Radiator

CBM-TRD TDR review
2017, March 14th

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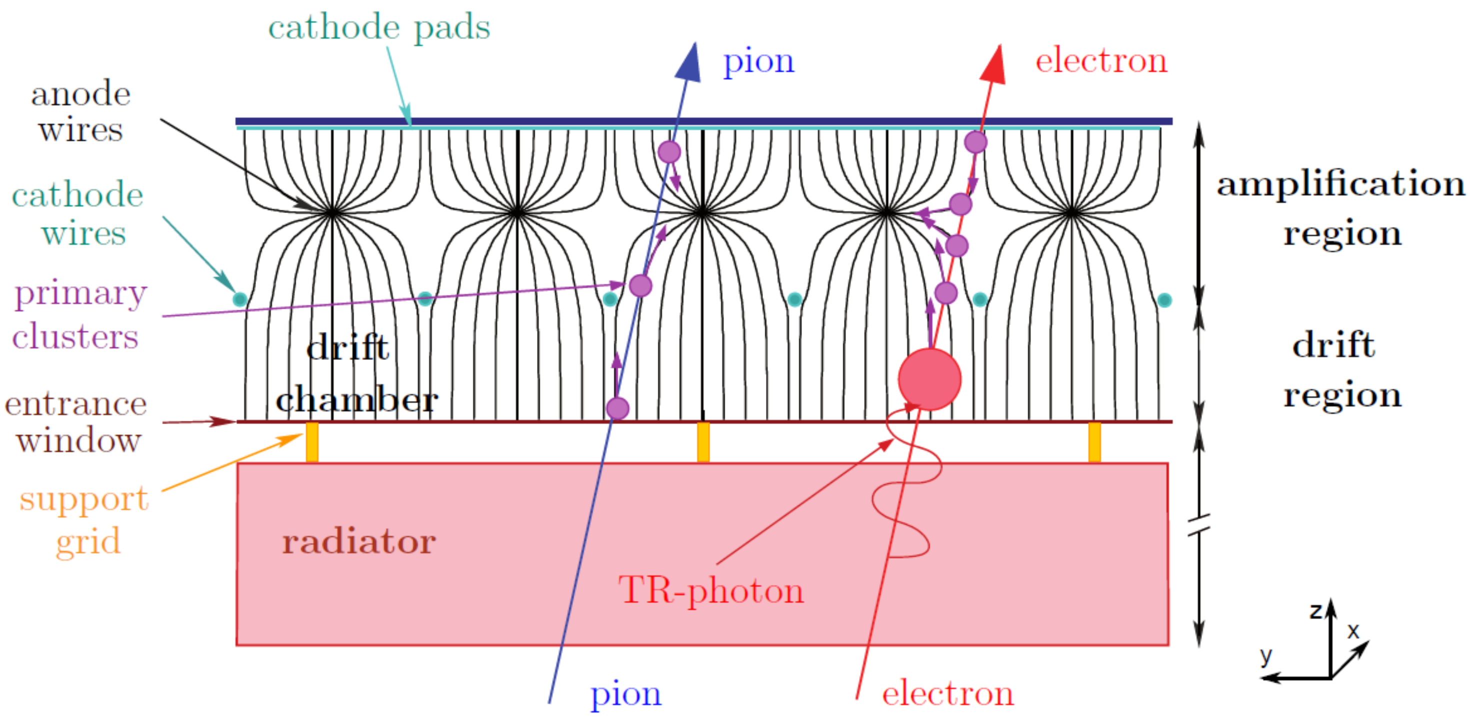
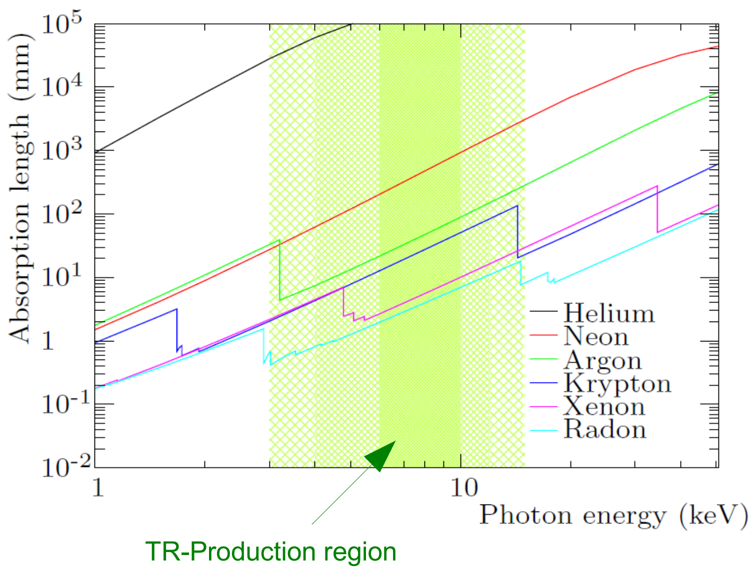
MWPC Operation Principle

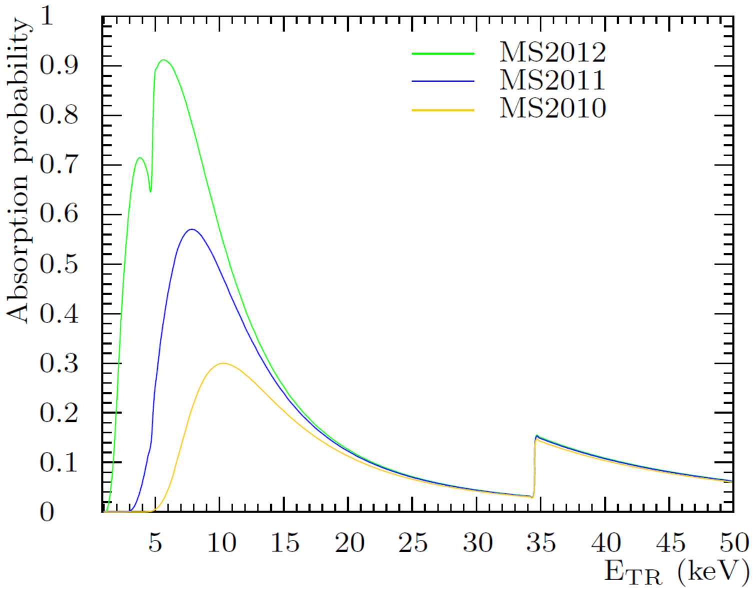


Optimization of the Chamber

Nobel gas choice:



