Dose Calculation in Brachytherapy

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Introduction

- Given a radiation field, the fluence rate distribution is governed by Linear Boltzman equation.
- Dose deposition is determined from the electron fluence rate.

NET FLOW (out) = + SCATTER-IN − SCATTER-OUT + ABSORBED

Boundary Condition = Fluence Rate Entering (Gantry Head)

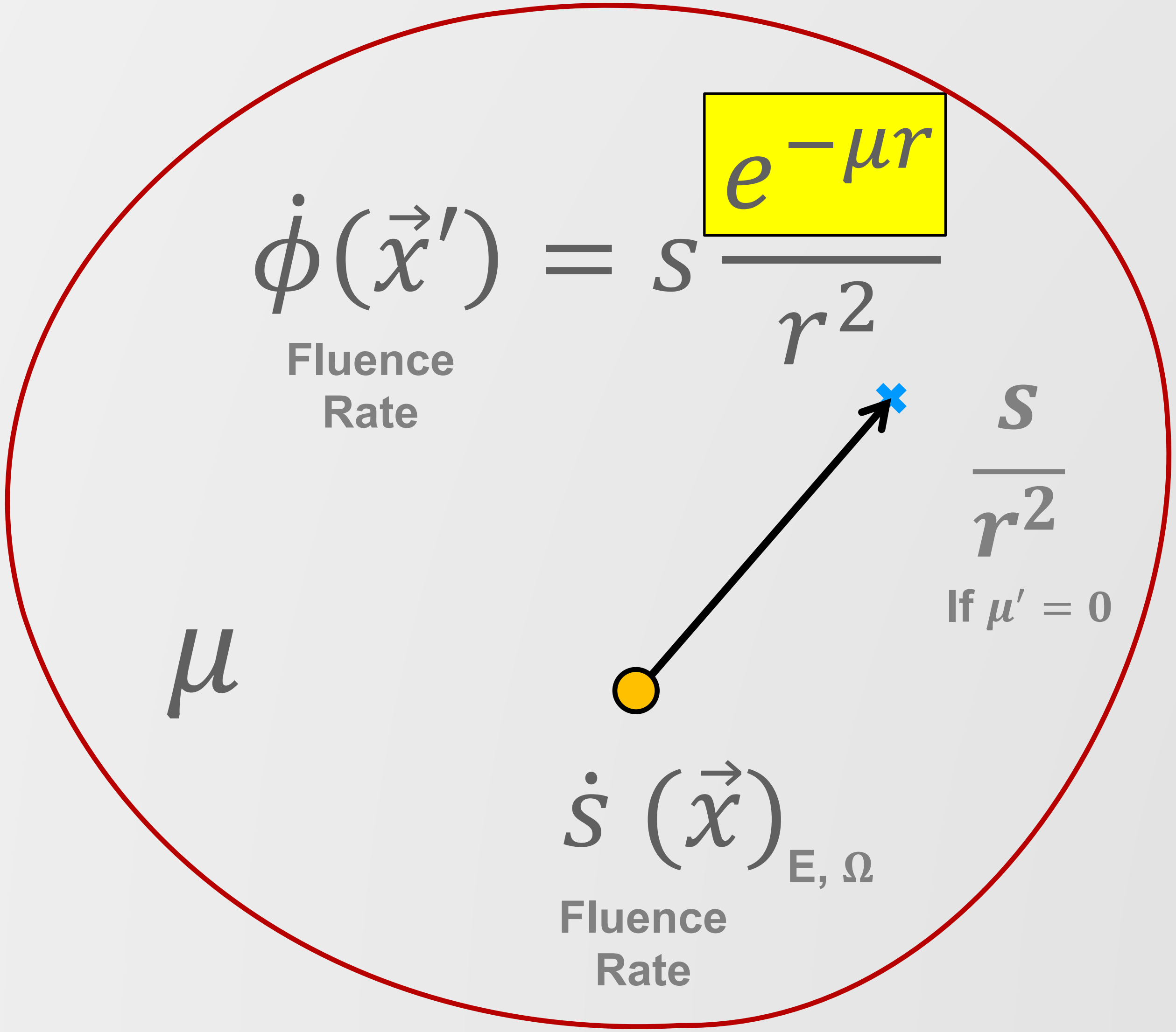
Introduction

- Brachytherapy adds an internal source.

