AD-4 Status Report 2012

48 Scientists from 20 Institutions

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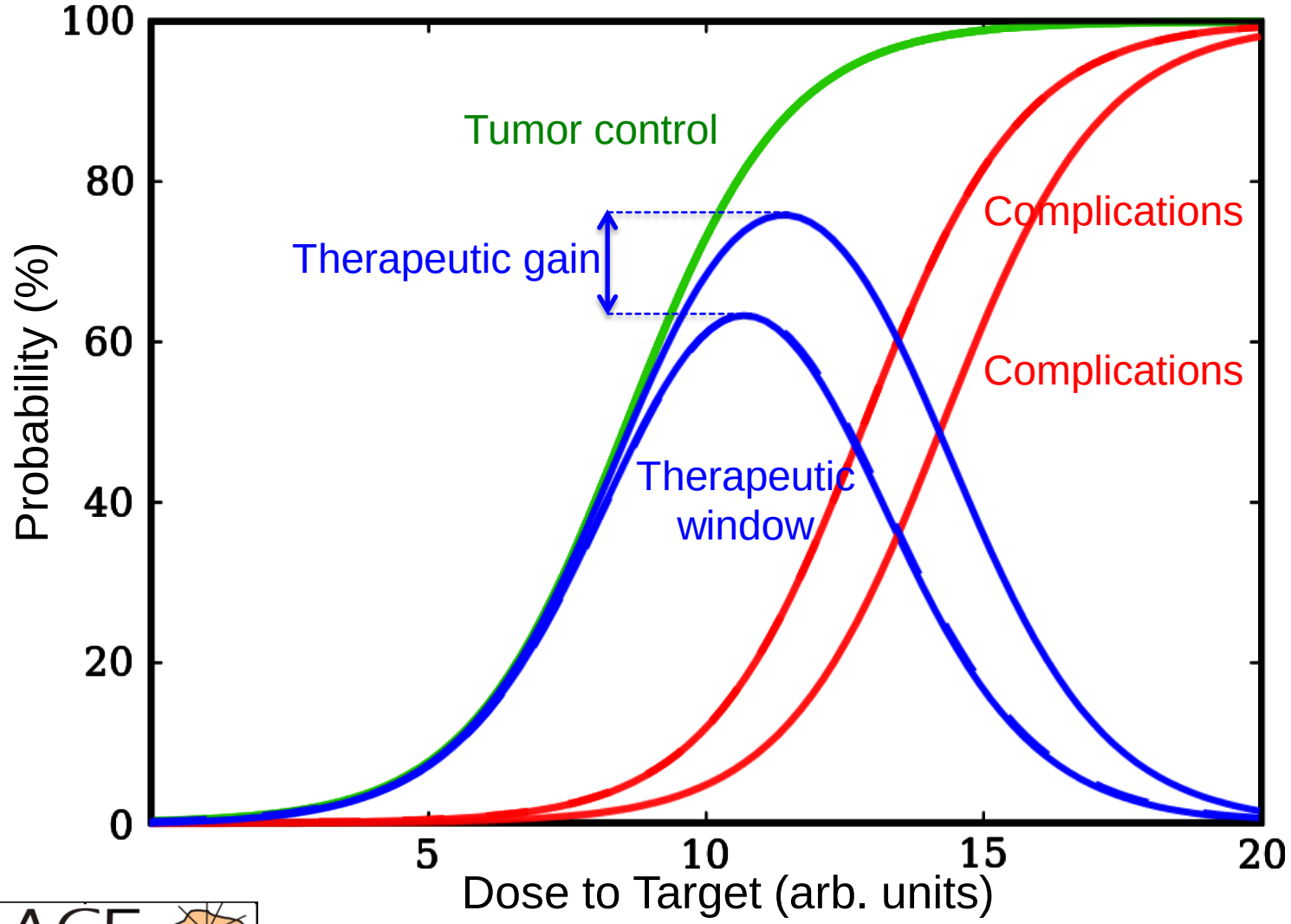
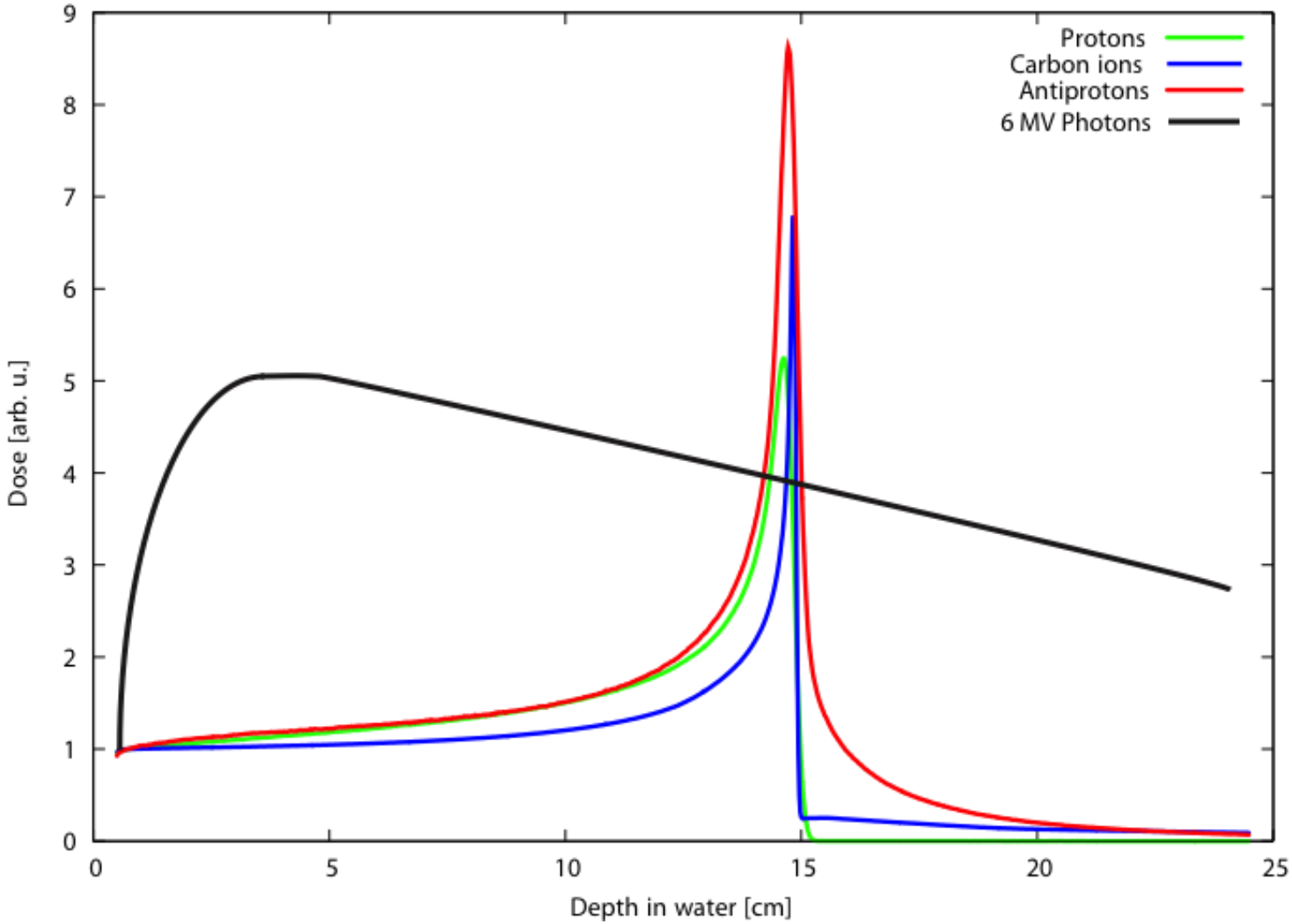
Rationale for Conformal Radiotherapy

Dose and tumor control are limited due to organs at risk.