Chamber absorption characteristic:



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Radiator Simulation

Effective description:

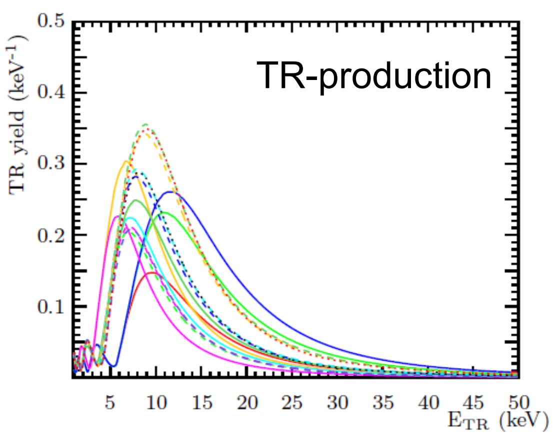
$$\frac{dN}{d\omega} = \frac{4\alpha}{\omega(\kappa+1)} \frac{1-\exp(-N\sigma)}{1-\exp(-\sigma)} \sum_n \theta_n \left(\frac{1}{\varrho_1+\theta_n} - \frac{1}{\varrho_2+\theta_n}\right)^2 [1-\cos(\varrho_1+\theta_n)]$$

Fabjan et al. 1977

$$\varrho_i = \frac{\omega l_1}{2c}\left(\gamma^{-2} + \left(\frac{\omega_{P,i}}{\omega}\right)\right) \qquad \kappa = \frac{l_1}{l_2} \qquad \theta_n = \frac{2\pi n - (\varrho_1 + \kappa\varrho_2)}{1+\kappa} > 0 \qquad \omega_{P,i} = \left(\frac{4\pi\alpha\rho_i N_A Z_i \hbar c}{A_i m_e / c^2}\right)^{1/2}$$

l_1: foil thickness l_2: gap thickness ρ_i: density

σ: photon absorption cross section $\omega_{P,i}$: plasma frequency



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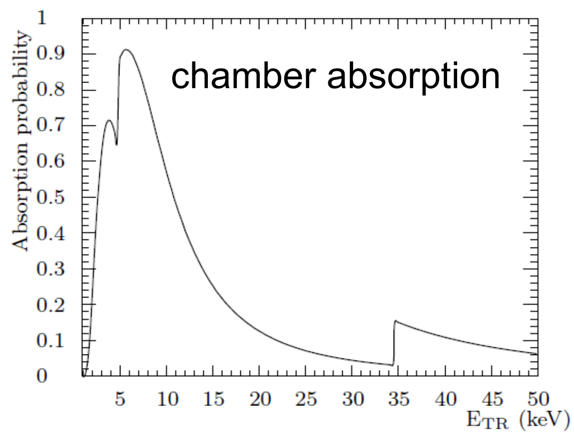

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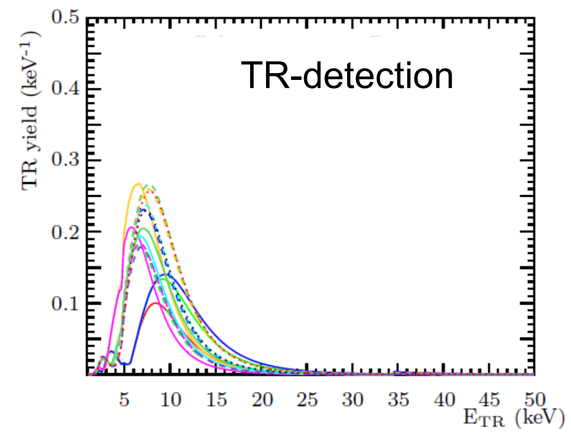
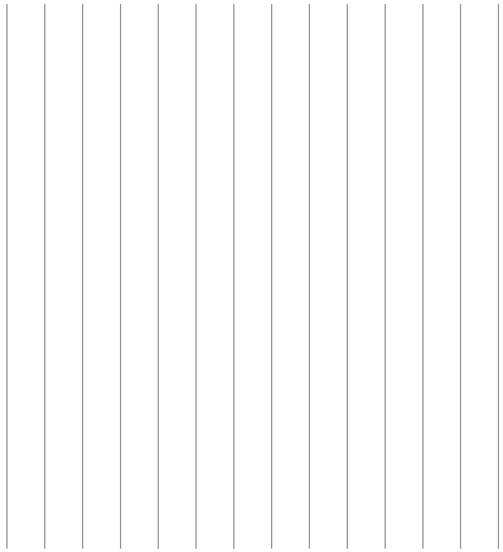
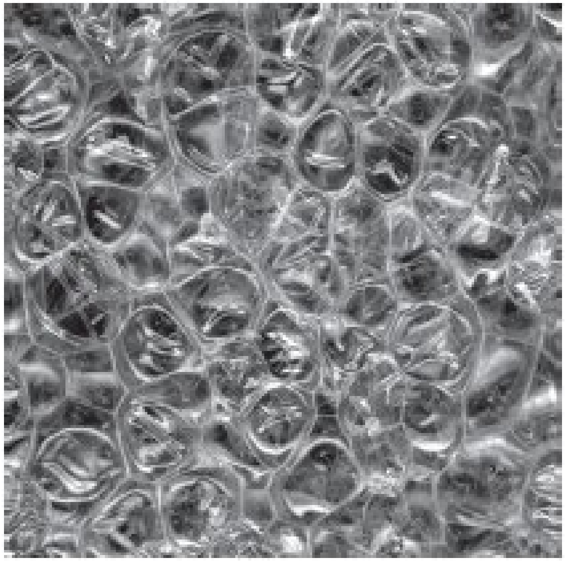
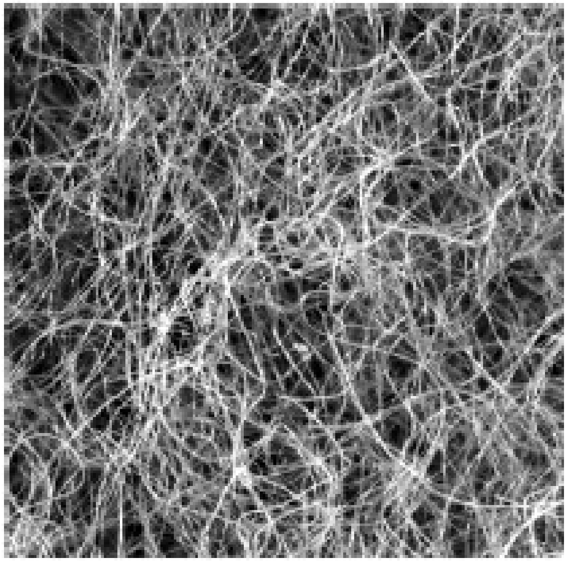


