# Shielding Calculations for the Target

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*DESY*

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# Outline

- Input conditions
  - Positron source options
  - Target area
  - FLUKA model
- Dose rates near the target without shielding
- Residual dose rate
  - Ordinary concrete shielding
  - Heavy concrete shielding
- FLUKA model extention
- Summary

# Positron Source Options

## Different OMD options:

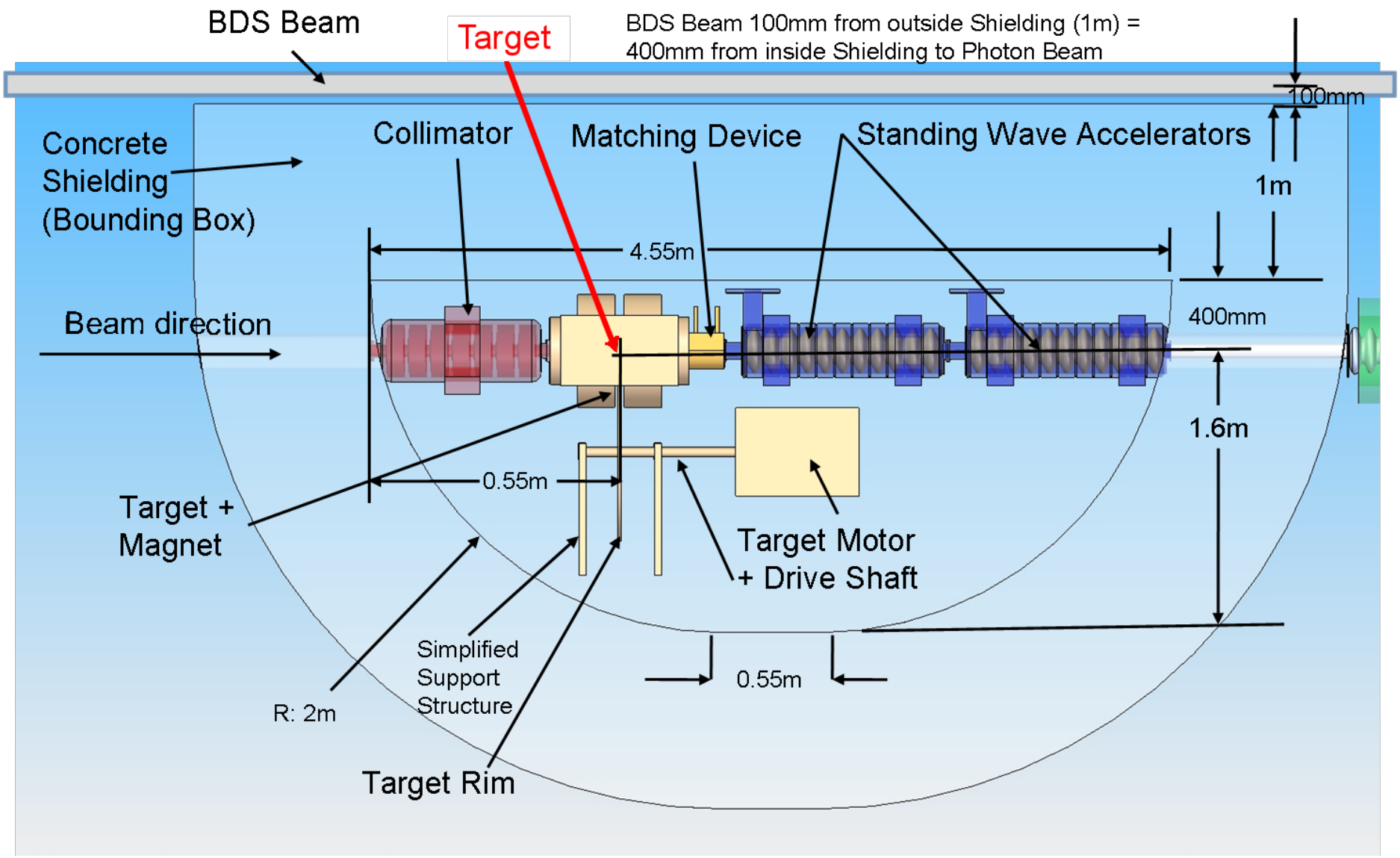
- **AMD, immersed target**: 14 cm long
- **AMD non-immersed target**: 14 cm long
- **Lithium lens**: 2 cm long, 1.4 cm in diameter
- **QWT**: 2 cm long