NET FLOW (out) = + SCATTER-IN − SCATTER-OUT + ABSORBED + source

Boundary Condition = Nothing Enters

Point Source Model

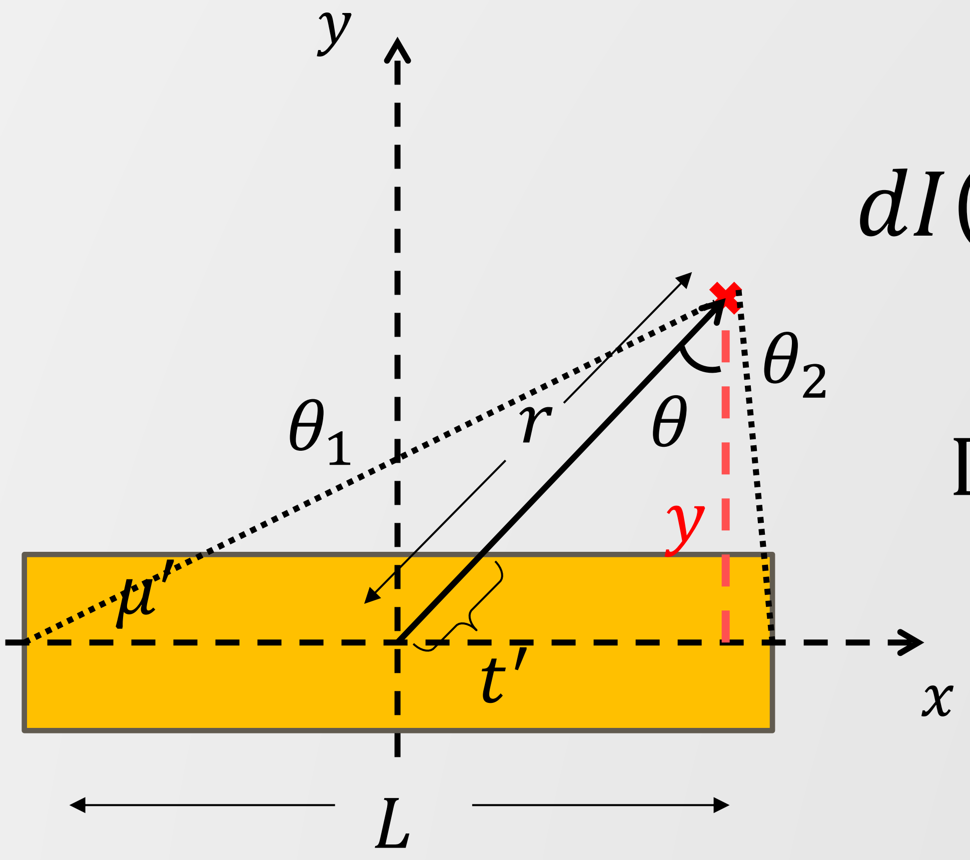


Build up

$$\dot{D} = B_r \dot{\phi}(\vec{x}')\left(\frac{\mu}{\rho}\right)$$

- ✗ Scatter photon fluence
- ✗ Electron fluence

Line Source Model (Silvert integral)



Fluence Rate

$$dI(x,y) = \dot{S}\frac{dx}{L}\cdot\frac{1}{r^2}\cdot e^{-\mu'\cdot t\cdot\sec\theta}$$

$$\dot{\mathrm{D}} \sim \dot{\Phi}(x,y) = \int dI(x,y)$$

$$= \frac{\dot{S}}{Ly} e^{\mu' t}\int_{\theta_1}^{\theta_2} e^{-\mu'.t.\sec\theta}\, d\theta$$