Radiator Classes

Regular Foil Stack	Irregular Foam	Irregular Fibers
		
high regularity high yield due to interference need mechanical support	low regularity (complex structure) low interference self-supporting	fully irregular minimal interference self-supporting

Material Density: ρ_1 and ρ_2

$$\frac{dN}{d\omega}=\frac{4\alpha}{\omega(\kappa+1)}\frac{\left(1-e^{(-N_f\sigma)}\right)}{\left(1-e^{(-\sigma)}\right)}\sum_n\theta_n\left(\frac{1}{\varrho_1+\theta_n}-\frac{1}{\varrho_2+\theta_n}\right)^2\left[1-\cos(\varrho_1+\theta_n)\right]$$

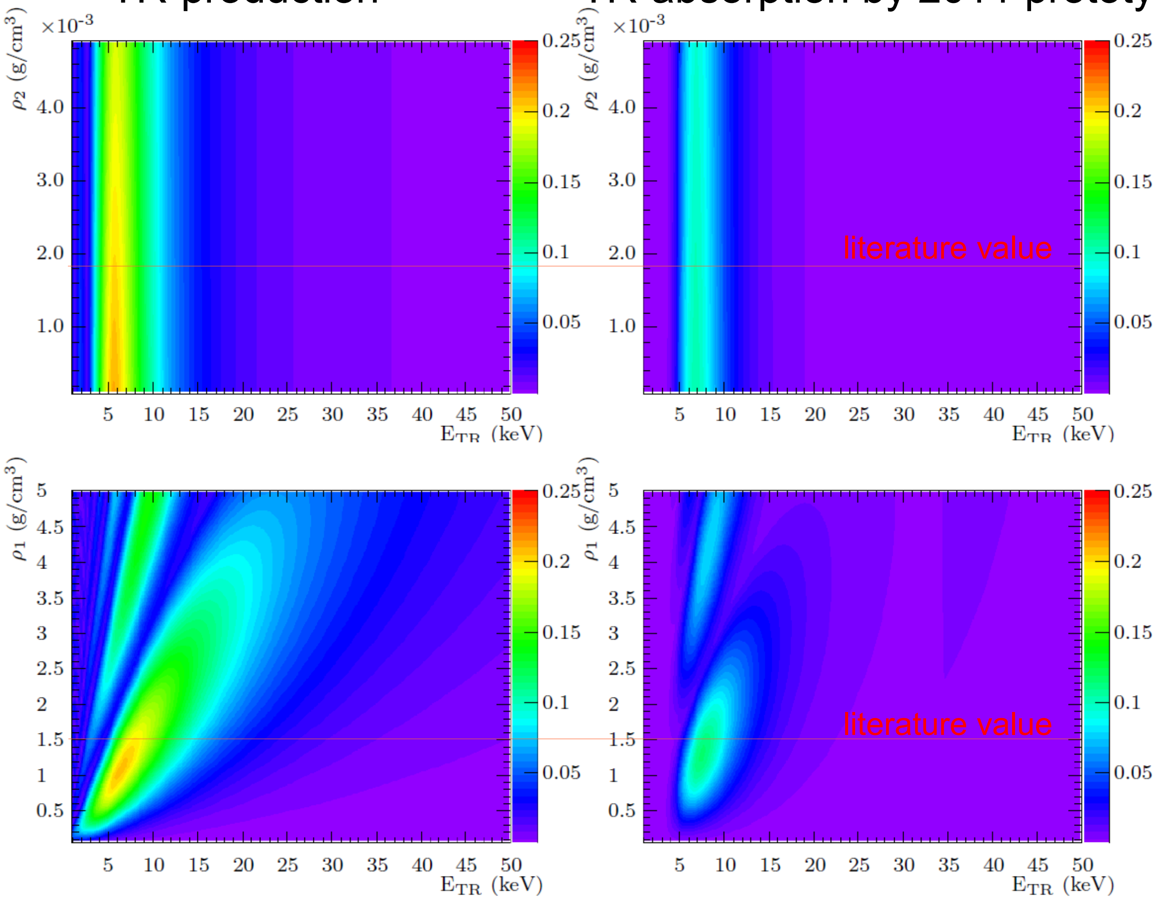
$$\varrho_i=\frac{\omega l_1}{2c}\left(\frac{1}{\gamma^2}+\left(\frac{\omega_{P,i}}{\omega}\right)^2\right),$$

$$\omega_{P,i}=\sqrt{\frac{n_{e,i}e^2}{\epsilon_0 m_e}},$$

$$n_{e,i}=\frac{\rho_i N_A Z}{A}$$

TR-production

TR-absorption by 2011 prototype



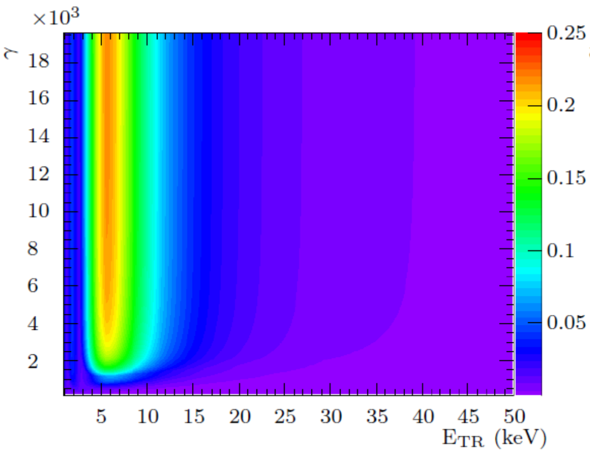
only small influence of ρ_2 due to factor 1000 smaller values