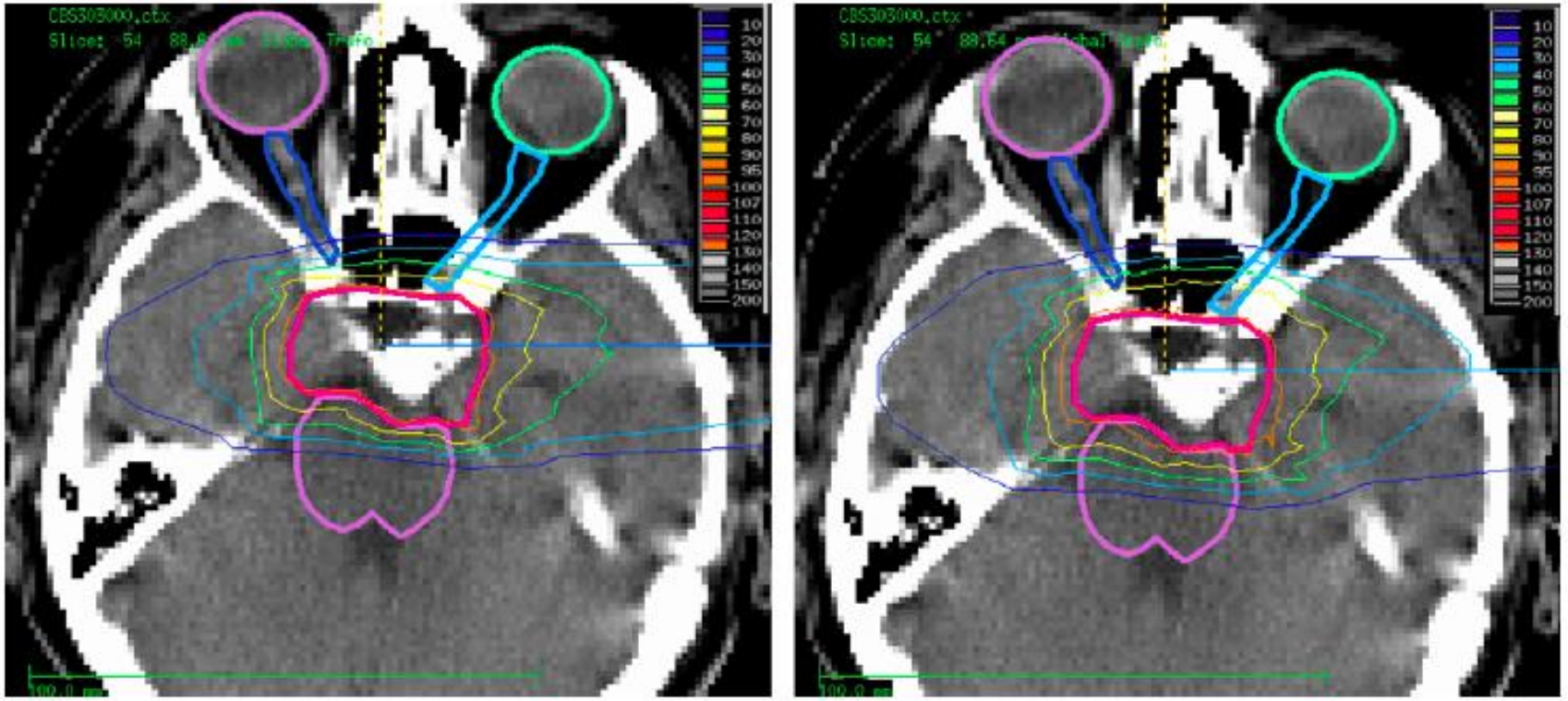


Physical Advantage of Antiprotons

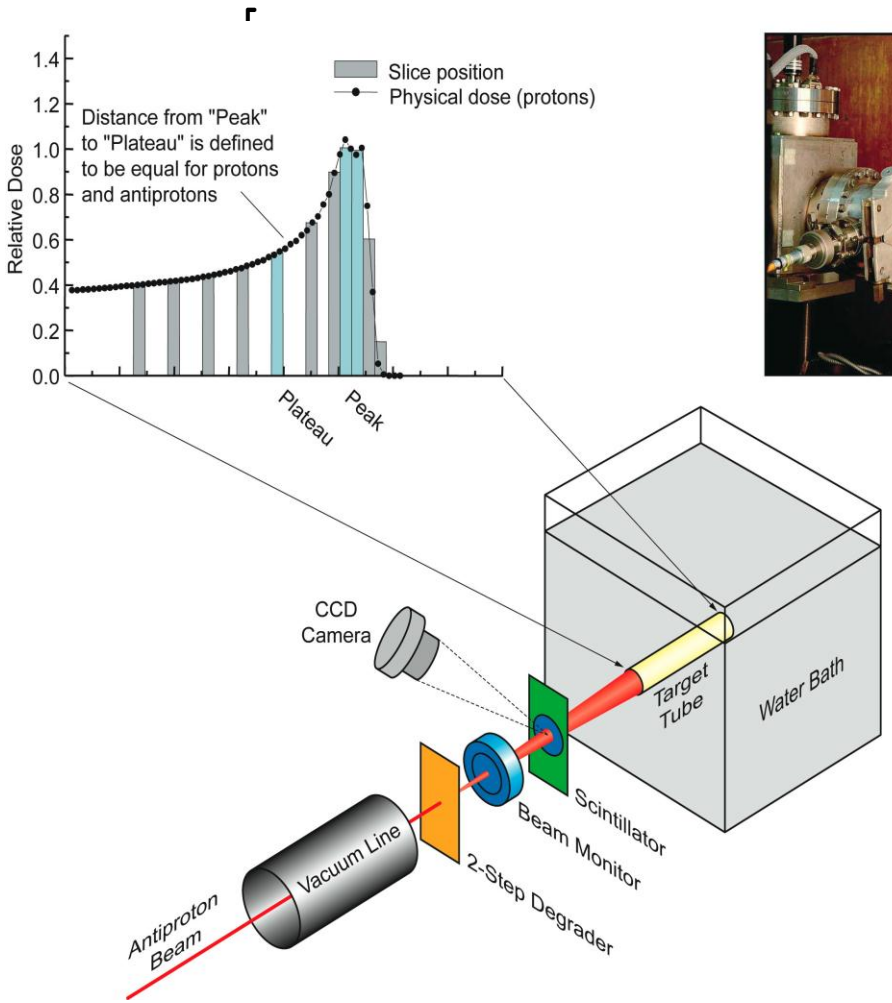


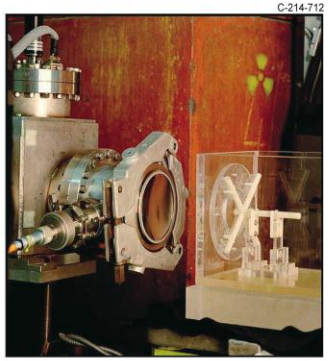
Dose Plan Comparison

based on physical dose only



The AD-4 Experiment at CERN





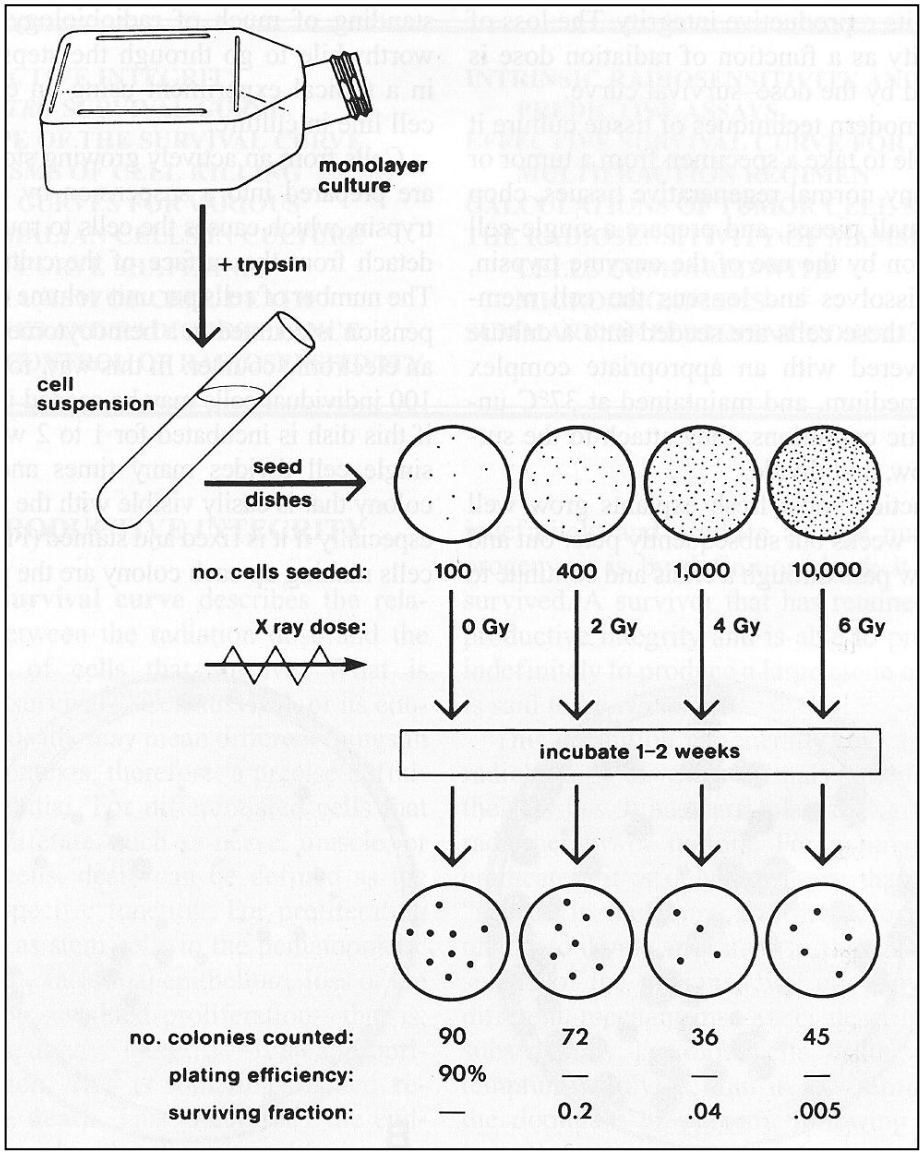
INGREDIENTS:

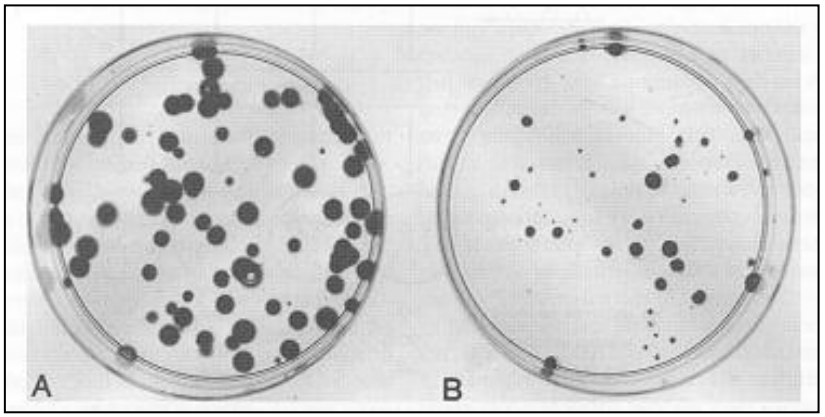
- **V-79 Chinese Hamster cells embedded in gelatin**
- **Antiproton beam from AD (126 MeV)**

V79

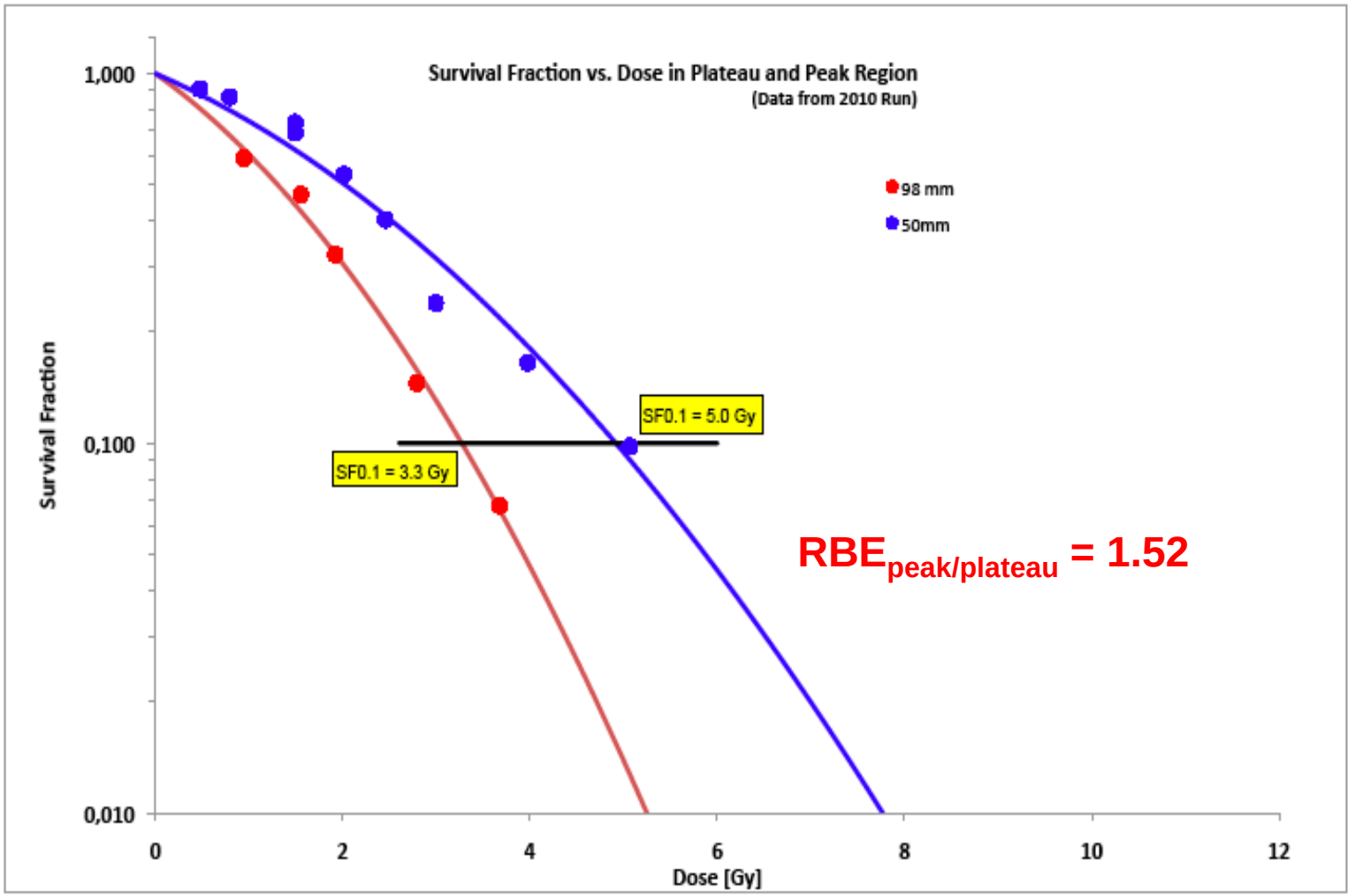
Developed by Ford and Yerganian in 1958 from lung tissue of a young male Chinese Hamster (Cricetulus griseus)

