Analytical approach for 3D detectors engineering

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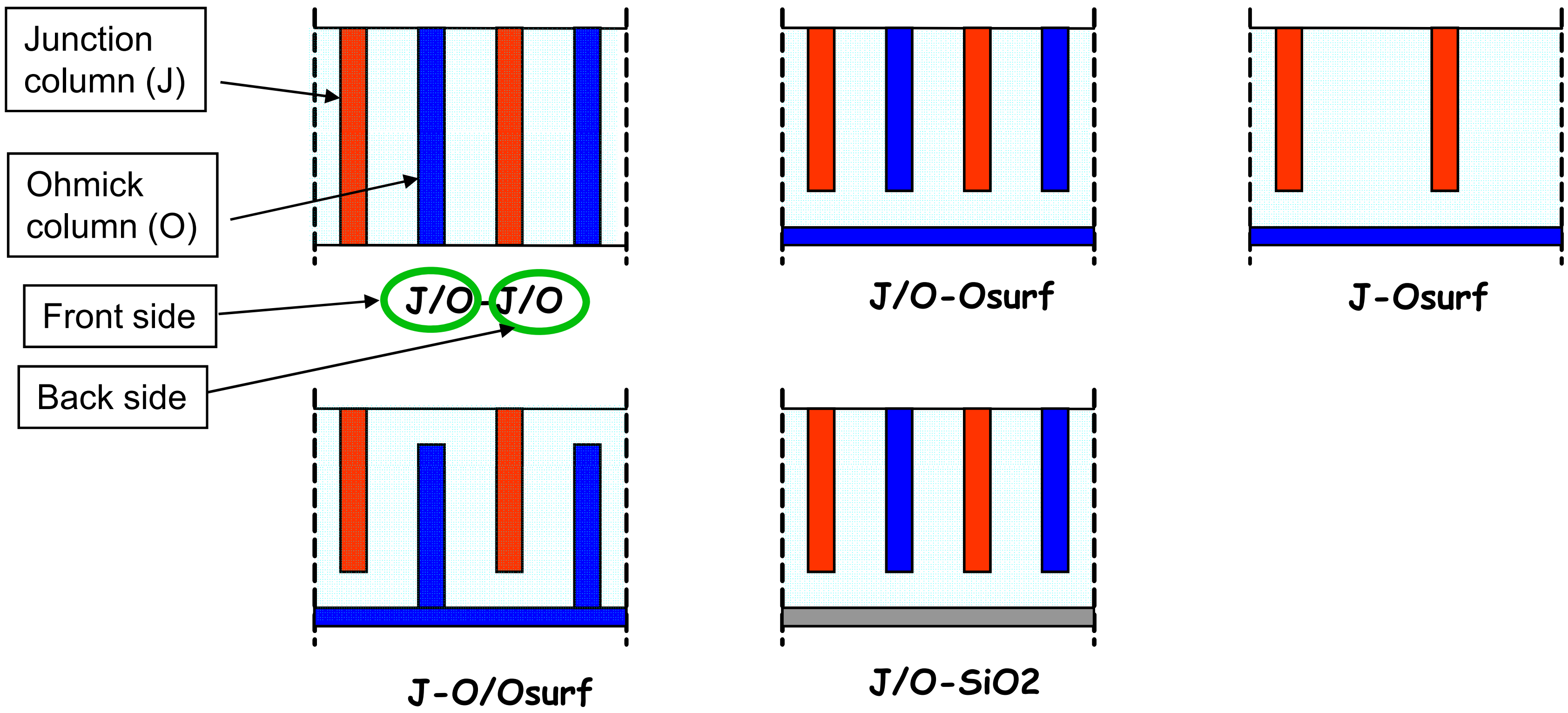
RD50 13-th meeting, CERN, 10-12 November, 2008