Lorentz-Factor: γ

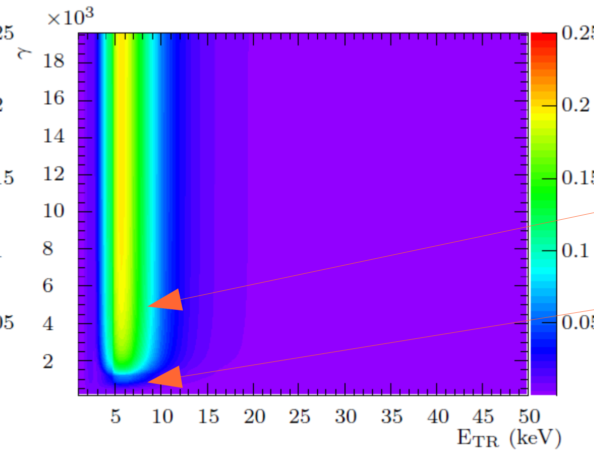
$$\frac{dN}{d\omega}=\frac{4\alpha}{\omega(\kappa+1)}\frac{\left(1-e^{(-N_f\sigma)}\right)}{\left(1-e^{(-\sigma)}\right)}\sum_n\theta_n\left(\frac{1}{\varrho_1+\theta_n}-\frac{1}{\varrho_2+\theta_n}\right)^2\left[1-\cos\left(\varrho_1+\theta_n\right)\right]$$

$$\varrho_i=\frac{\omega l_1}{2c}\left(\frac{1}{\gamma^2}+\left(\frac{\omega_{P,i}}{\omega}\right)^2\right),$$

TR-production



TR-absorption by 2011 prototype



Saturation around $\gamma = 5.0$

Threshold around $\gamma = 0.5$

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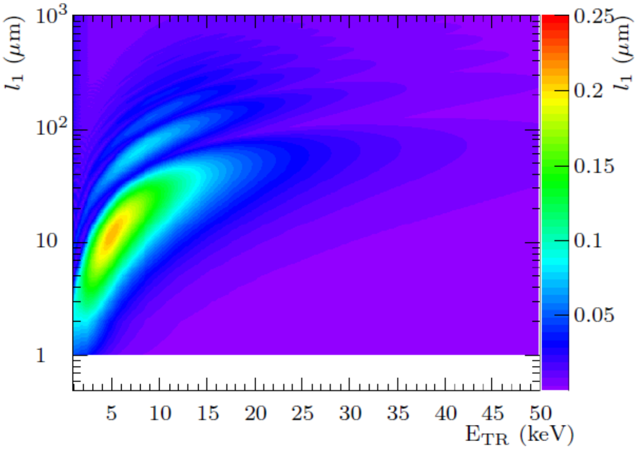
Foil Thickness: l_1

$$\frac{dN}{d\omega}=\frac{4\alpha}{\omega(\kappa+1)}\frac{\left(1-e^{(-N_f\sigma)}\right)}{\left(1-e^{(-\sigma)}\right)}\sum_n \theta_n\left(\frac{1}{\varrho_1+\theta_n}-\frac{1}{\varrho_2+\theta_n}\right)^2\left[1-\cos(\varrho_1+\theta_n)\right]$$

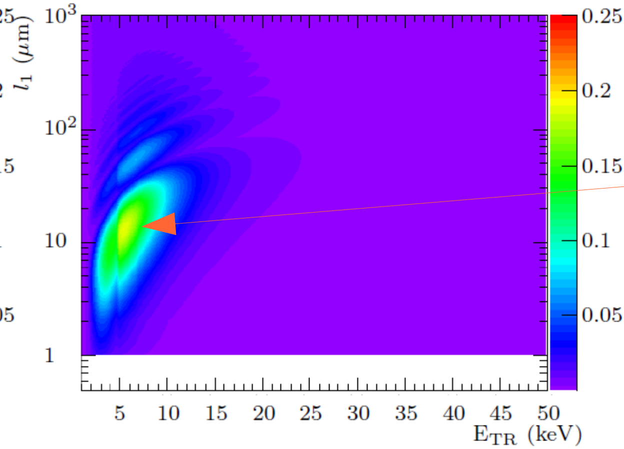
$$\kappa=\frac{l_2}{l_1},$$

$$\theta_n=\frac{2\pi n-(\varrho_1+\kappa\varrho_2)}{1+\kappa}>0,$$

TR-production



TR-absorption by 2011 prototype



Complex interference pattern

Highest emission probability between 9 and 18 µm

Parameter distribution unknown for irregular prototypes

Approximate mean value from sample

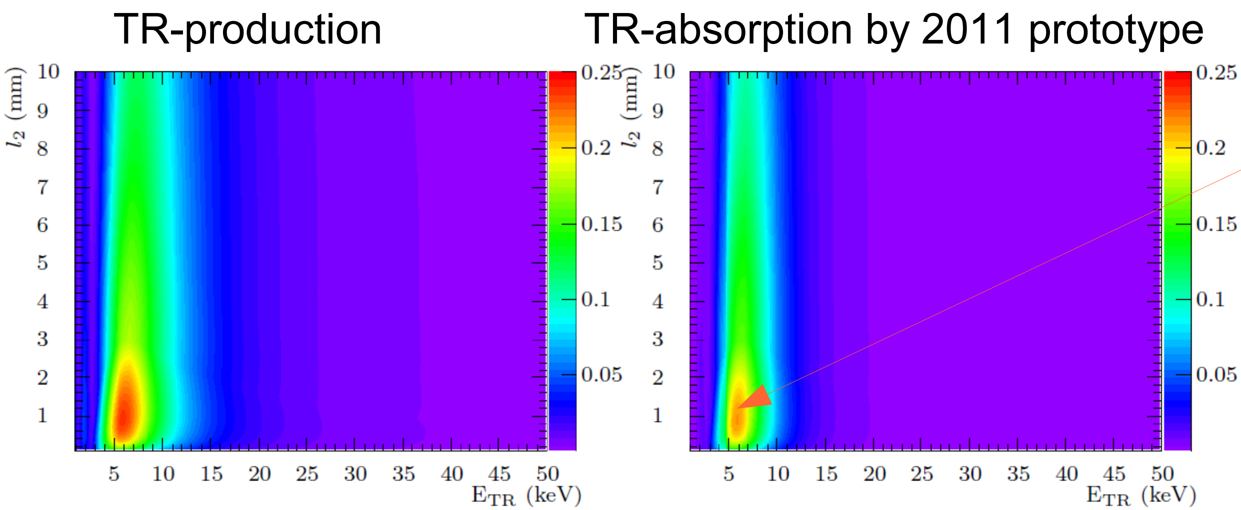
Large uncertainty for irregular radiators