$$= \frac{\dot{S}}{Ly}(\theta_2 - \theta_1)$$

$\theta \neq 0, \pi$

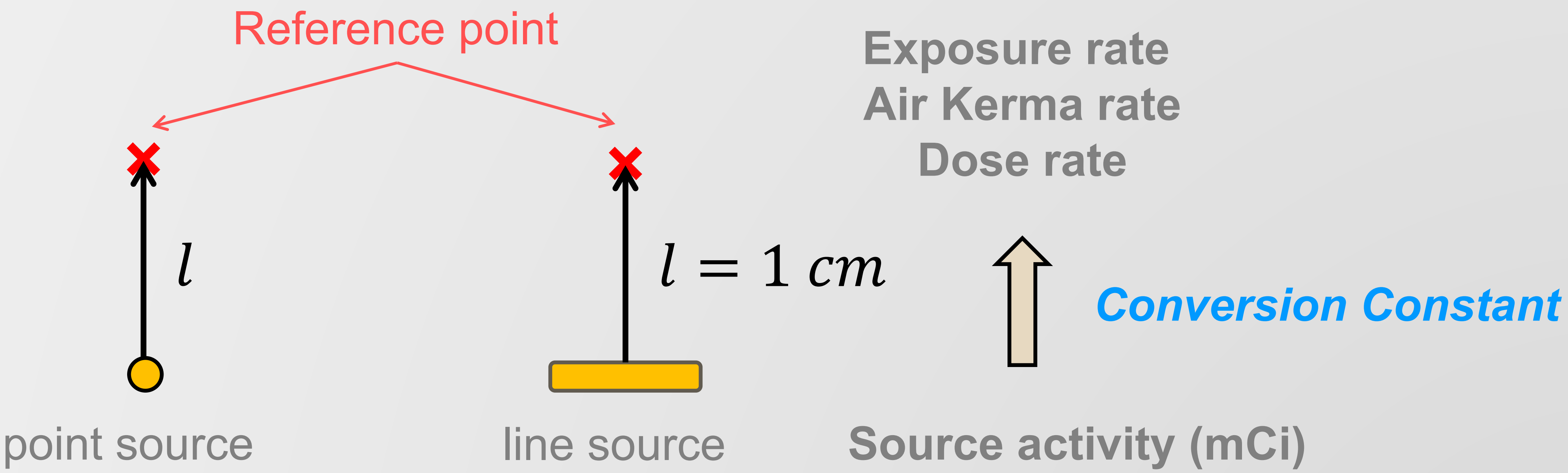
If $\mu' = 0$

- ✗ Scatter photon fluence
- ✗ Electron fluence

Limitation

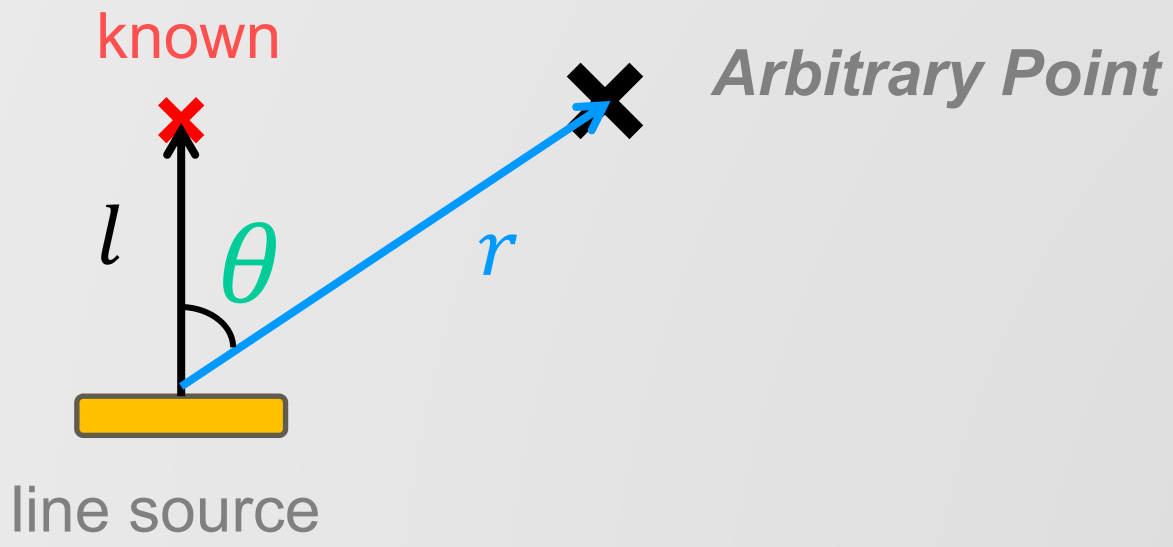
✕ Scatter photon fluence	➡	Scatter photon in air
✕ Electron fluence	➡	High energy photon
✕ Photon attenuation	➡	Capsulation, Tissue