* OMD optimization studies and required undulator length have been done by Wanming Liu and Wei Gai (ANL)

| $e^+$ source options | **RDR** | **SB2009** |
|---|---|---|
| $e^-$ Drive Beam | | |
| Beam energy, GeV | 150 | 250 |
| No. of $e^-$ per bunch | $2 \cdot 10^{10}$ | |
| No. of bunches per pulse | 2625 | 1312 |
| Positron Yield | | |
| Positron Yield, $e^+/e^-$ | 1.5 | 2 |
| Helical Undulator | | |
| Undulator K-value | 0.92 | |
| Undulator period, cm | 1.15 | |
| Undulator Length*, m | | |
| AMD immersed target | 100 | 50 |
| AMD non-immersed target | 137 | 53 |
| QWT | 231 | 100 |
| Li-Lens | 100 | 40 |
| Ti6Al4V Target, 0.4 $X_0$ | | |

# Concrete Shielding Sketch

provided by Norbert Collomb, Neil Bliss (Science & Technology Facilities Council)



# FLUKA Model

FLUKA allows to calculate in one step:

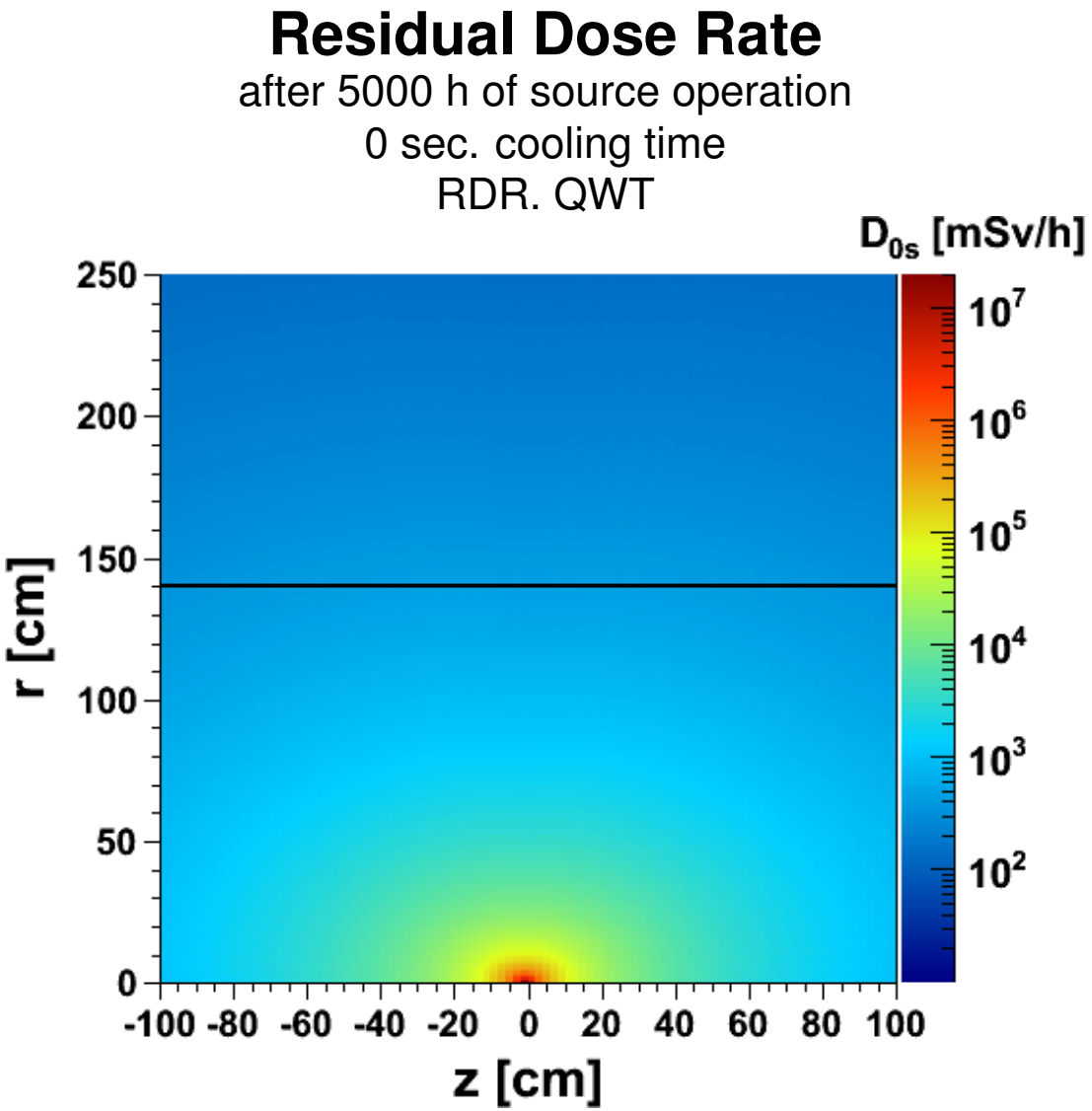
- (activation of source)
- dose rate during source operation
- residual dose rate after 5000 h of source operation and different cooling times:
  - 0 second
  - 1 hour
  - 1 day
  - 1 week

Dose $\equiv$ Ambient Dose Equivalent from ICRP74 and Pelliccioni data (AMB74)

Geometry simplifications:

- **Target**:
  Ti6Al4V disk
  thickness = 1.48 cm,
  radius = 15 mm
- **Vacuum chamber**:
  steel hollow cylinder,
  inner radius = 65 mm,
  thickness = 4 mm
- **Shielding**:
  concrete hollow cylinder,
  inner radius = 40 cm ,
  thickness = 1 m

# Residual Dose Rate. QWT (Target only)




## Dose Rate [mSv/h]

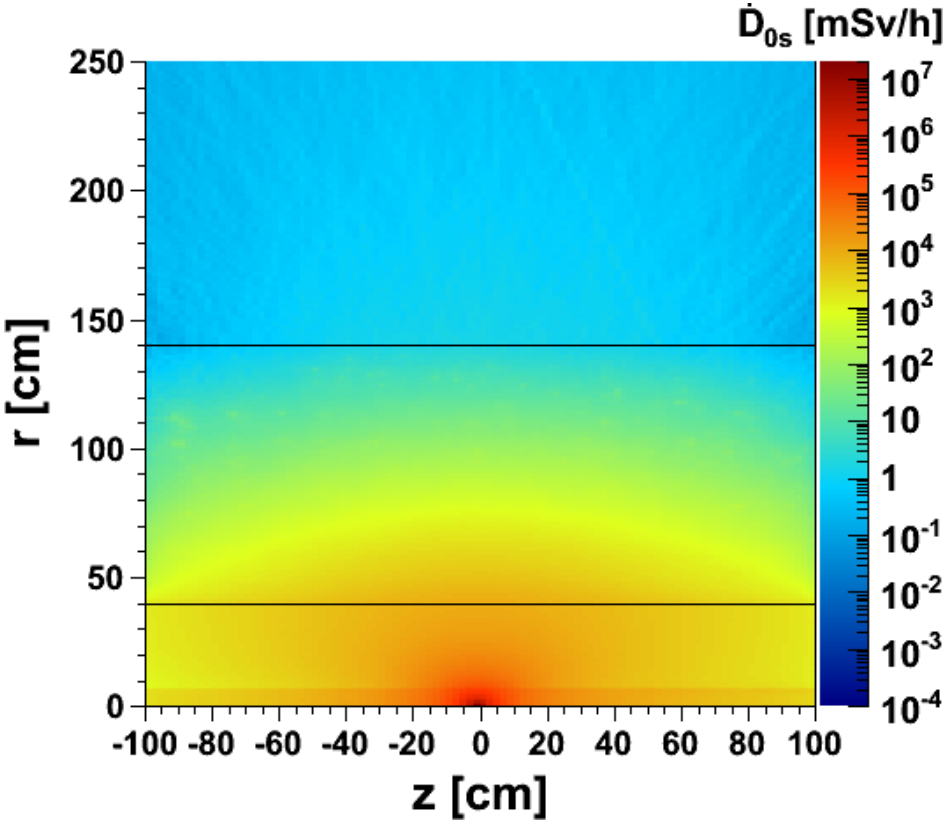
r = 140 cm

QWT, Rotating Target

| Decay Time | RDR | SB2009 |
|---|---|---|
| 0 sec. | 258.4 | 254.2 |
| 1 hour | 208.9 | 213.7 |
| 1 day | 111.0 | 121.3 |
| 1 week | 79.1 | 83.8 |

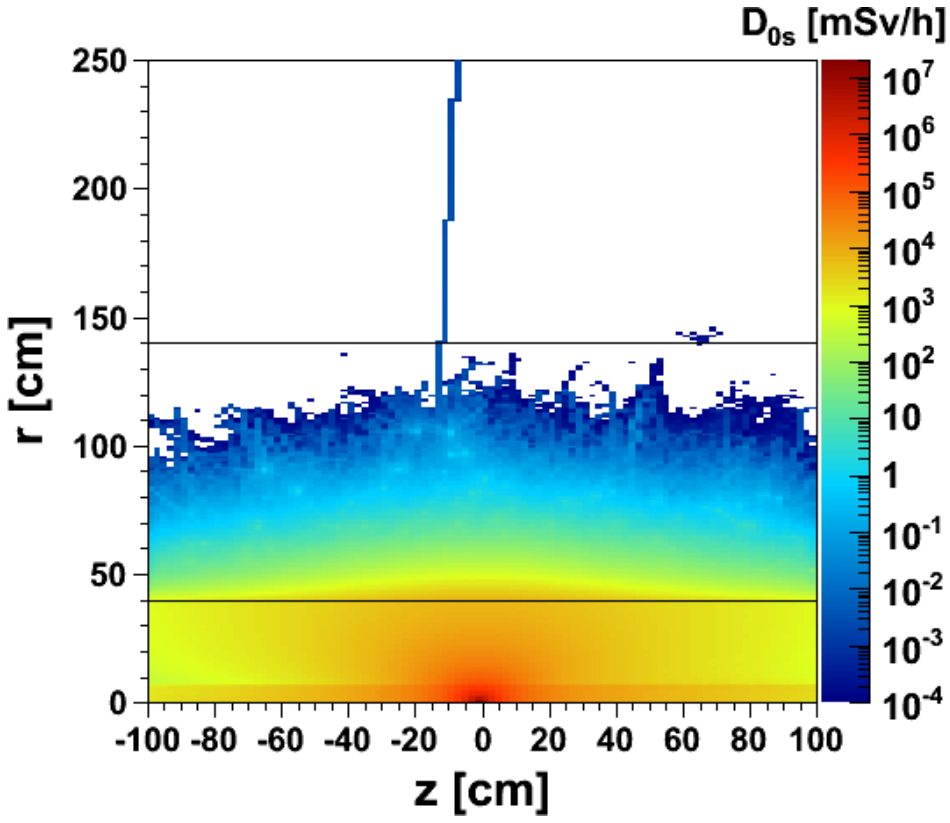
# RDR. QWT. Ordinary and Heavy Concretes