Gap Thickness: l_2

$$\frac{dN}{d\omega}=\frac{4\alpha}{\omega(\kappa+1)}\frac{\left(1-e^{(-N_f\sigma)}\right)}{\left(1-e^{(-\sigma)}\right)}\sum_n \theta_n\left(\frac{1}{\varrho_1+\theta_n}-\frac{1}{\varrho_2+\theta_n}\right)^2\left[1-\cos\left(\varrho_1+\theta_n\right)\right]$$

$$\kappa=\frac{l_2}{l_1},$$

$$\theta_n=\frac{2\pi n-\left(\varrho_1+\kappa\varrho_2\right)}{1+\kappa}>0,$$



Broad maximum between 700 and 1200 µm

Parameter distribution unknown for irregular prototypes

Approximate mean value from sample

Large uncertainty for irregular radiators

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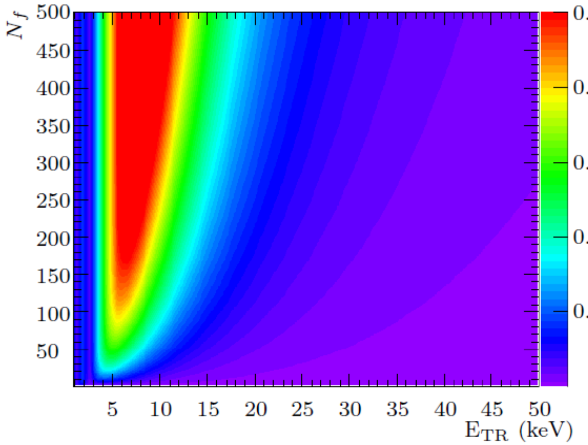
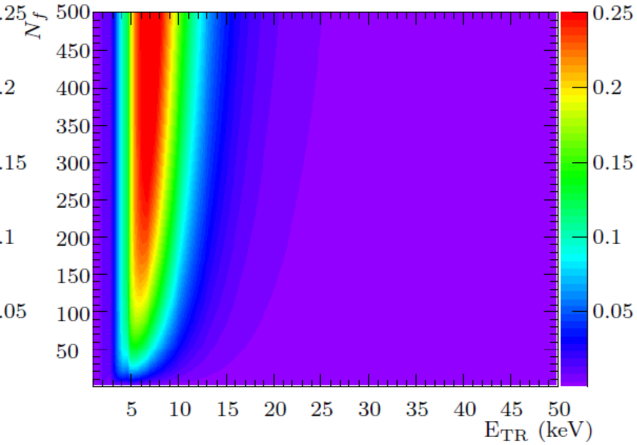
Number of Foils N_f

$$\frac{dN}{d\omega}=\frac{4\alpha}{\omega(\kappa+1)}\frac{\left(1-e^{(-N_f\sigma)}\right)}{\left(1-e^{(-\sigma)}\right)}\sum_n \theta_n\left(\frac{1}{\varrho_1+\theta_n}-\frac{1}{\varrho_2+\theta_n}\right)^2\left[1-\cos(\varrho_1+\theta_n)\right]$$

TR-production



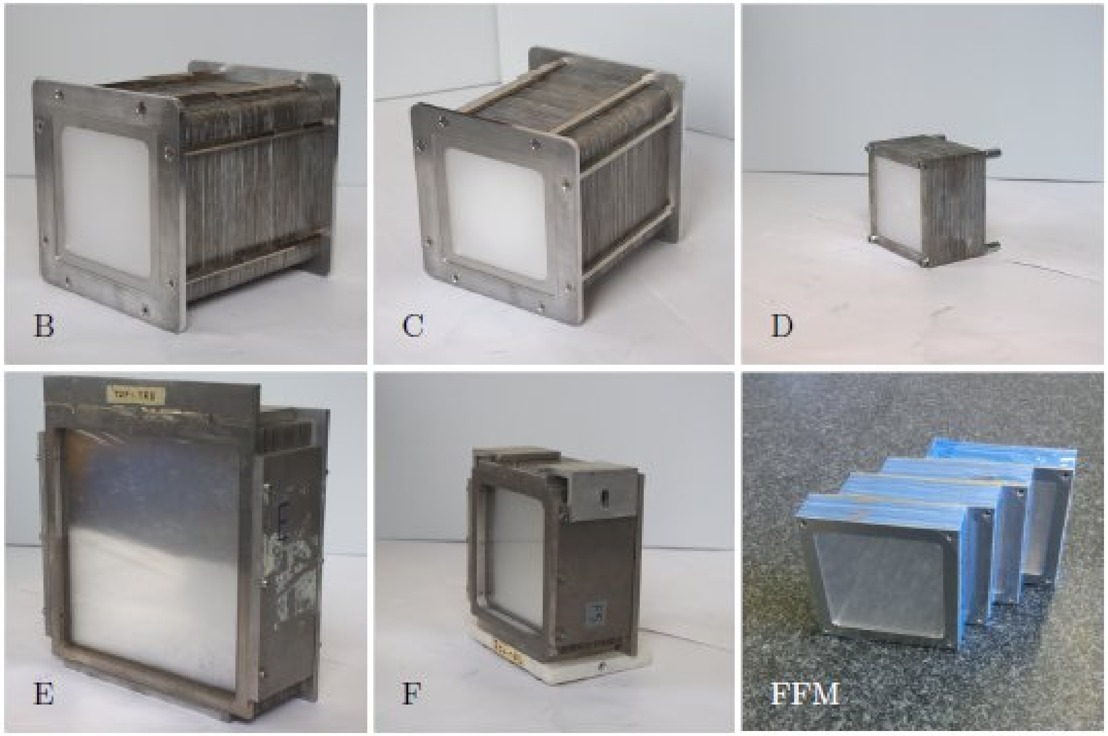
TR-absorption by 2011 prototype



TR-yield increases continuously

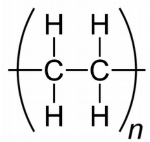
Large uncertainty for irregular radiators