Reference Point



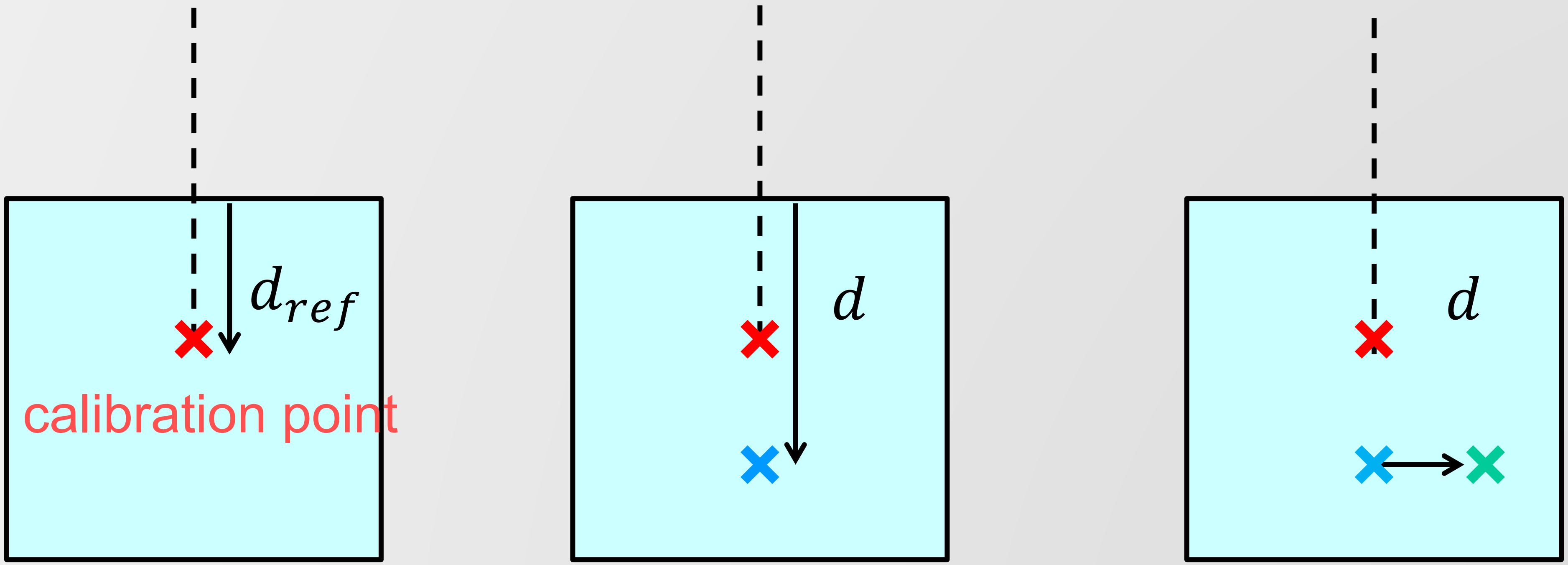
Pivot Question

How to infer the dose rate at arbitrary location of the medium given the reference point dose rate?



Analogy to EBRT: TG-51, TG-71

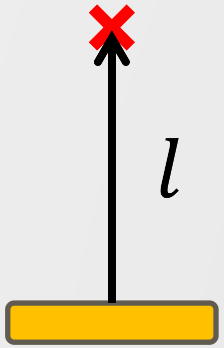
$k_q D_w$ $\quad$ $\text{PDD}(d)$ $\quad$ $\text{OAR}(d, r)$



Machine, Energy, Field Size

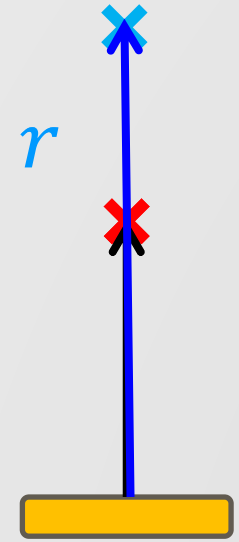
Back to Brachytherapy: TG-43 (U)