Biological Analysis Method



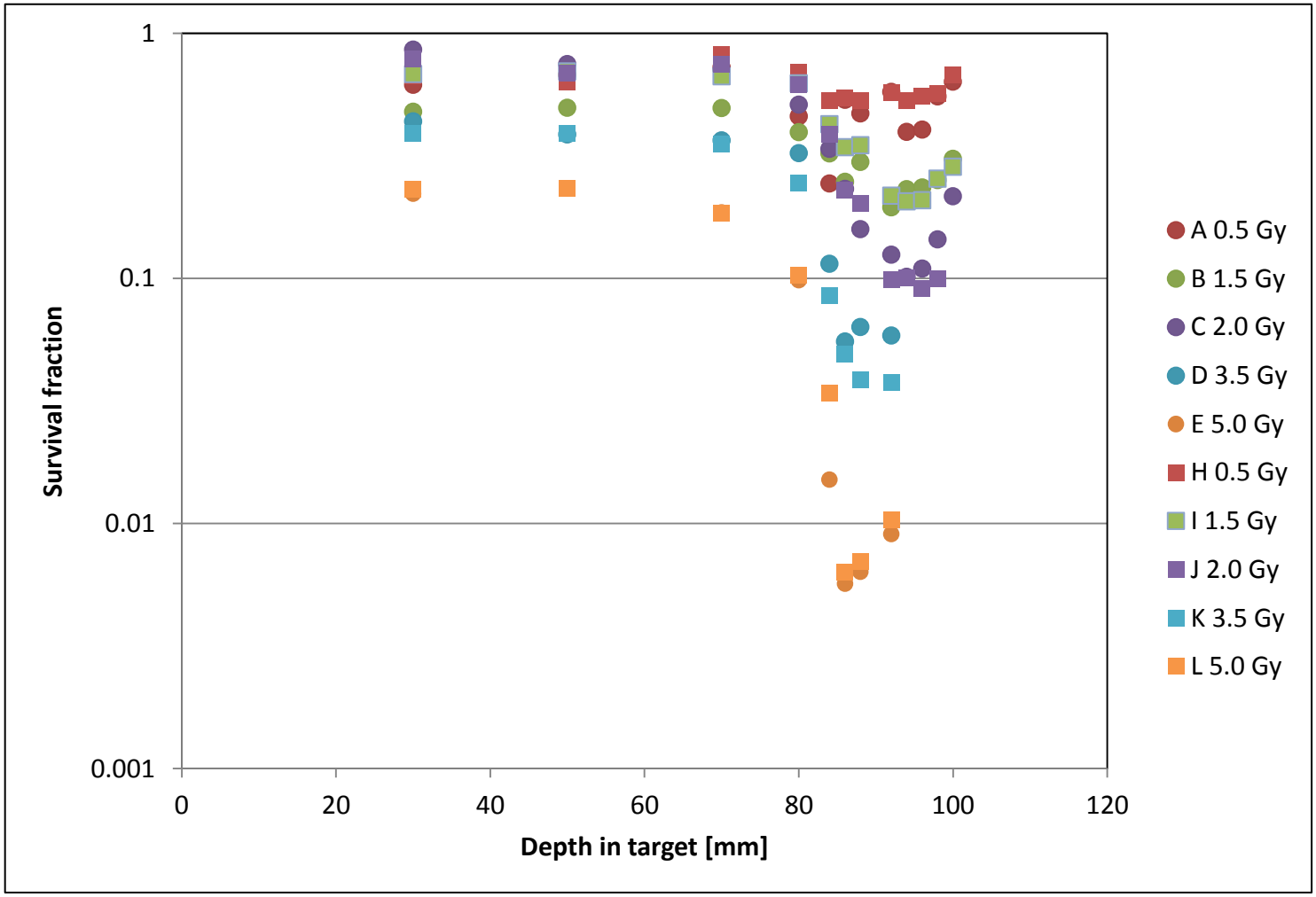


Cell Survival vs. Dose for 2010 Data



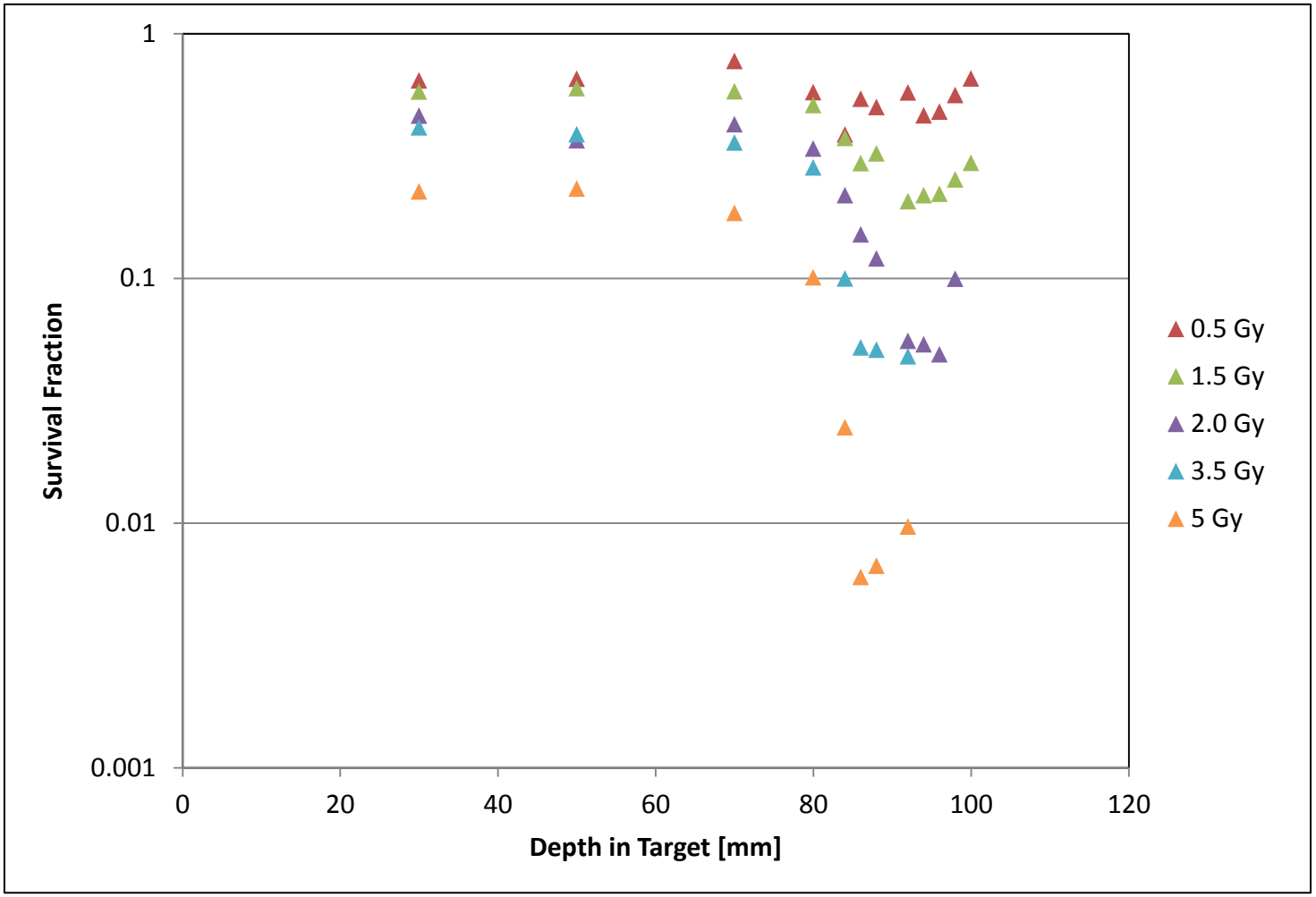
Need low LET Reference Irradiation to translate to absolute RBE

Survival vs. Depth 2012



2 independent runs (preliminary dose values)