## Ordinary Concrete
($\rho = 2.3$ g/cm$^3$)




$\dot{D}_{0s}$(r = 140 cm) $\approx$ 1.5 mSv/h
$\gg 10\mu$Sv/h

## Heavy Concrete
($\rho = 4.68$ g/cm$^3$)




$\dot{D}_{0s}$(r = 140 cm) $\lesssim 10^{-5}$ mSv/h
$\ll 10\mu$Sv/h

# QWT. Ordinary Concrete. Rotating Target

## Dose Rate at r = 140 cm

| | **RDR** | | **SB2009** | |
|---|---|---|---|---|
| Decay Time | $\dot{D}$, mSv/h | Err, % | $\dot{D}$, mSv/h | Err, % |
| 0 sec. | 0.96 | 4.6 | 1.26 | 8.2 |
| 1 hour | 0.75 | 5.9 | 0.94 | 9.5 |
| 1 day | 0.26 | 6.0 | 0.32 | 9.6 |
| 1 week | $6.3 \cdot 10^{-4}$ | 31.5 | $5.1 \cdot 10^{-4}$ | 24.6 |

# Different OMD. Ordinary Concrete. Rotating Target

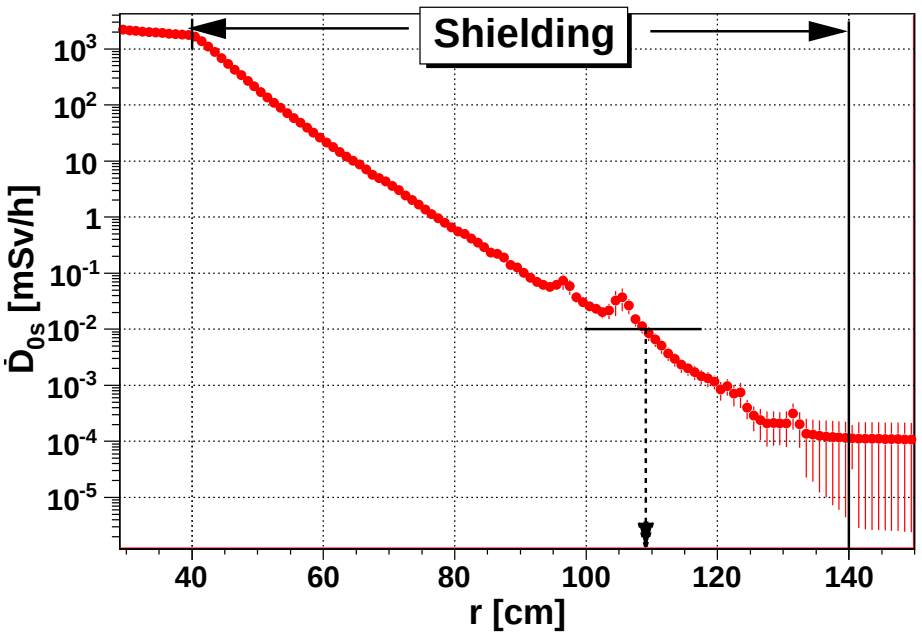
## Dose date at r = 140 cm, decay time = 0 s

$$\dot{D}_{0s}(r = 140 \text{ cm}) \text{ [mSv/h]}$$

| OMD | **RDR** | **SB2009** |
|---|---|---|
| AMD immersed target | 0.41 | 0.63 |
| AMD non-immersed target | 0.57 | 0.67 |
| QWT | 0.96 | 1.26 |
| Li-lens | 0.41 | 0.5 |

# QWT. Heavy Concrete
## "Required" Thickness of Concrete

RDR. QWT. Heavy Concrete




Radius [cm],
where $\dot{D}_{0s}$ = 10 $\mu$Sv/h

| OMD | **RDR** | **SB2009** |
|---|---|---|
| AMD imm. | 101.4 | 117.6 |
| AMD non-imm. | 102.7 | 117.8 |
| QWT | 109.1 | 118.7 |
| Li-lens | 101.4 | 117.2 |