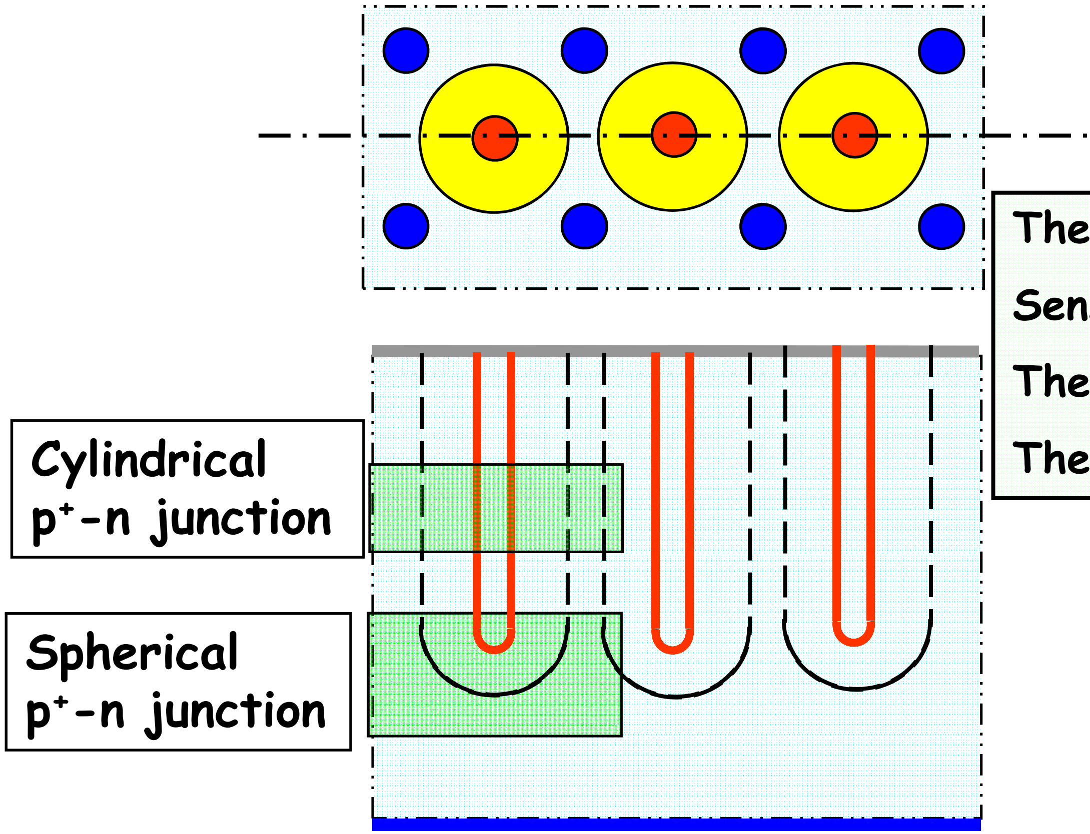
Outline

1. Typical constructions of 3D detectors
2. Electric field in 3D detectors
3. Radiation effects in 3D detectors
4. Conclusions

Typical 3D detector constructions



The Large Scale Model and operational parameters



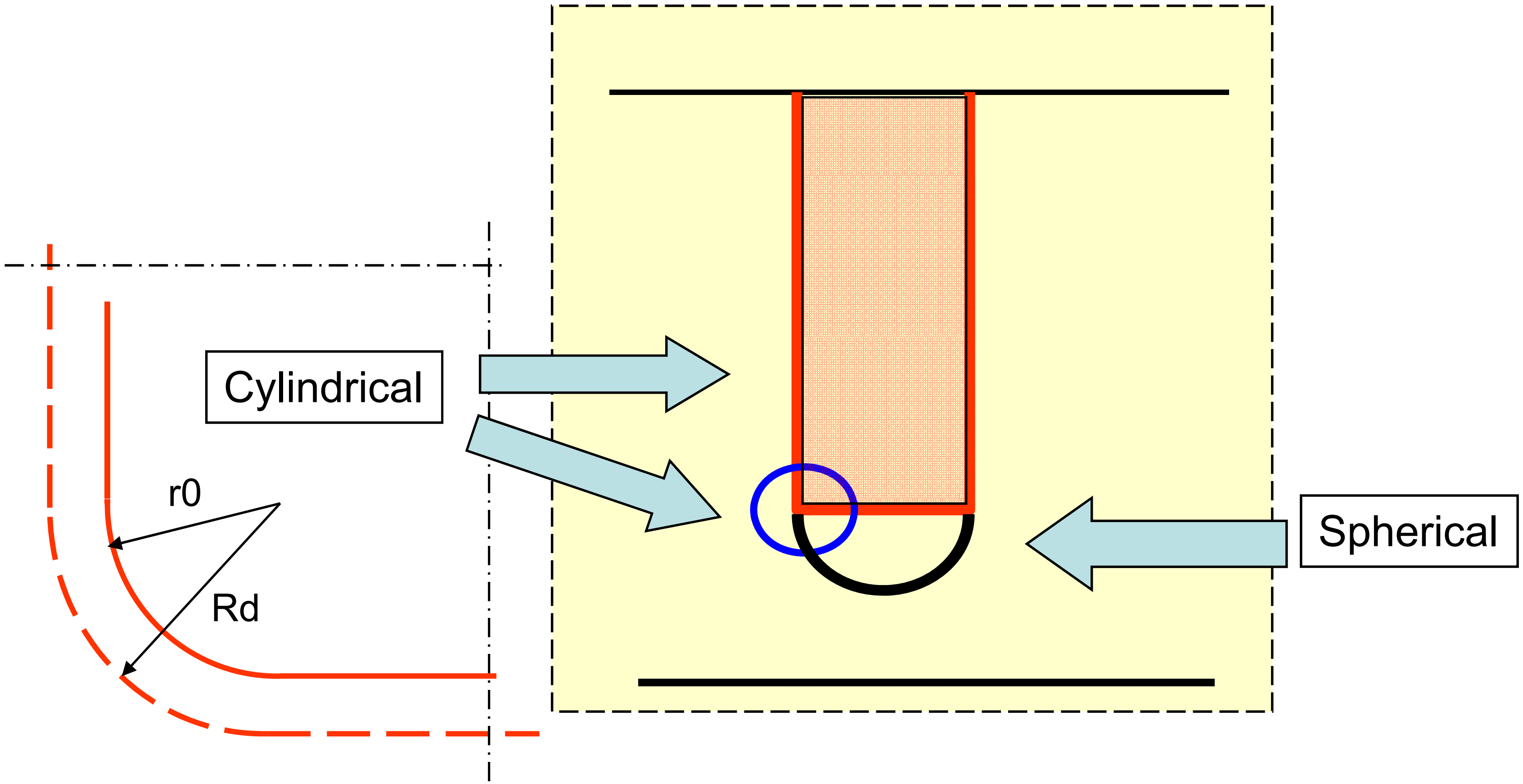
The depleted radius (Rd)