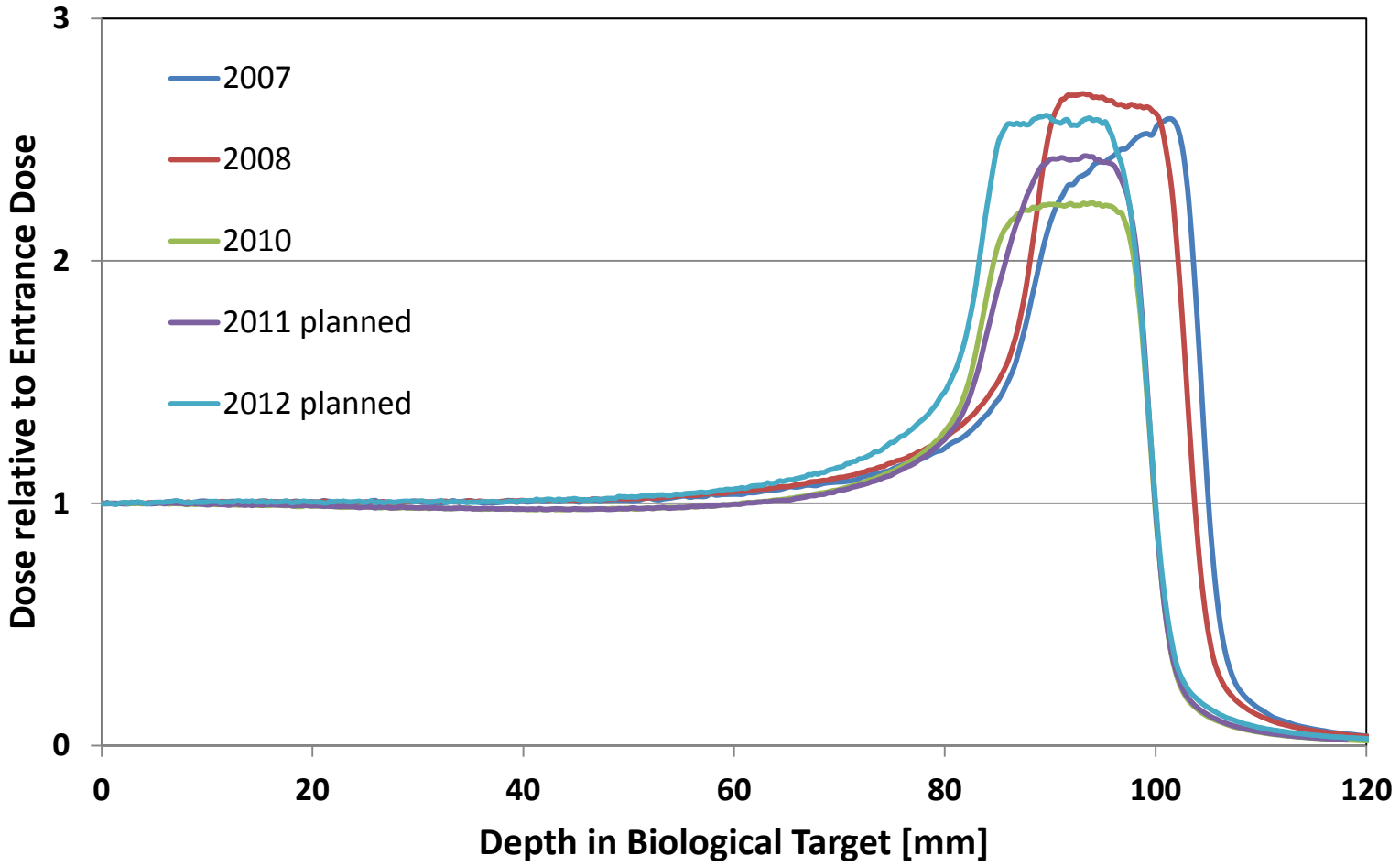
Survival vs. Depth 2012



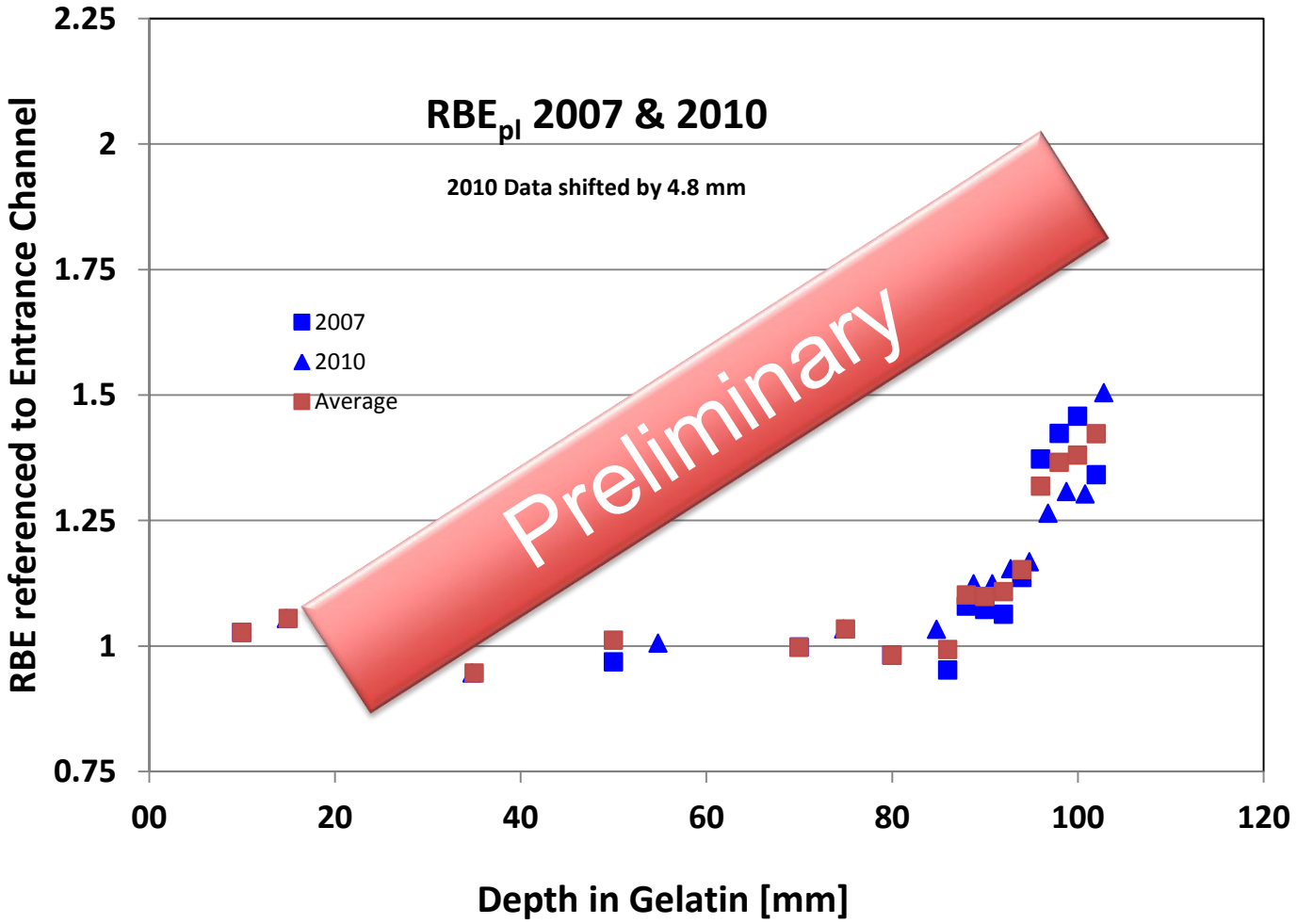
Average of the two independent runs

5 Years of Running –
5 Depth Dose Distributions !?!

Depth Dose Distributions 2007 - 2012



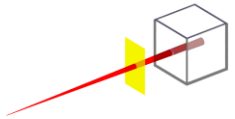
Combined $RBE_{plateau}$ for 2007 and 2010

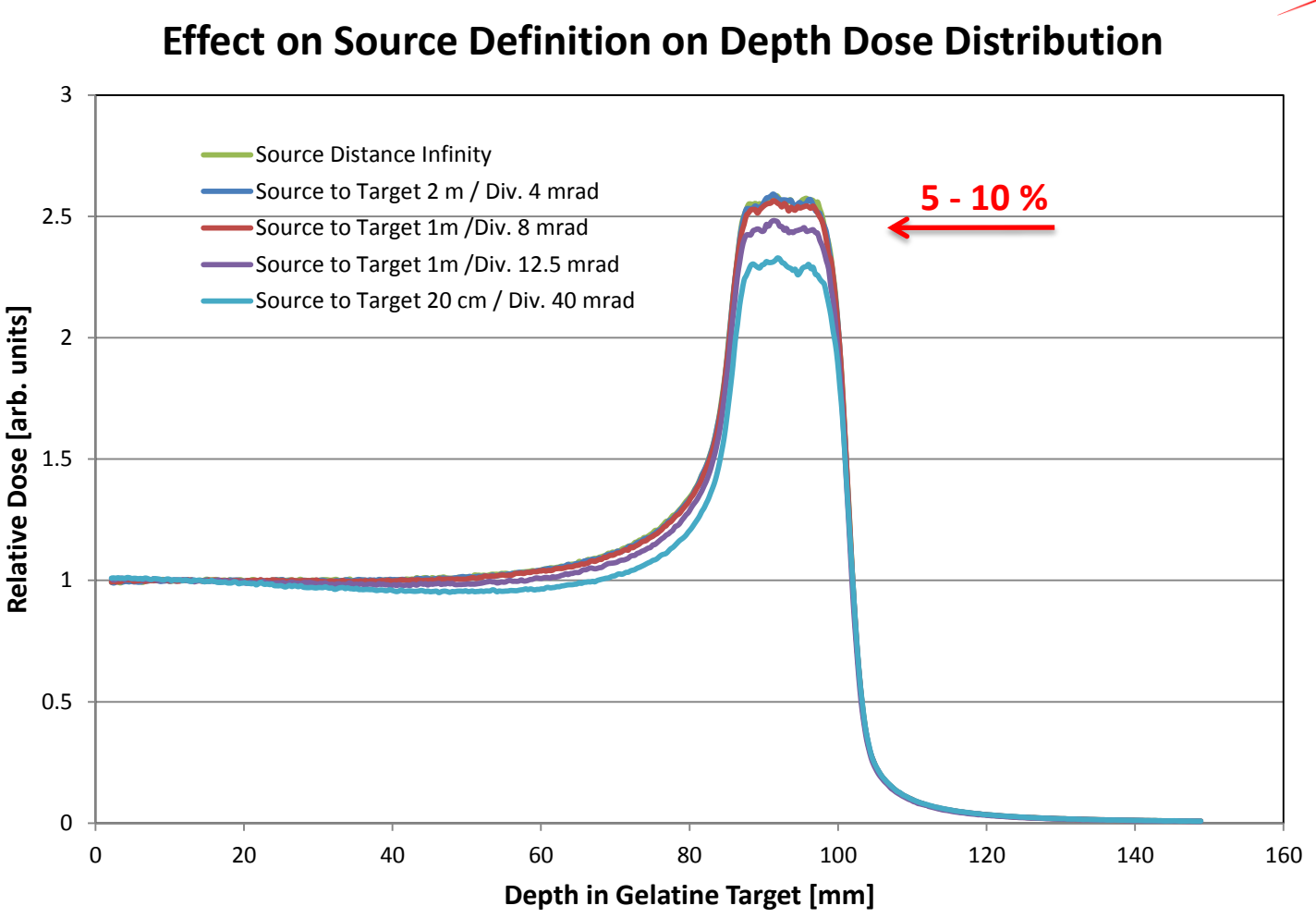


RBE Analysis for Antiprotons

- **Physical dose calculations require exact knowledge of beam parameters (intensity, radial profile, and divergence) as input for FLUKA**