Γ_{q}



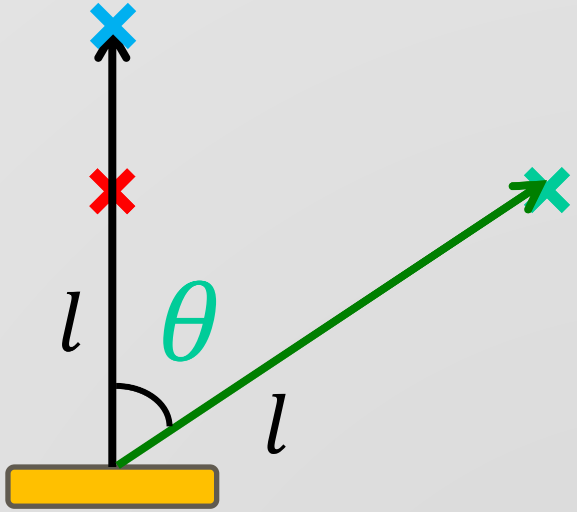
Source Type
construction
Capsulation

$g^*(r)$



Source

$F(r, \theta)$



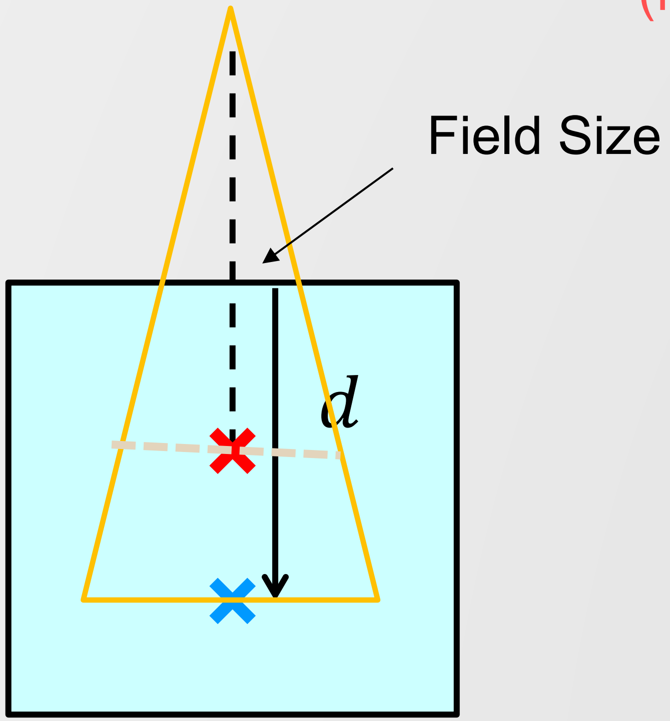
Source

Geometric factor

$$\mathrm{PDD}(d)$$

Geometric Falloff
(inverse square)

Scatter photon
(field size)



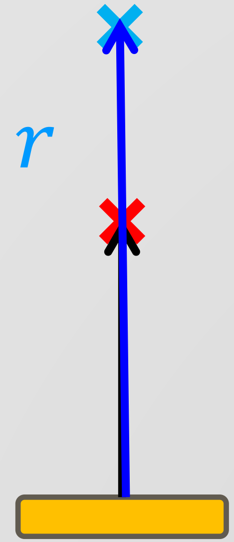
$$g(r)$$

Scatter photon
(field size)

Geometric Falloff
(inverse square)

$$\times G(r, \theta)$$

- point $\frac{1}{r^2}$
- line $\frac{(\theta_2 - \theta_1)}{Ly}$



construction

Air-Kerma Strength

Lab → User

Calibration (In Vacuo) | ***Reference Point***

Exposure rate
Air Kerma rate
Dose rate

→ $\dot{K}_\delta(d)$ $\dot{D}(r_0, \theta_0)$

Conversion Constant

Dose Rate Constant Γ

Source activity (mCi) ⇄ $S_K = \dot{K}_\delta(d) d^2$

Air Kerma Strength

$(1\ U = \mu Gy \cdot m^2 \cdot h^{-1})$

10 Ci Ir-192 ~ 40,000 U

$$\Lambda = \frac{D(r_0, \theta_0)}{S_K}$$

Common Sources

Source	Half Life	Mean Gamma Energy (Mev)	Decay Mode	HVL (mm Pb)
Ir-192	73.8 d	0.372	Beta	3.0
I-125	59.4 d	0.036	Electron Cap	0.02
Pd-103	17.0 d	0.021	Electron Cap	0.008
Cs-137	30.1 y	0.662	Beta	7.0
Co-60	5.26 y	1.25	Beta	11.0

About TG43

- AAPM Task Group 43 report (1994) proposed a standardized dose calculation formula for LDR interstitial sources: Ir-192, I-127, and Pd-103.
- The report was updated in 2004 to implement new calibration standards and many new sources.
- TG43U1S1 (2007) - Consensus data sets for new I-125 and Pd-103 sources