Regular Prototypes

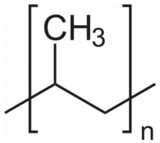


B: POKALON N470
C: Polypropylene
D: Polypropylene
E: Polyethylene
F: Polyethylene

FFM: Polyethylene



Polyethylene $(C_2H_4)_n$

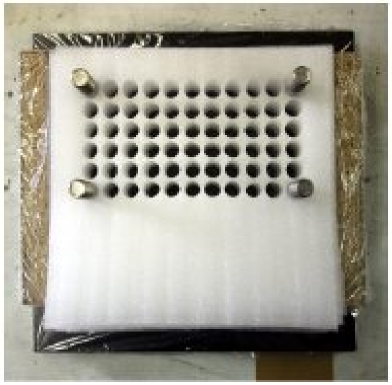
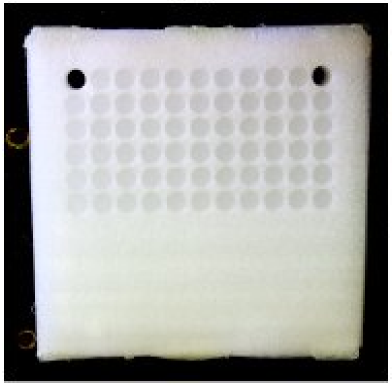


Polypropylene $(C_3H_6)_n$

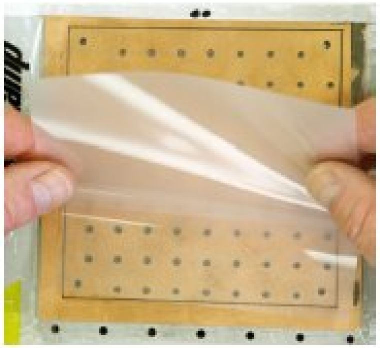
POKALON N470 $(C_{16}H_{14}O_3)_n$

Mixed Prototypes

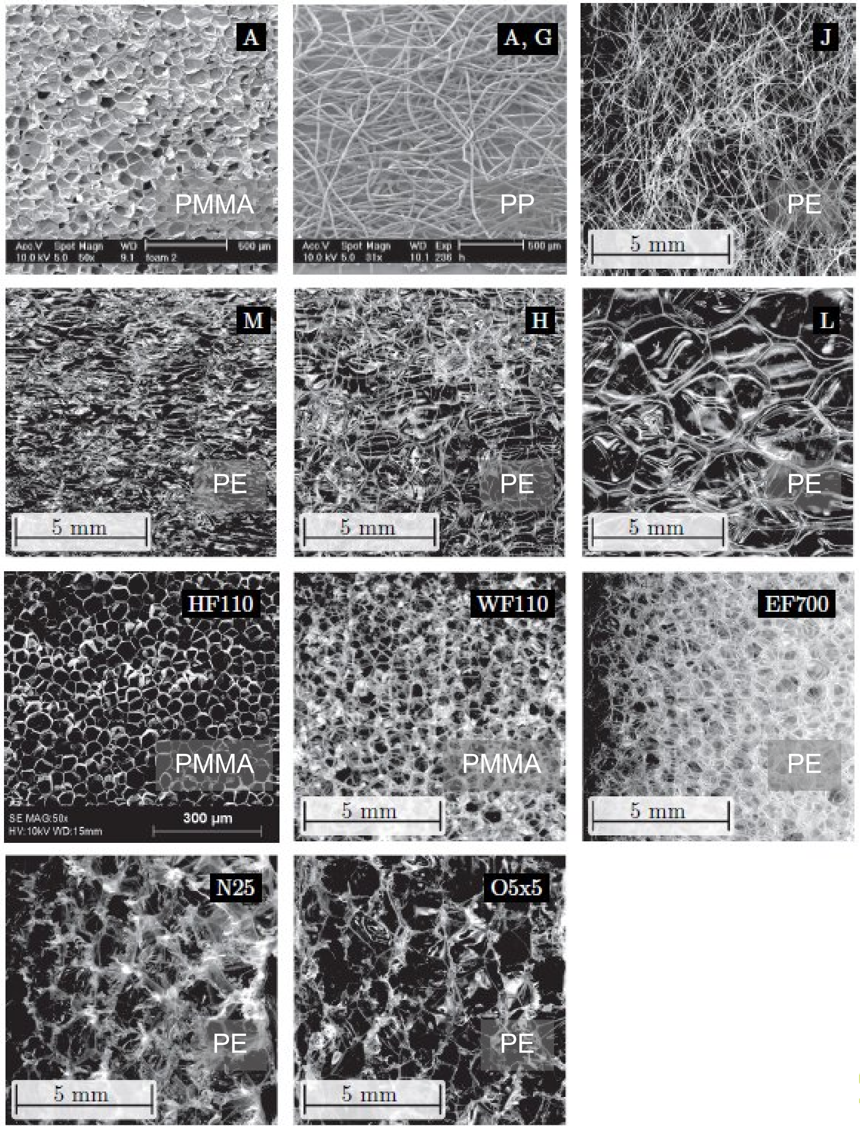
Self-Supporting PE Foam Foil Spacer Mixed Radiator