Thickness of shielding $\lesssim$ 80 cm

# FLUKA Model Modifications

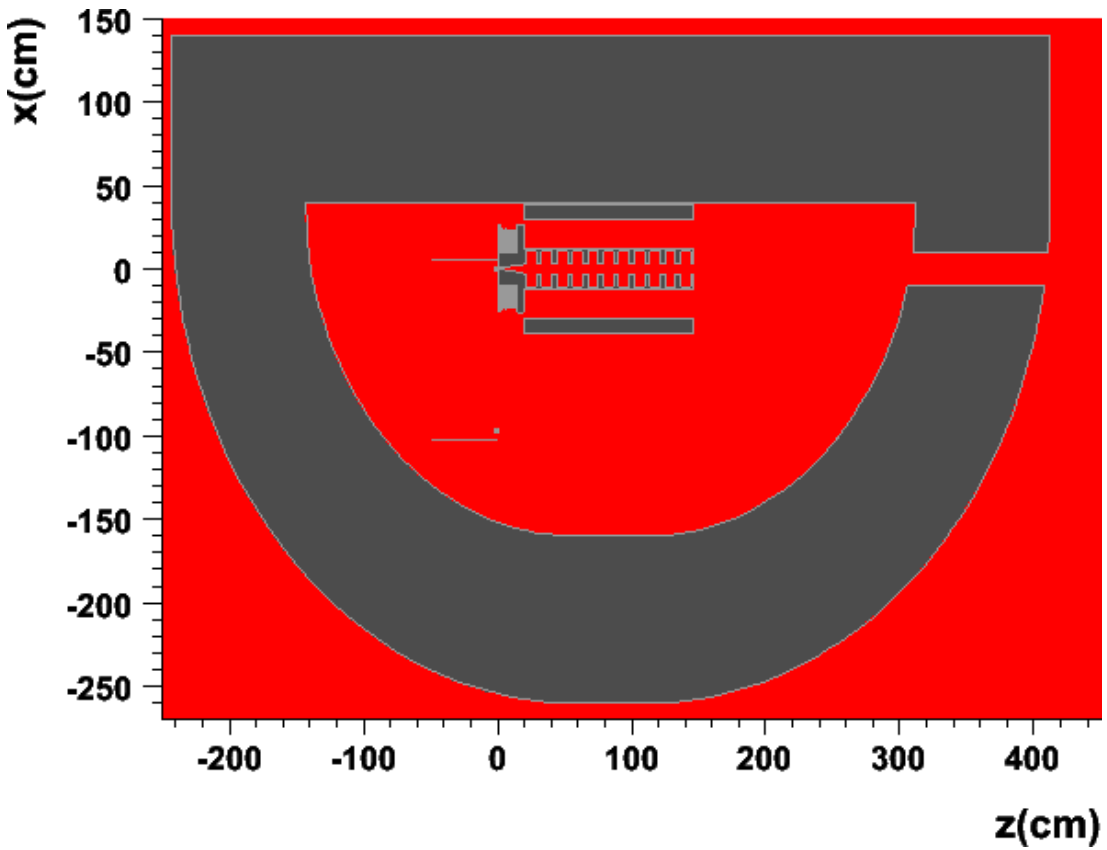
**Modified:**

- Concrete box
- Target rim (water cooled)
- Vacuum chamber

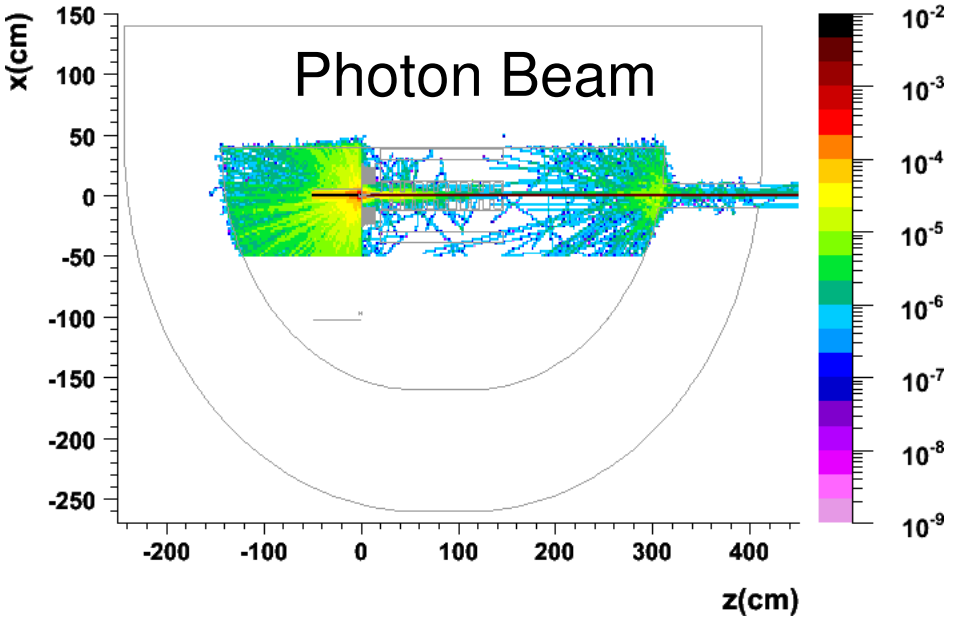