Sensitive volume (S)

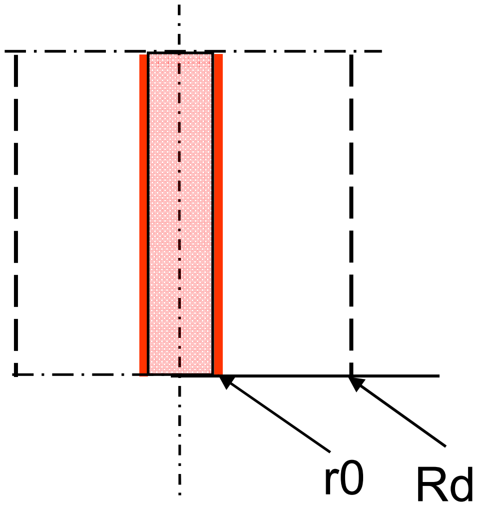
The pinch-off voltage (Vpf)

The maximum operational voltage (Vm)

The critical regions of 3D detectors

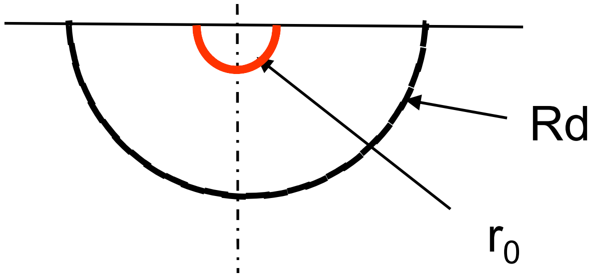


The main equations



$$\frac{1}{r}\frac{d}{dr}\left(r\frac{d\varphi}{dr}\right) = -\frac{q_0 N_{eff}}{\varepsilon\varepsilon_0}$$

$$E(r) = \frac{q_0 N_{eff}}{2\varepsilon\varepsilon_0} r\left[\left(\frac{R_d}{r}\right)^2 - 1\right]$$