Lack of precise knowledge of beam parameter





RBE Analysis for Antiprotons

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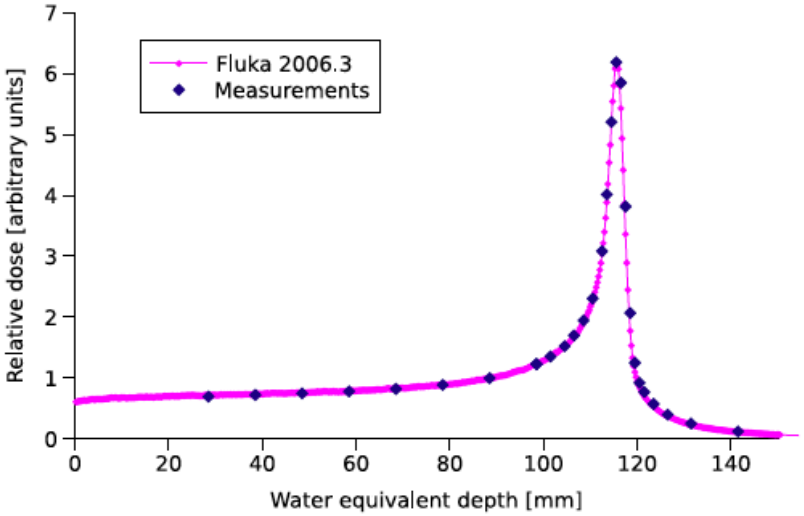
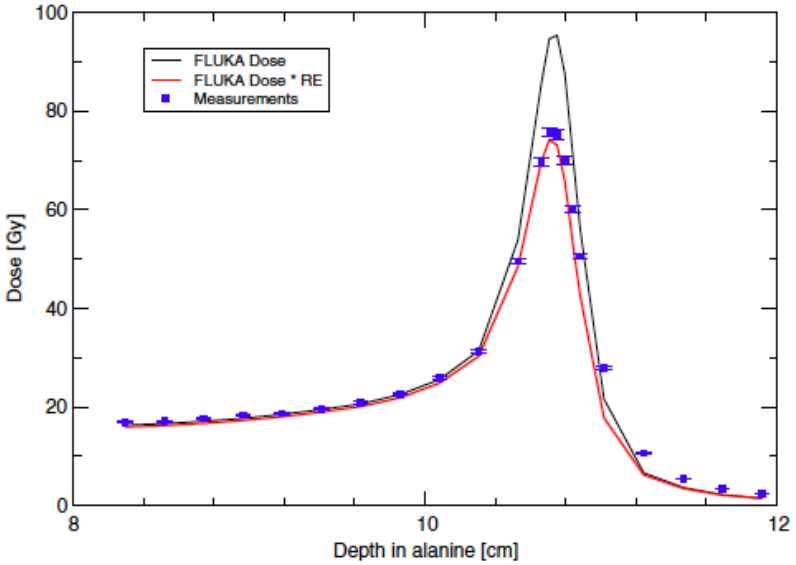
- **Changes in FLUKA code from year to year require new dose calculations for all years using the same version of the code. Due to time constraints the only benchmark measurements available are from 2006.**

Relative and absolute dosimetry



Relative dose measured with ionization chamber normalized to entrance channel compared to FLUKA calculation. (Bassler et al.; Phys. Med. Biol. 53 (2008)

Absolute dose measurement using Alanine tablets corrected with the response model by Hansen and Olson (Bassler et al. NIM B 266 (2008)



Perfect agreement between data and FLUKA probably due to cancellation of two or more errors

RBE Analysis for Antiprotons

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- Changes in FLUKA code from year to year require new dose calculations for all years using the same version of the code. Due to time constraints the only benchmark measurements available are from 2006.
- **Biological Variability necessitates multiple Independent Experiments under Identical Conditions**

RBE Analysis for Antiprotons

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- **Biological Variability necessitates multiple Independent Experiments under Identical Conditions**

==> Combining all data is a big (but manageable) task!