**Added:**

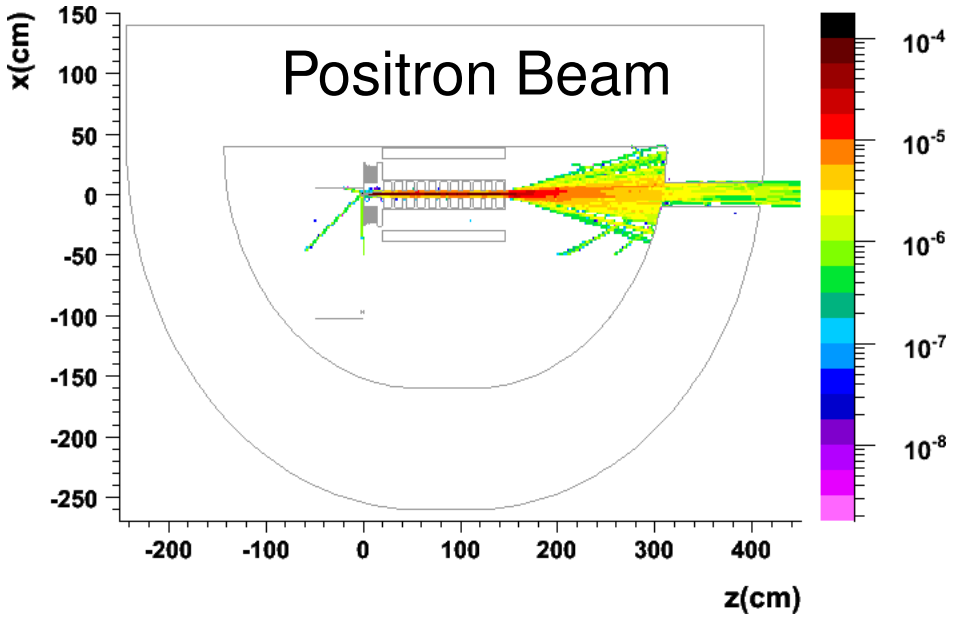
- AMD (20 cm long)
- 1st RF cavity (11 cell)
- 0.5 T solenoid

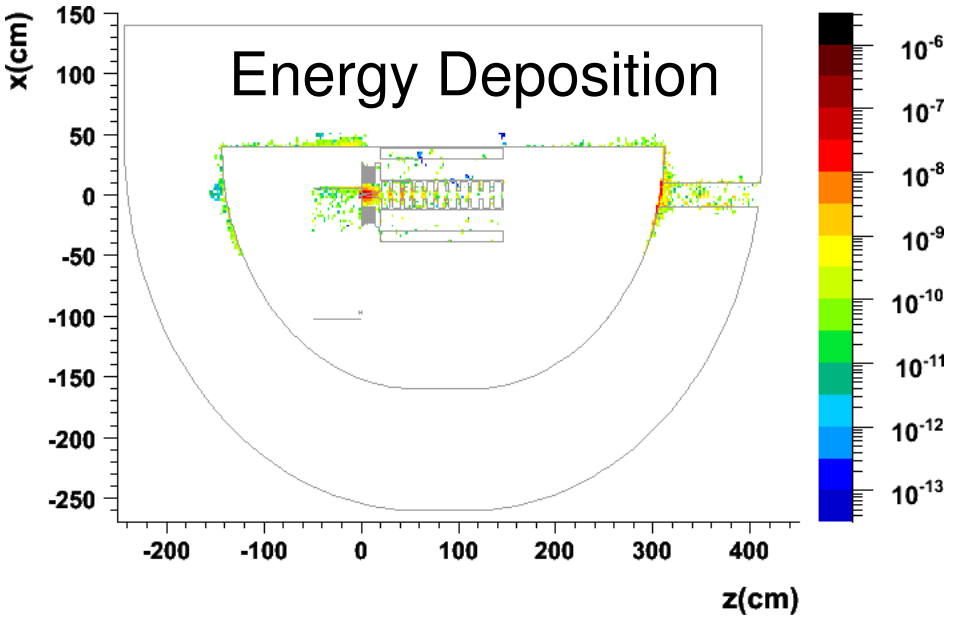
✓ AMD field
✓ Solenoid field
no Electric field