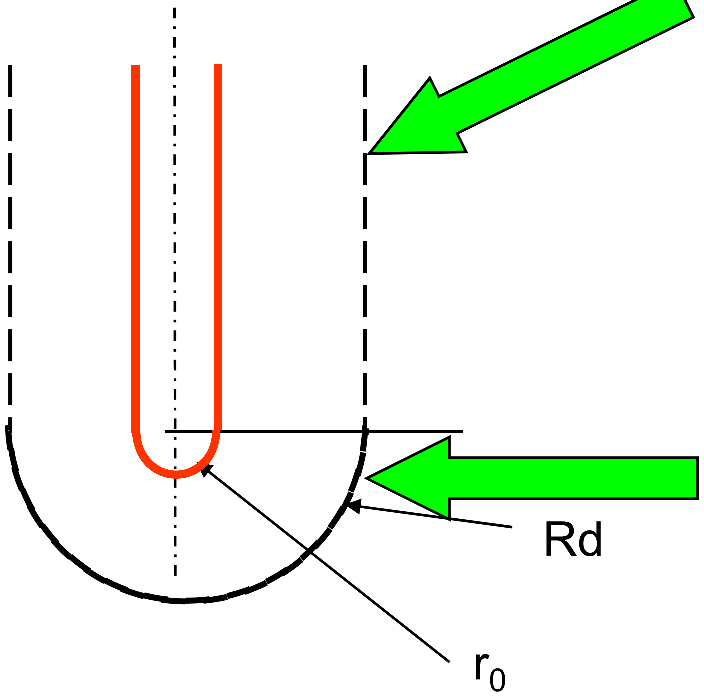


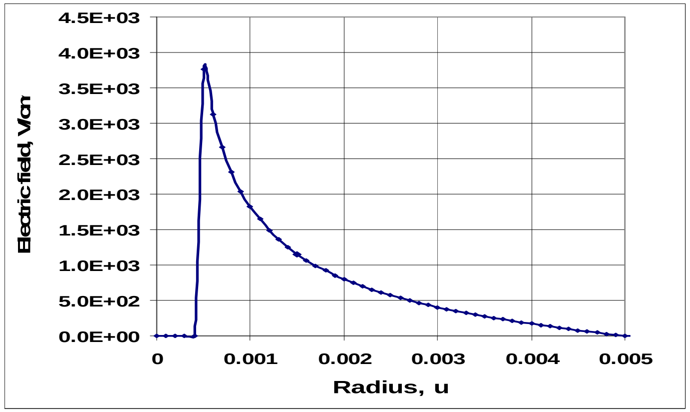
$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d\varphi}{dr}\right) = -\frac{q_0 N_{eff}}{\varepsilon\varepsilon_0}$$

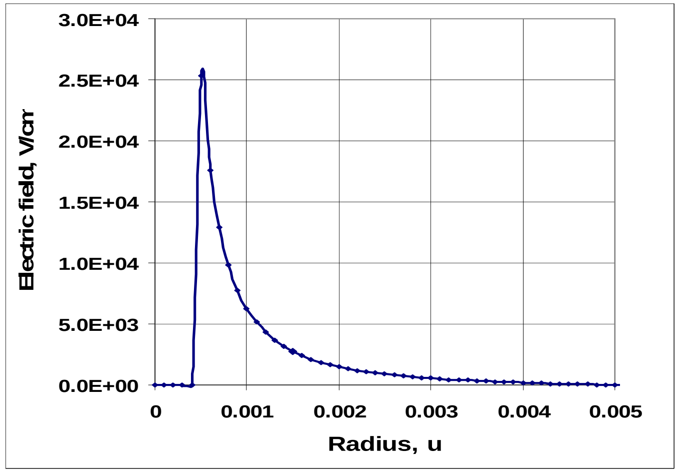
$$E(r) = \frac{q_0 N_{eff}}{3\varepsilon\varepsilon_0} r\left[\left(\frac{R_d}{r}\right)^3 - 1\right]$$