Self-Supporting Micro-structured Foil Radiator

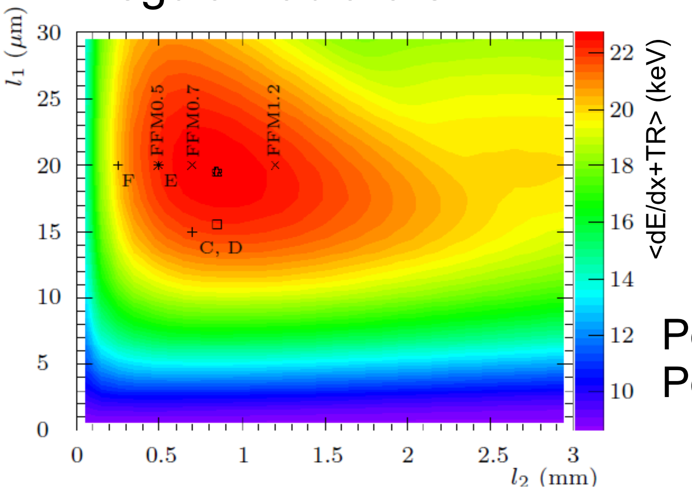
Irregular Prototypes



Mean E-Loss per Electron

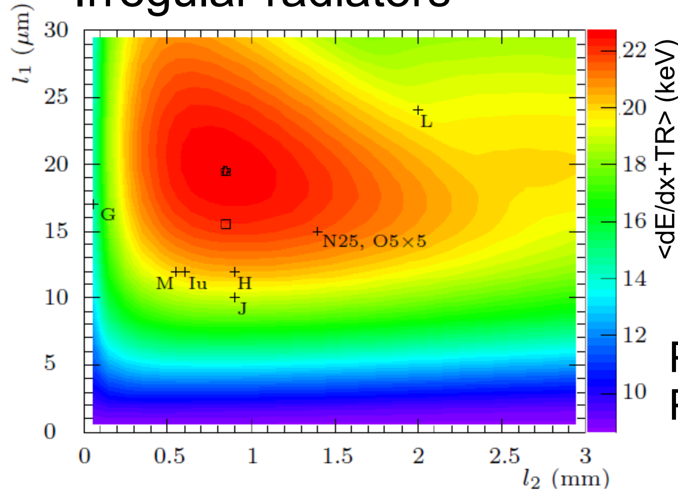
N_f=200, p=2GeV/c

Regular radiators

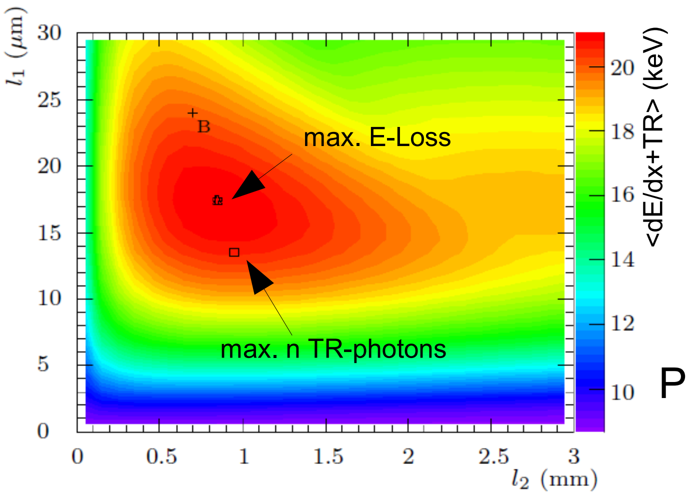


Polyethylene/
Polypropylene

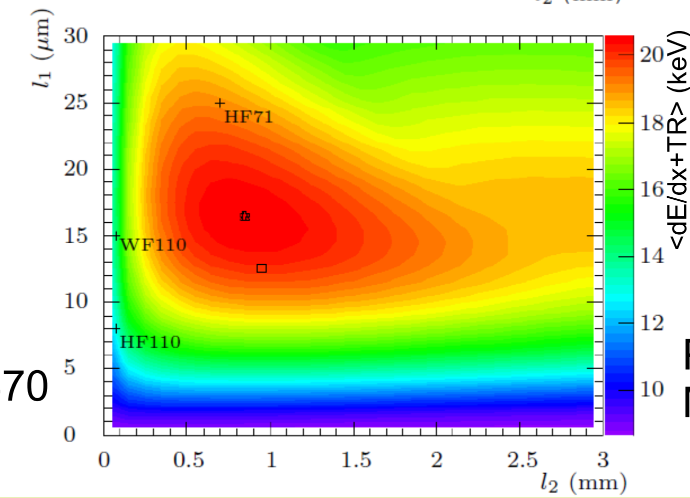
Irregular radiators



Polyethylene/
Polypropylene



POKALON N470



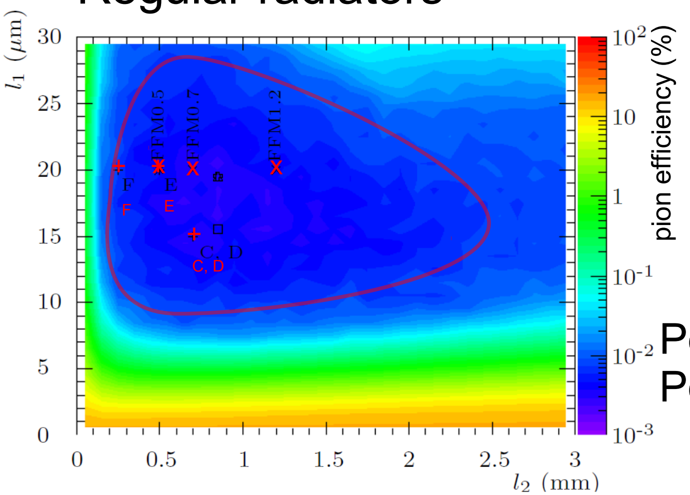
Poly(Methyl-
MethAcrylate)