# Photon and Positron Beams, Energy Deposition



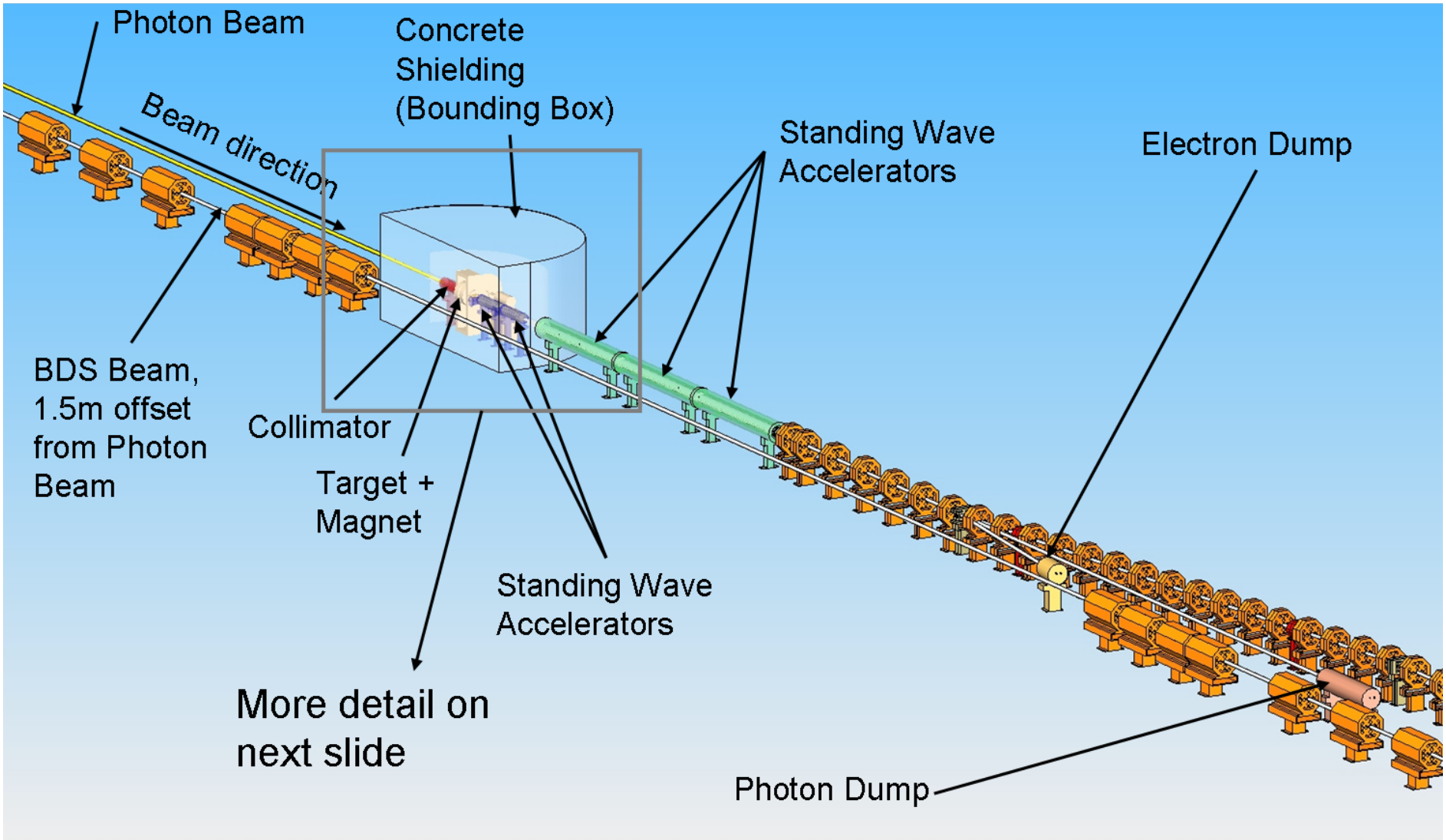



# Summary and Outlook

- Estimations of dose rates for different OMD options give similar results (the highest rate is for QWT)
- Residual dose rates have been calculated for ordinary and heavy concretes:
  - 1 m thick ordinary concrete shielding is not sufficient,
  - heavy concrete shielding with thickness $\sim$80 cm should be enough
- Future plans: Simulations of more sophisticated geometry model