The electric field distribution around the column

$N_{eff}=10^{12}cm^{-3}$
r0=5u
Rd=50u

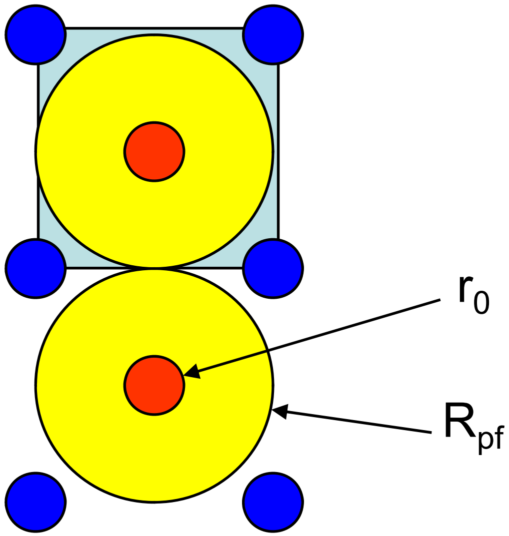


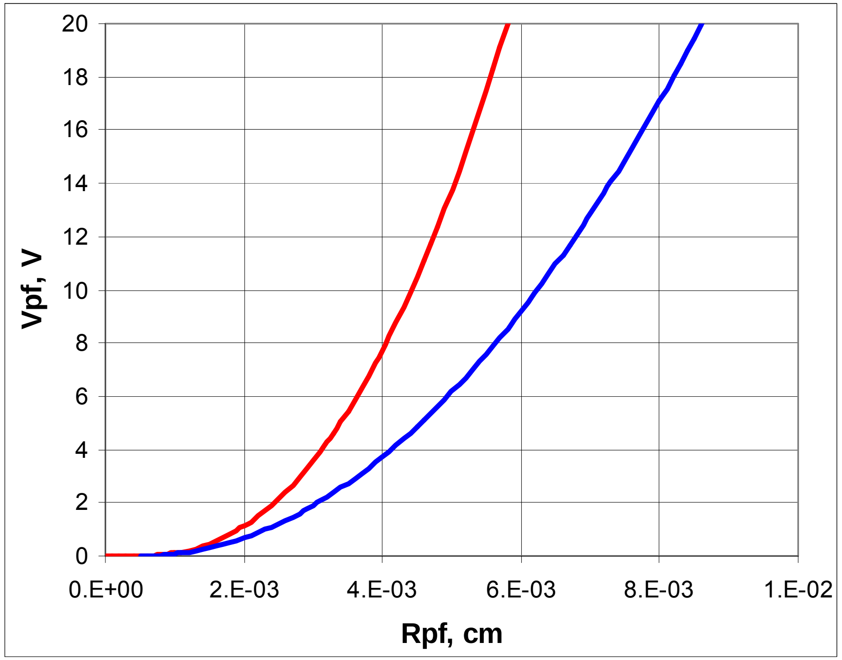




The pinch-off voltage

MCZ: 1k cm
$N_{eff}=4x10^{12}cm^{-3}$
r0=5u
Rpf=50u





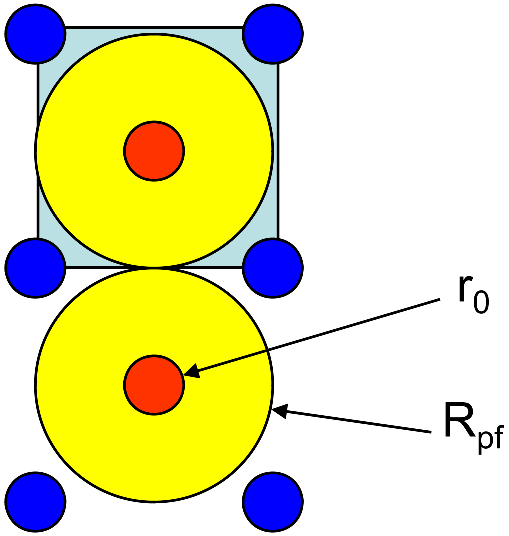
$$S = \pi \cdot R_{pf}^{\ 2}$$

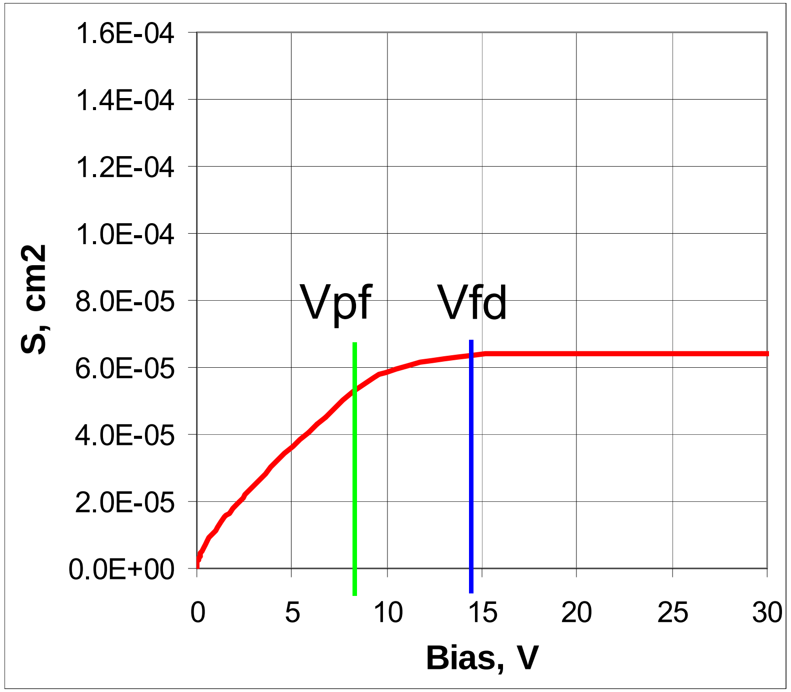
$$V_{pf} = \frac{q_0 N_{eff}}{4\varepsilon\varepsilon_0} R_{pf}^{\ 2} \left[\ln\left(\frac{R_{pf}}{r_0}\right)^2 - \left(1 - \left(\frac{r_0}{R_{pf}}\right)^2\right) \right]$$