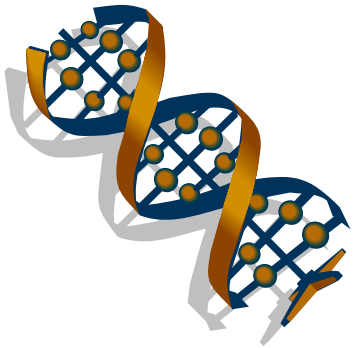
ACE

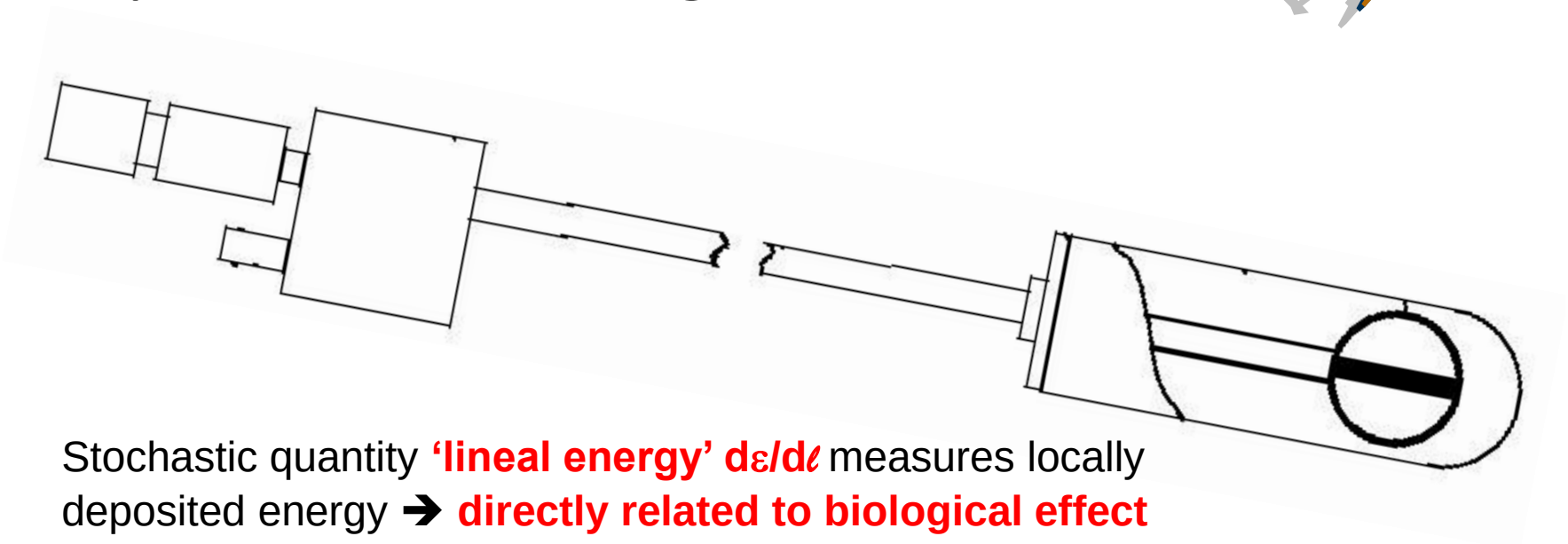
Microdosimetry and biological effect

Sphere diameter: ½” = 1.27 cm

Simulated diameter: 2 µm

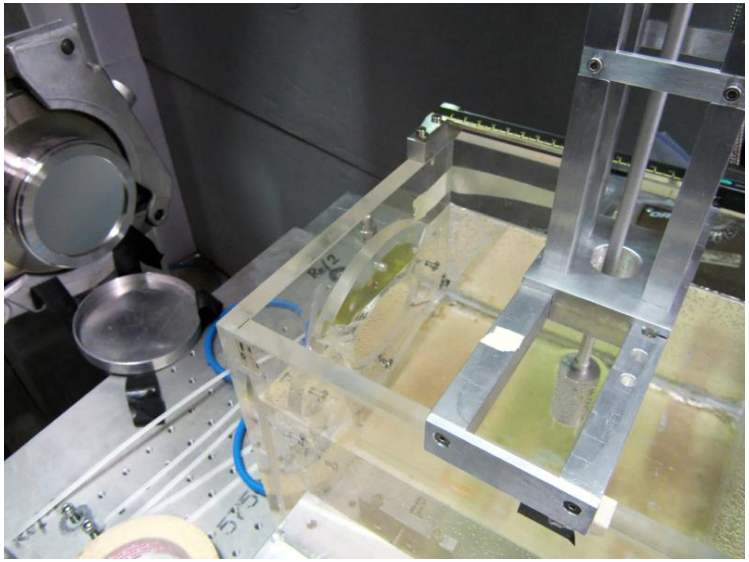
Propane-based TEPC gas mixture

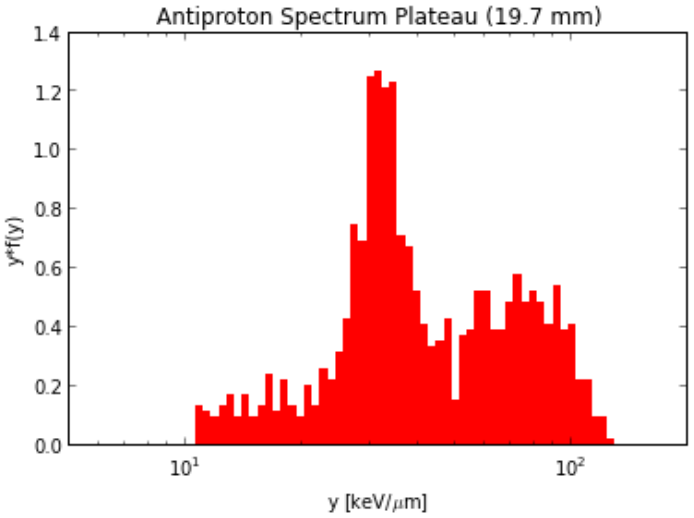




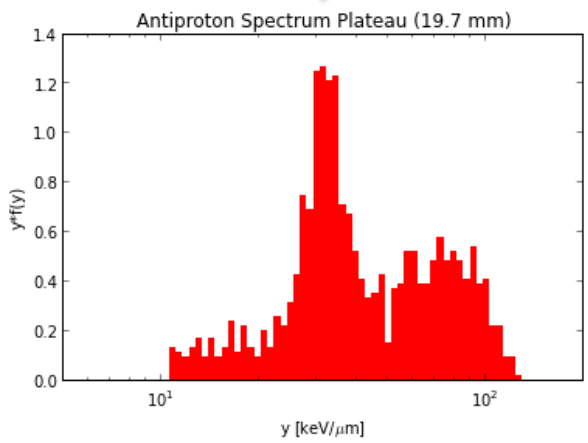
Stochastic quantity **‘lineal energy’ $d\varepsilon/d\ell$** measures locally deposited energy ➔ **directly related to biological effect**