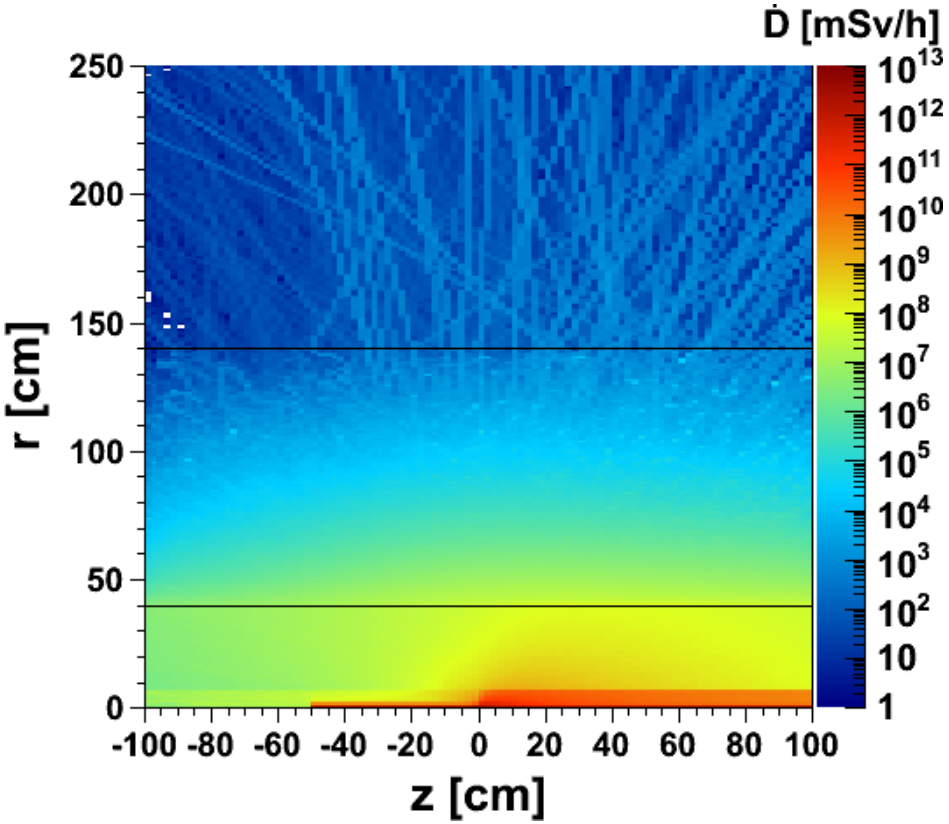
# Provisional Target Area Sketch

provided by Norbert Collomb, Neil Bliss (Science & Technology Facilities Council)

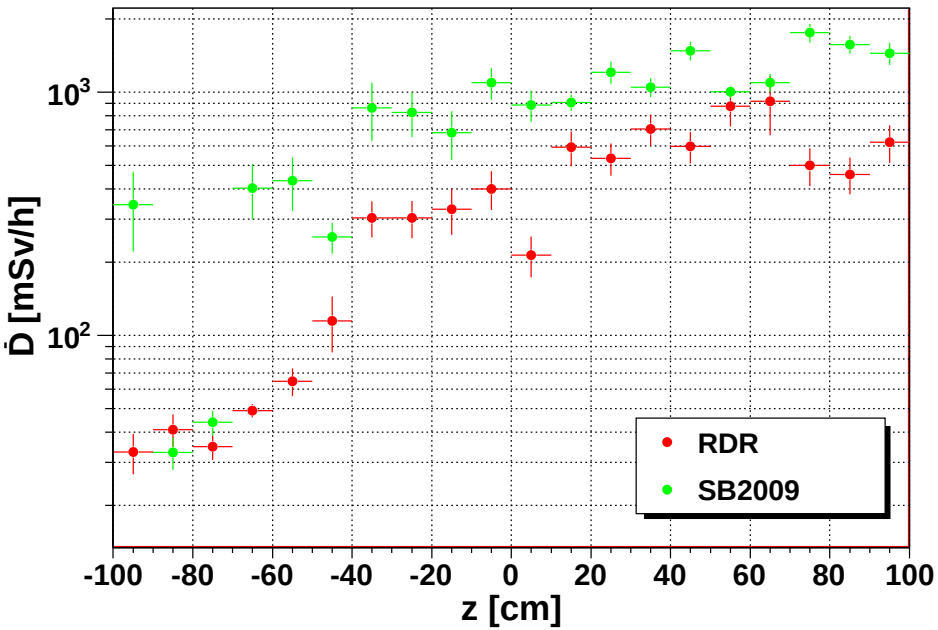


# Dose Rates during Source Operation

RDR. QWT. Ordinary Concrete




Dose Rate along Z (R = 140 cm)
QWT. Ordinary Concrete.
RDR and SB2009




Behind the concrete shielding:
Dose rates during source operation approx. **1000** times higher than residual dose rates

# Concrete Composition

| | Ordinary | Heavy |
|---|---|---|
| Density, g/cm$^3$ | 2.3 | 4.68 |
| H | 1.0 | 0.89 |
| C | 0.1 | 0.55 |
| O | 52.9 | 37.07 |
| Na | 1.6 | 0.14 |
| K | 1.3 | 0.12 |
| Mg | 0.2 | 0.36 |
| Al | 3.4 | 0.80 |
| Si | 33.7 | 2.45 |
| S | 0.0 | 0.29 |
| Ca | 4.4 | 9.98 |
| Fe | 1.4 | 47.35 |