$$\eta = \pi / 4 = 0.78$$

The full depletion voltage

MCZ: 1k cm
$N_{eff}=4\times10^{12}cm^{-3}$
r0=5u
Pitch=a=40u





$$S = \pi \cdot R_{pf}^{\ 2}$$

$$V_{fd} = \frac{q_0 N_{eff}}{4\varepsilon\varepsilon_0} a^2 \left[\ln\left(\frac{a}{r_0}\right)^2 - \left(1 - \left(\frac{r_0}{a}\right)^2\right) \right]$$

$$\eta = \pi / 4 = 0.78$$

The maximal electric field and pinch-off voltage increase with fluence

Cylindrical part

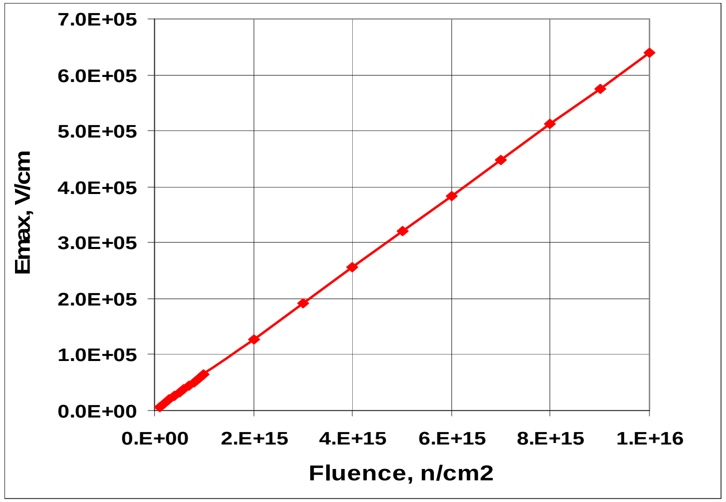