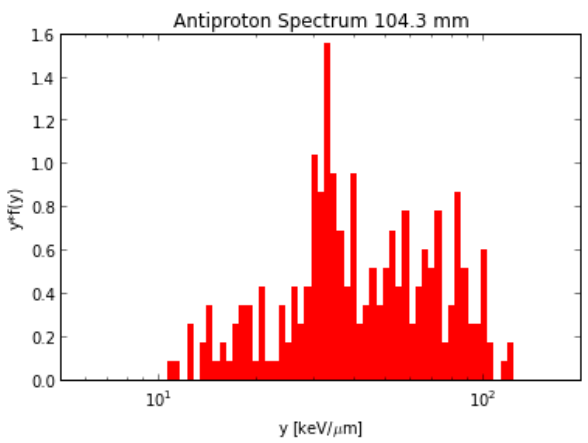
Microdosimetry Experiment

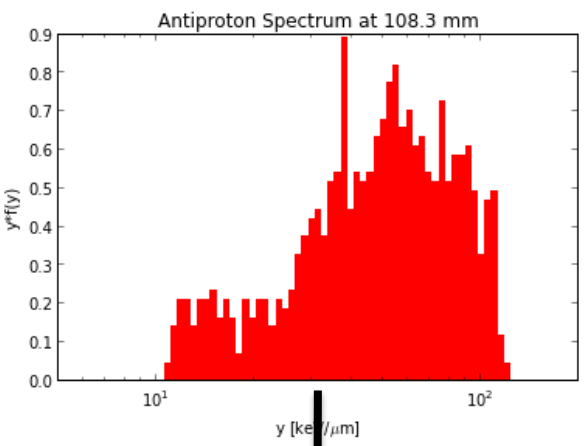


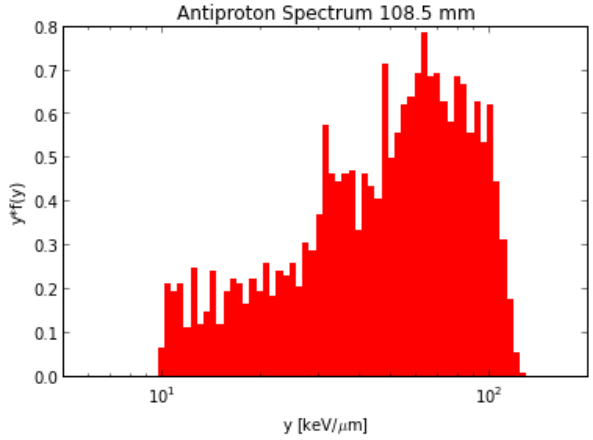


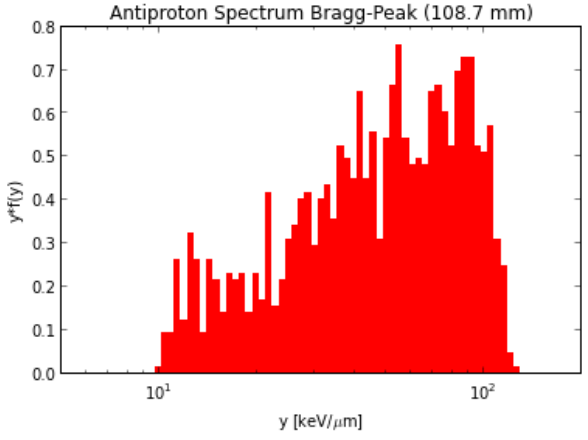
Microdosimetry along beam axis

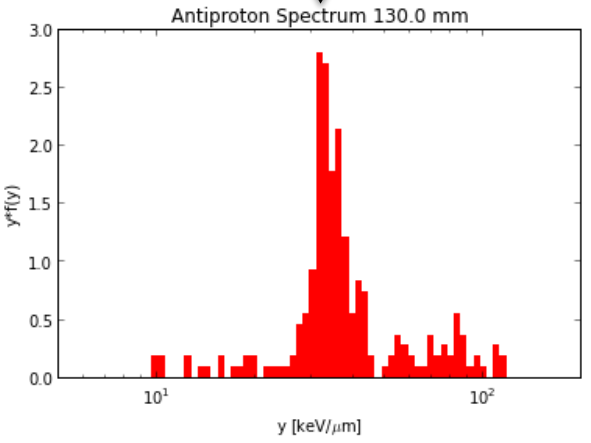








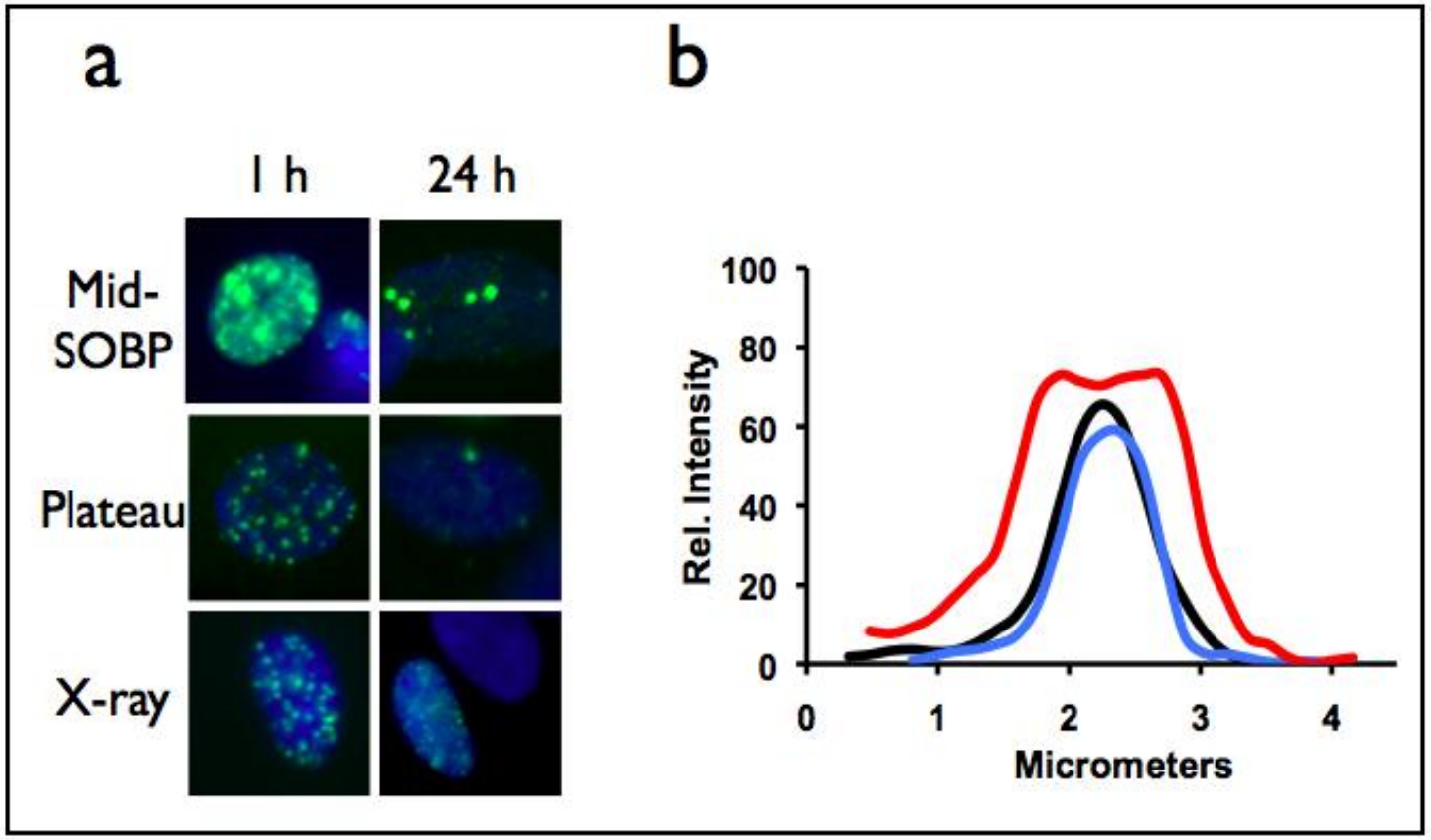




Clear differentiation between kinematic stopping power (peak) and annihilation events

high $d\varepsilon/d\ell$ confined to Bragg peak

Micro-Nuclei Studies



Micro-nuclei produced by annihilating antiprotons are substantially larger and more persistent than those produced by x-rays or antiprotons in-flight

DNA Damage and Repair

- No further experimental work with antiprotons was performed in 2012
- Experiments with protons and ions took place elsewhere
- Full Summary report of this portion of work in ACE will be available in PhD thesis of Joy Kavanagh
- Paper submitted recently to Nature Communications

Summary

What we wanted to do in 2012

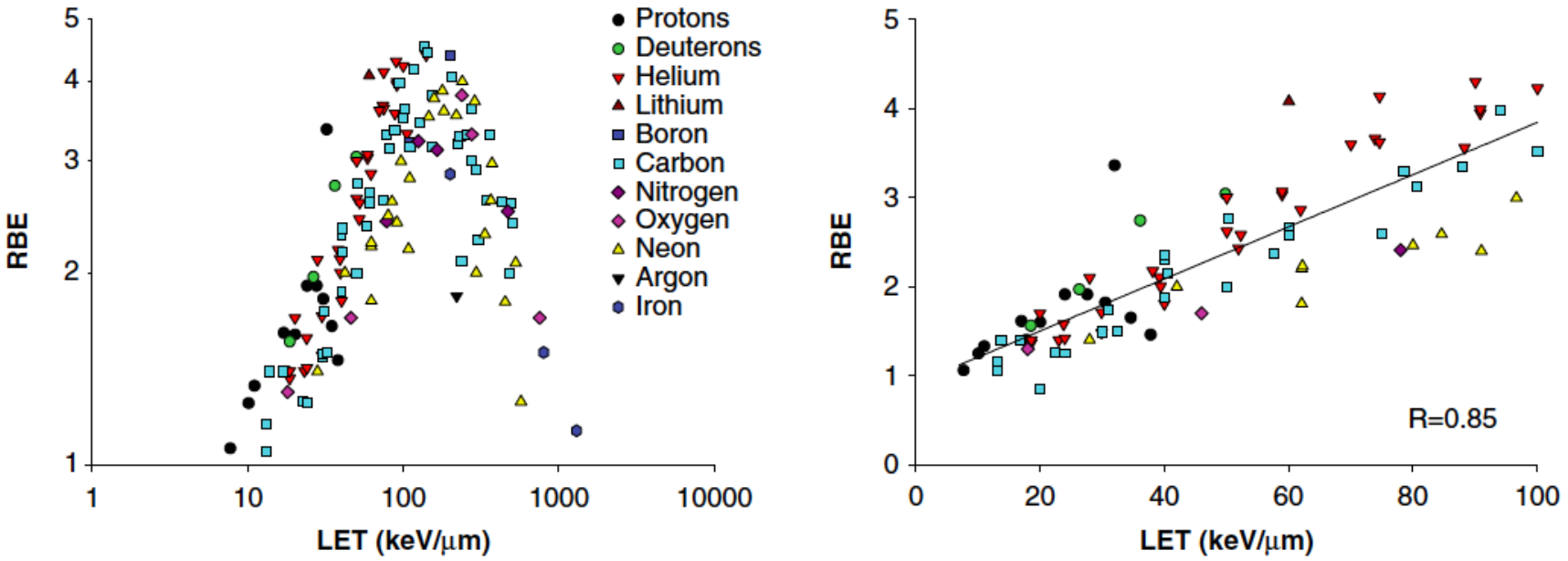
- ✓ Add two more independent data sets (identical conditions) to improve RBE results
- ✓ Perform low LET reference measurements
- Benchmark FLUKA code against measured depth dose distributions.
- Recalculate DDD's for all years with identical code
- Combine all years for final result to publish

ACE will have achieved its goals

- **Once absolute RBE values have been established with error bars comparable to existing knowledge on protons and carbon ions**
- **These values have been used to study specific cancer cases proposed as candidates for antiproton therapy (brain tumors with difficult access channels, re-irradiation, etc.) and clinical judgments have been reached**

RBE Data Base

Multiple experiments by varying institutions using different set-ups and different cell lines



from: Brita Singers Sørensen et al.; Acta Oncologica, 2011; 50: 757–762

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- These values have been used to study specific cancer cases proposed as candidates for antiproton therapy (brain tumors with difficult access channels, re-irradiation, etc.) and clinical judgments have been reached

- **Five independent data sets have been collected and await final analysis of RBE vs. Depth.**
- **Other experiments at the cellular level could be of interest (i.e. DNA damage, repair mechanism on singular cell level, oxygenation, etc) but will require new proposal by the collaboration.**
- **Please keep the capability to deliver MeV beams of antiprotons to a dedicated target station for such experiments and many other potential users of "high" energy antiprotons available.**

Thank You

- **CERN and the SPSC to give us the opportunity to perform these unusual experiments**
- **AD–Team for providing the non-standard extraction scheme to our experiment and for your continued interest in our measurements through the years**
- **AD Users Community for tolerating us, coping with all the real and perceived problems caused by our presence, and for all the help offered over the years.**