre for dosimetry purposes

- Implementation of a fibre optic dosimetry system
  - *Application not only at now discussed zones IR3 and IR7*
  - *Everything is available (sensors, infrastructure, equipment)*
  - *Only data for interpretation of anyway acquired data is needed*
  - *Possible extension:*
    Integration and comparison with other dosimetry systems at LHC
  - *Reliable and proofed system used at several accelerators*

Additional testing in mixed field

- Mixed field testing
  - *Compare response of communication fibres obtained with ^{60}Co*
  - *Compare bare fibres and cables with/without ducts*
  - *Compare obtained dosimetry calibration for P-doped fibres*

Other fibre optic radiation sensor systems

- Cherenkov-based systems
  - *Very fast and sensitive*
  - *High time and local resolution*
  - *Radial resolution extendable*
  - *Very helpful for commissioning*
  - *Established system at several accelerators*
  - *Limited to shorter lengths or local installation*
- Systems based on Bragg-Gratings
  - *Extreme high dose range measurable (several 100 kGy)*
  - *Long range ability, many sensing location*
  - *Easy to deploy(?), some efforts in development needed*

Summary

- Primary objectives of current project achieved
  - *Operation of optical fibres definitively possible*
  - *Drastic differences between different products revealed*
- Actual prediction of radiation effects (at least) very difficult

- Main question now:
  What is the best solution with the knowledge we have?
- Next question:
  What data would be needed or help to find lasting solution?

- Possible application of fibre radiation sensors at LHC?