MCZ: 1k cm
r0=5u
Rpf=50u

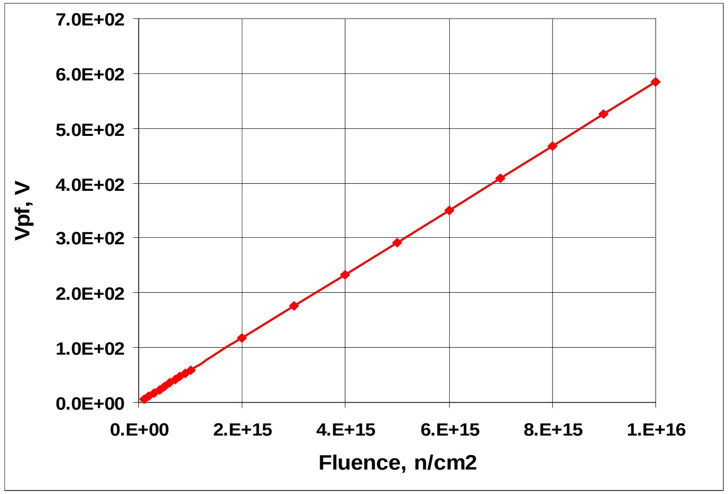
Neff=βxF

β=1.7e-2

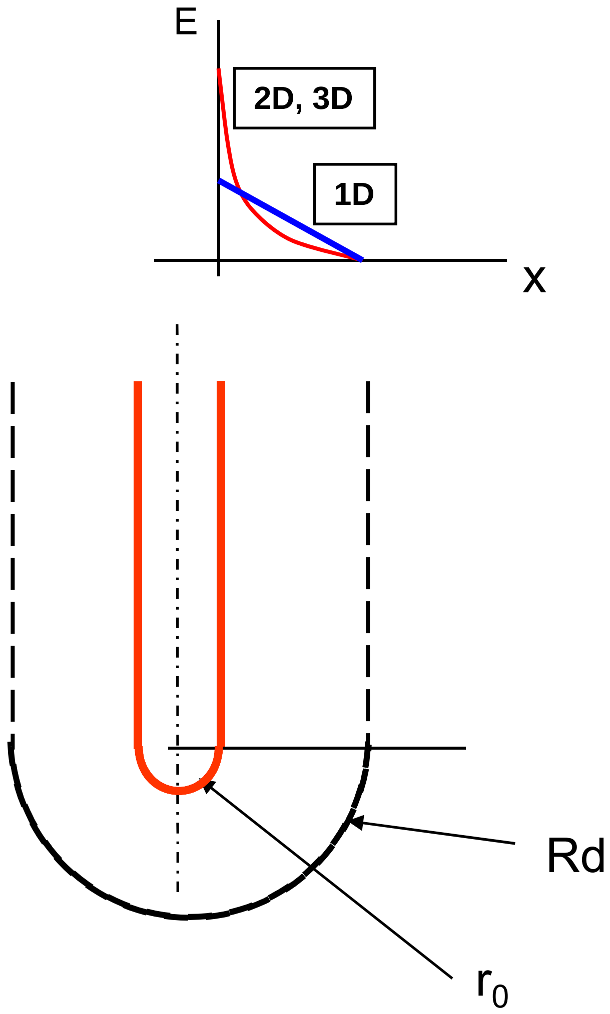
$$E_{\max} = \frac{q_0 N_{eff}}{2\varepsilon\varepsilon_0} r_0 \left[\left(\frac{R_{pf}}{r_0} \right)^2 - 1 \right]$$

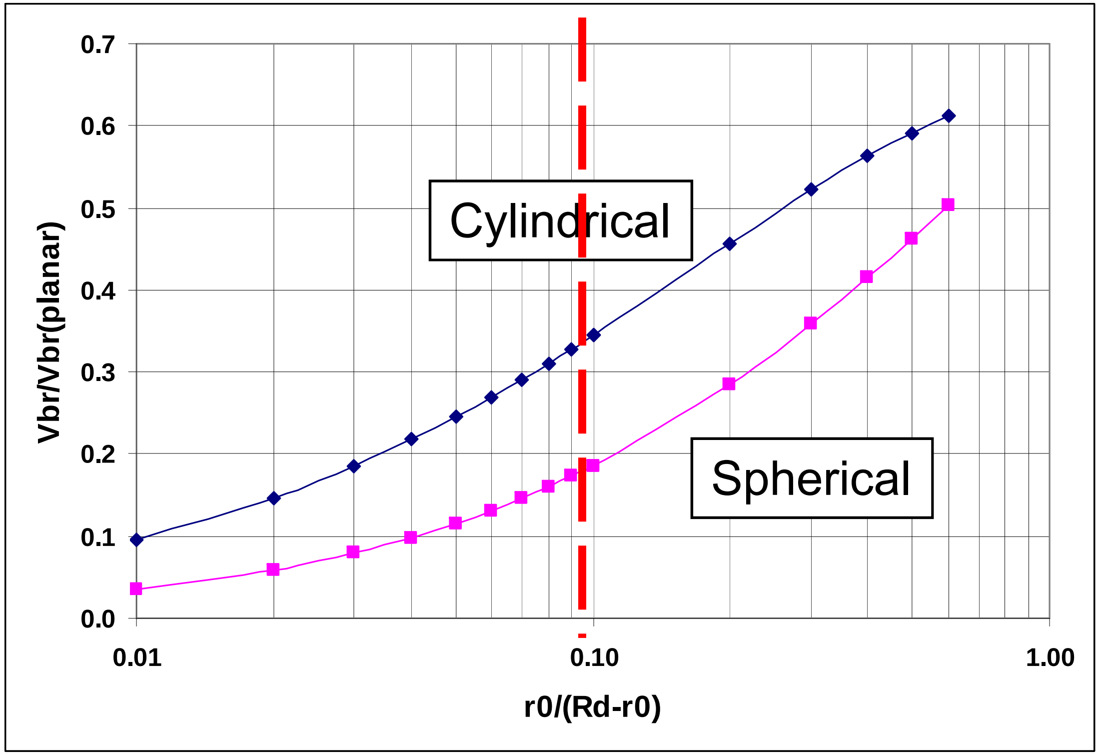
$$V_{pf} = \frac{q_0 N_{eff}}{4\varepsilon\varepsilon_0} R_{pf}^2 \left[\ln\left(\frac{R_{pf}}{r_0} \right)^2 - \left(1 - \left(\frac{r_0}{R_{pf}} \right)^2 \right) \right]$$