Summary

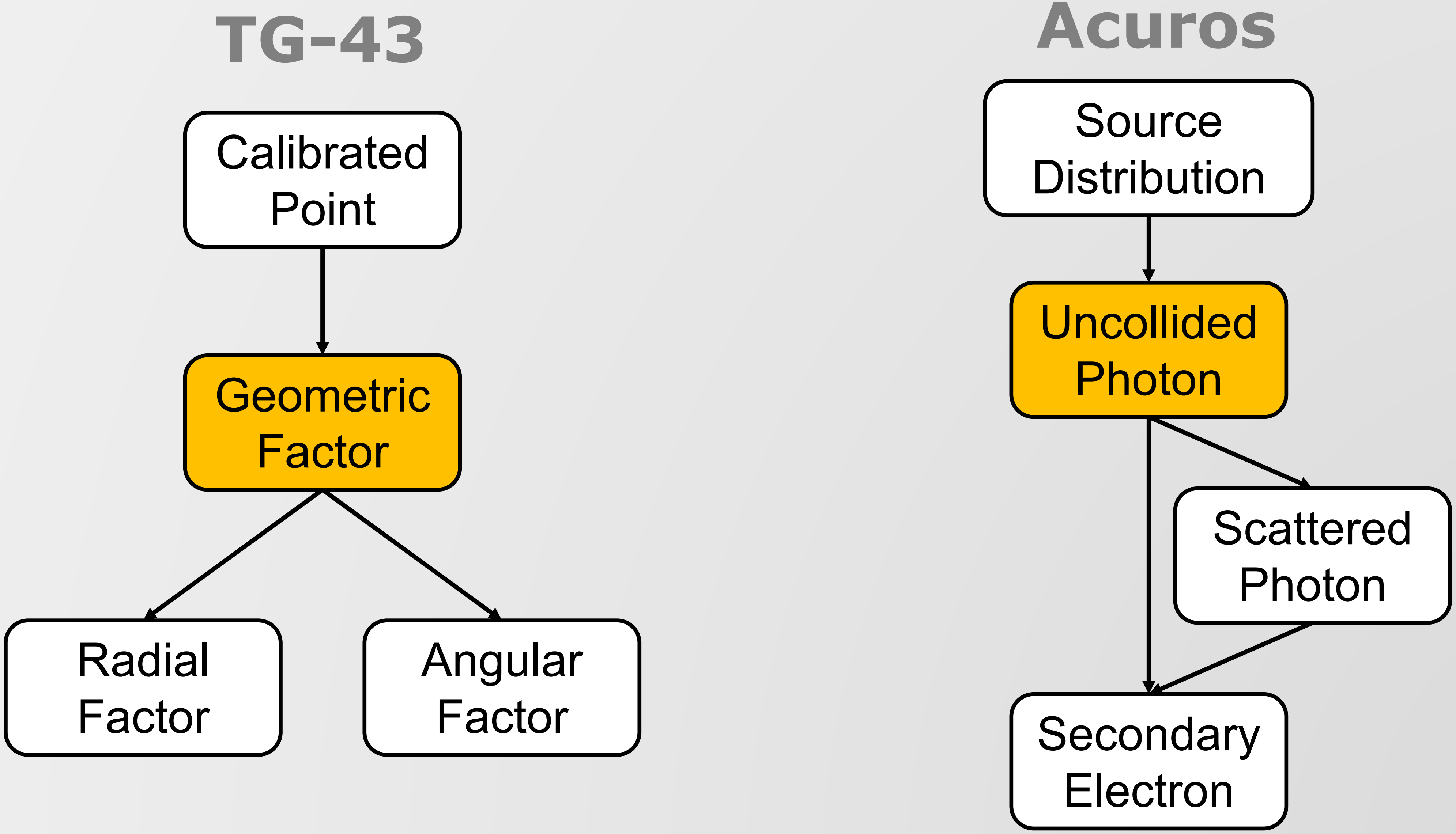
Uncollided
Unattenuated

$$\dot{D}(r,\theta) = \frac{S_K \Lambda}{G(r_0,\theta_0)} G(r,\theta) g(r) F(r,\theta)$$

Reference Point

Tabulated Tabulated

TG-43 vs Acuros



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