Positron source: Target shielding studies

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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
- Dose rates during source operation (prompt radiation)
- Summary

Positron Source Options

Different OMD options:

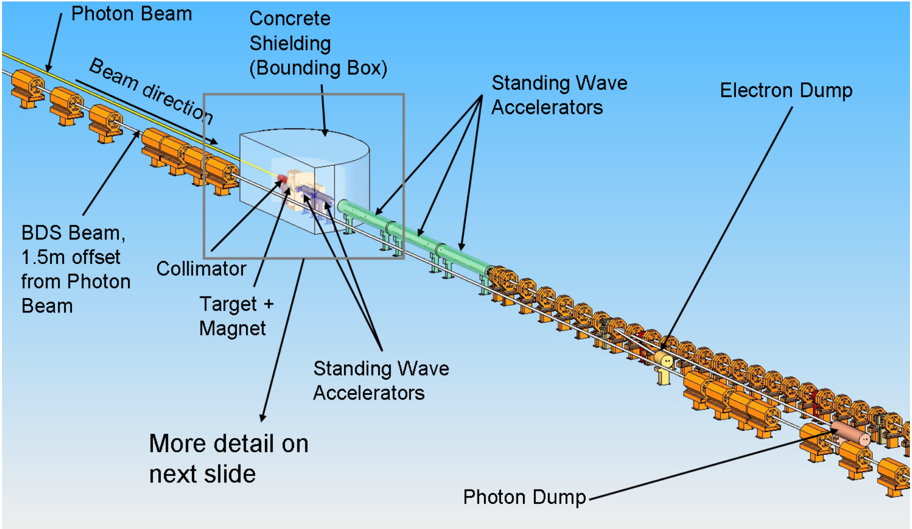
- **AMD, immersed target**: 14 cm long
- **AMD non-immersed target**: 14 cm long
- **Lithium lens**: 2 cm long, 1.4 cm in diameter
- **QWT**: 2 cm long

* 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		

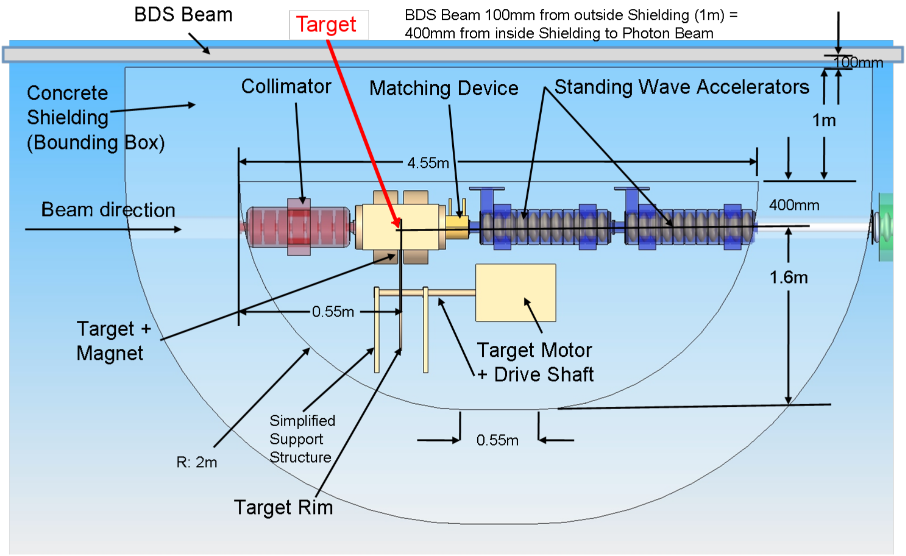
Provisional Target Area Sketch

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



Concrete Shielding Sketch

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



FLUKA Model

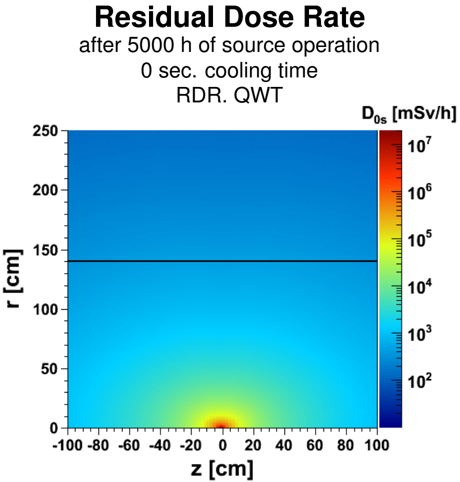
FLUKA allows to calculate in one step:

- (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

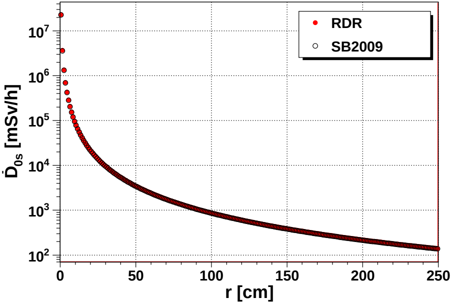
Dose $\equiv$ Ambient Dose Equivalent from ICRP74 and Pelliccioni data (AMB74)

Geometry simplifications:

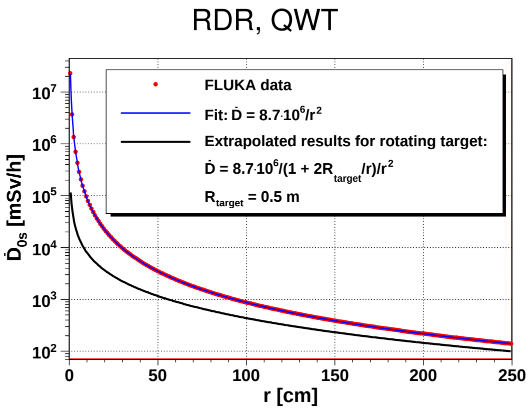
- **Target**:
  Ti6Al4V disk
  thickness = 1.48 cm,
  radius = 15 mm
  no rotation
- **Vacuum chamber**:
  steel hollow cylinder,
  inner radius = 65 mm,
  thickness = 4 mm
- **Shielding**:
  concrete hollow cylinder,
  inner radius = 40 cm ,
  thickness = 1 m



RDR (231 m Undulator)
SB2009 (100 m Undulator)



Dose Rates: QWT (Target only, with Rotation)



Extrapolation from original (non-rotating) data to rotating target:

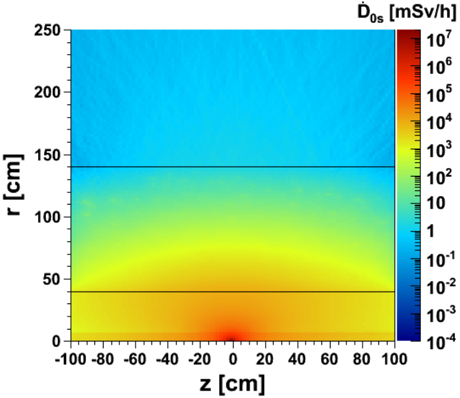
$$\dot{D} = \dot{D}_{\text{original}} \Big/ \left(1 + \frac{2R_{\text{target}}}{r}\right)$$