Effect of 2D and 3D focusing on the breakdown voltage



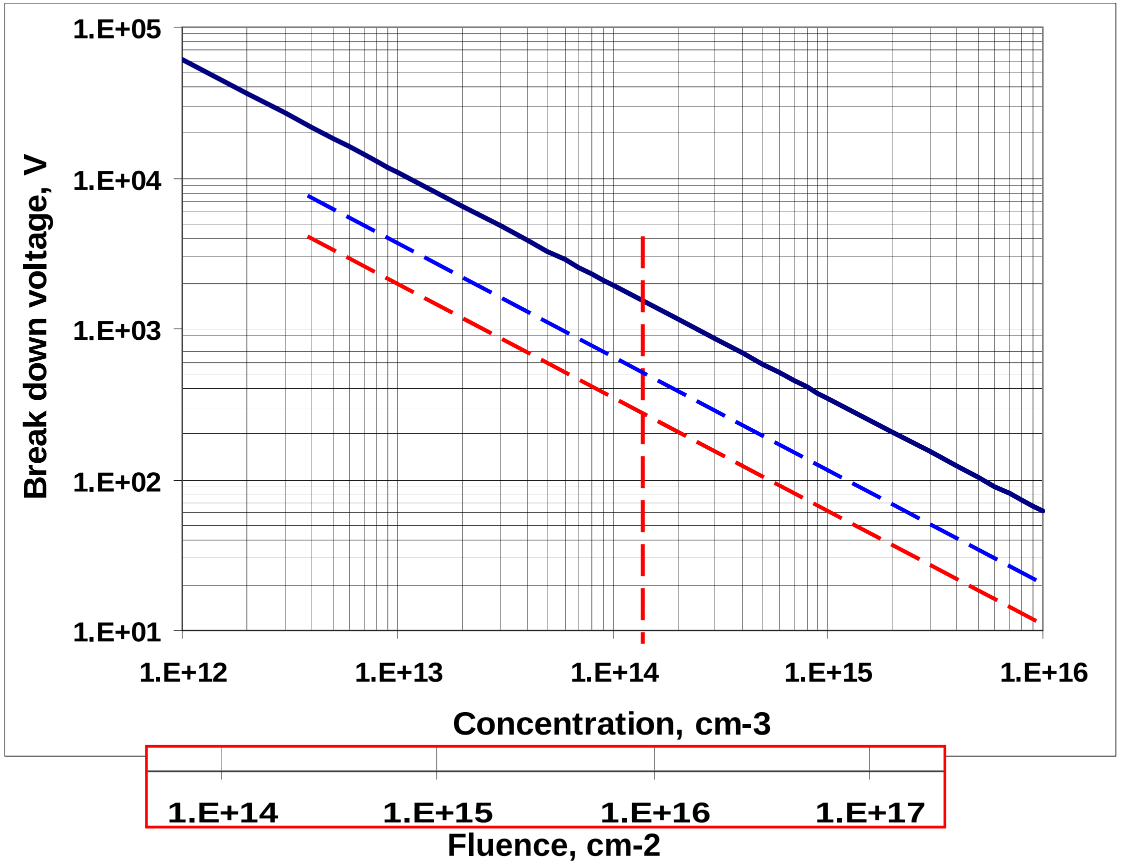


Vbr(cyl)=0.4Vbr(planar)

Vbr(spher)=0.18Vbr(planar)

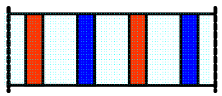
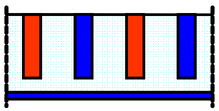
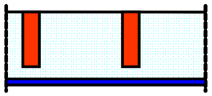
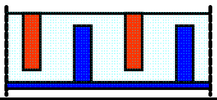
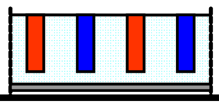
$r_0/Rd = 10$

The breakdown characteristics of 3D planar detectors at different fluences



Conclusions

1. The simple analytical equations can be applied for the engineering of 3D detectors
2. At fluence of 1e16 neutrons/cm^2 the pinch-off voltage is close to the breakdown voltage for cylindrical junction.
3. The type of 3D detectors J-O/Osurf with the dead ends of junction and Ohmick columns is promising for the high fluence application

Configuration	Type	Break-down	Response	Dead volume	Technology
	J/O-J/O				DS
	J/O-Osurf				SS
	J-Osurf				SS
	J-O/Osurf				DS
	J/O-SiO2				SS

Thank you for you attention