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

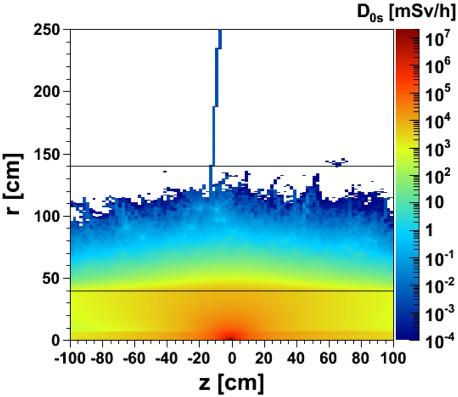
RDR. QWT. Ordinary and Heavy Concretes

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



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

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



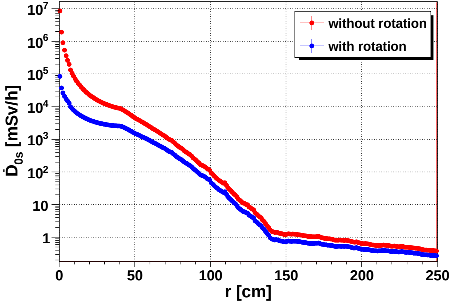
$\dot{D}_{0s}$(r = 140 cm) $\lesssim 10^{-5}$ mSv/h
$\ll$ 10μSv/h

Concrete Composition

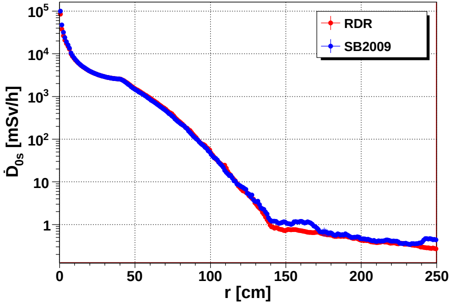
	Ordinary	Heavy
Density, g/cm^3	2.3	4.68
H	1.0	0.89
C	0.1	0.55
O	52.9	37.07
Na	1.6	0.14
K	1.3	0.12
Mg	0.2	0.36
Al	3.4	0.80
Si	33.7	2.45
S	0.0	0.29
Ca	4.4	9.98
Fe	1.4	47.35

QWT. Ordinary Concrete. Radial Profile of Dose Rate

RDR. QWT. Ordinary Concrete



Rotating Target



Dose Rate at r = 140 cm

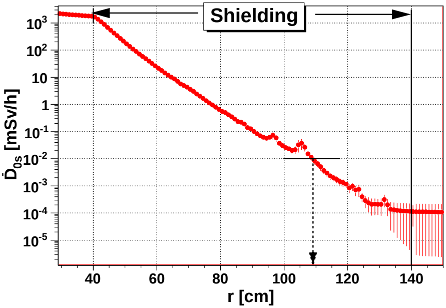
	RDR		SB2009	
Decay Time	$\dot{D}$, mSv/h	Err, %	$\dot{D}$, mSv/h	Err, %
0 sec.	0.96	4.6	1.26	8.2
1 hour	0.75	5.9	0.94	9.5
1 day	0.26	6.0	0.32	9.6
1 week	$6.3 \cdot 10^{-4}$	31.5	$5.1 \cdot 10^{-4}$	24.6

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

RDR. QWT. Heavy Concrete



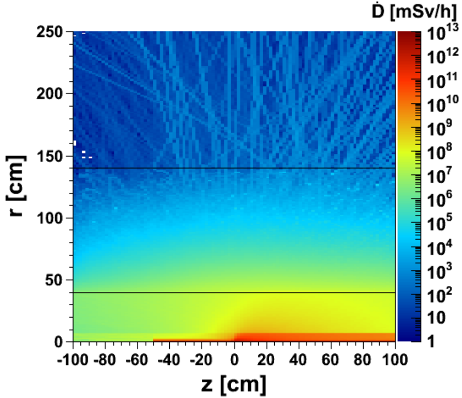
Radius [cm],
where $\dot{D}_{0s}$ = 10 μSv/h

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

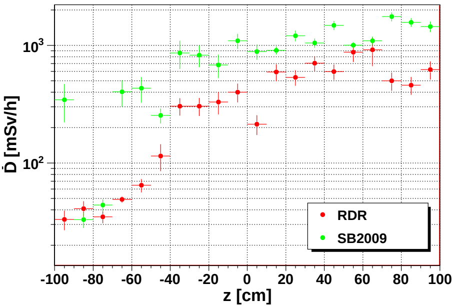
Thickness of shielding $\lesssim$ 80 cm

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

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
- Dose rate during source operation has been estimated
- Future plans: Simulations of more sophisticated geometry model