Pion Efficiency

at 90% Electron Efficiency and 10 hits per track

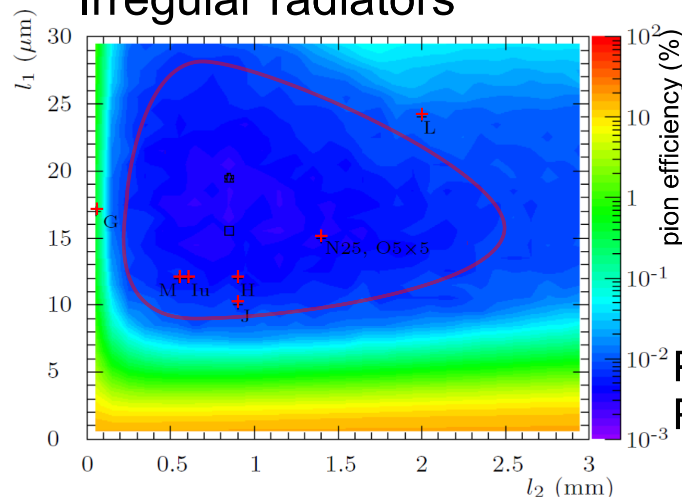
N_f=200, p=2GeV/c

Regular radiators

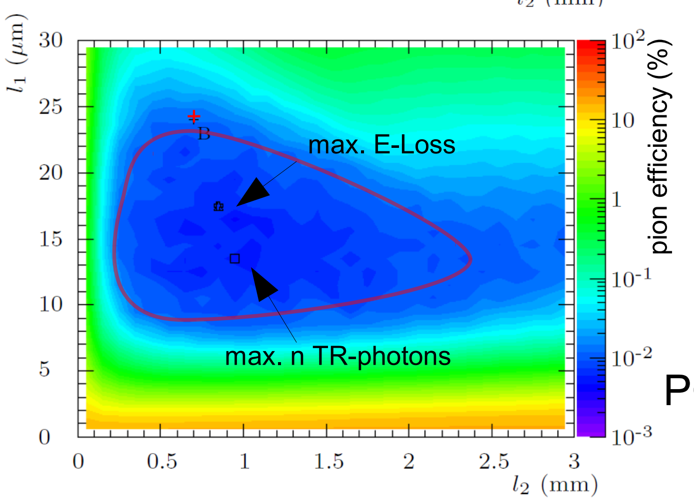


Polyethylene/
Polypropylene

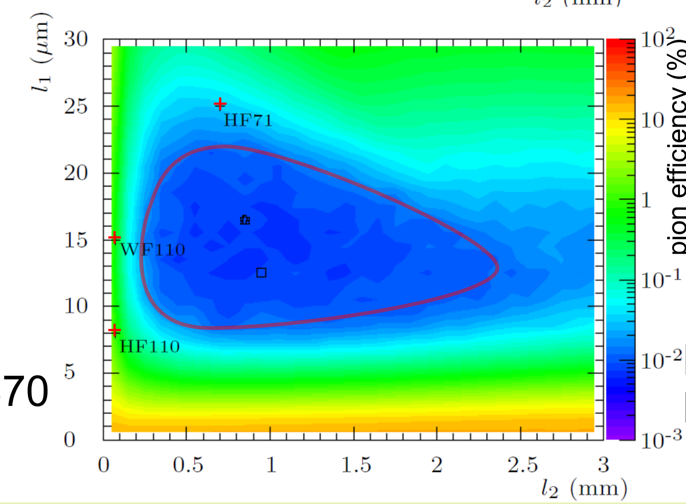
Irregular radiators



Polyethylene/
Polypropylene

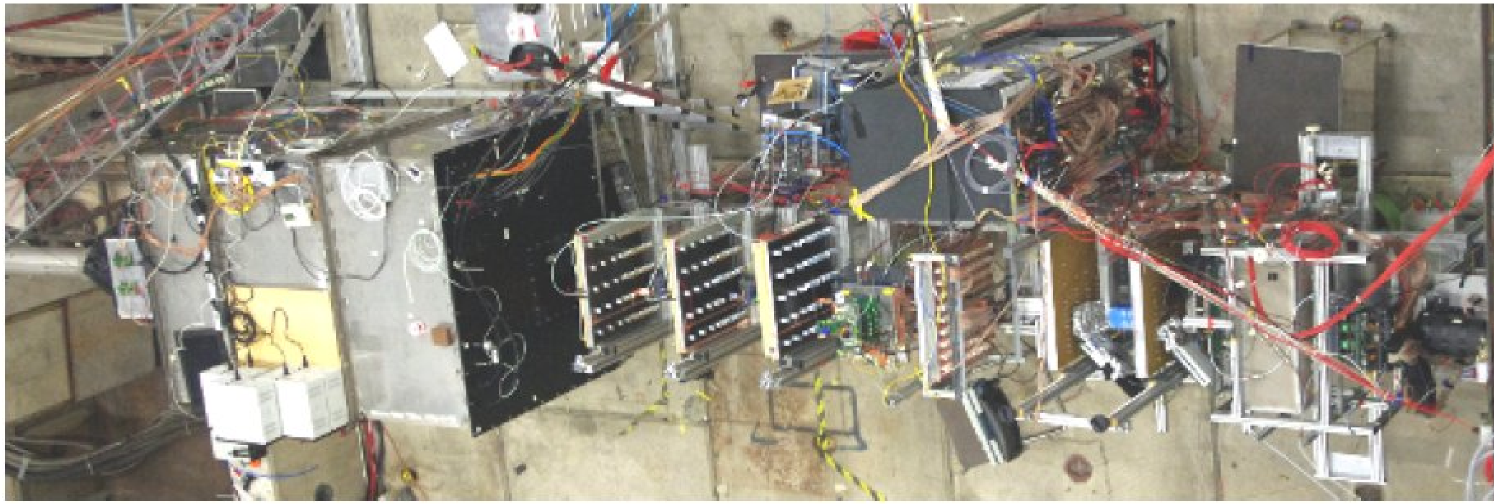


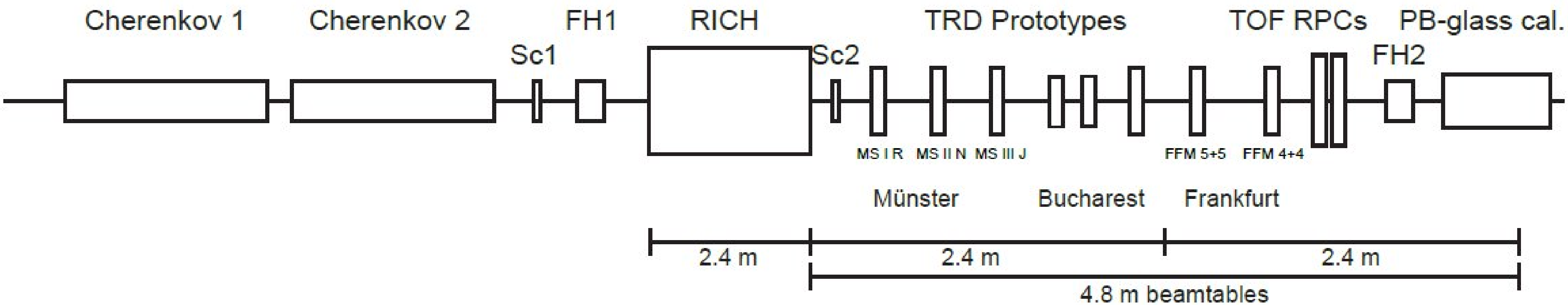
POKALON N470



Poly(Methyl-
MethAcrylate)

Testbeam Setup at CERN PS 2012





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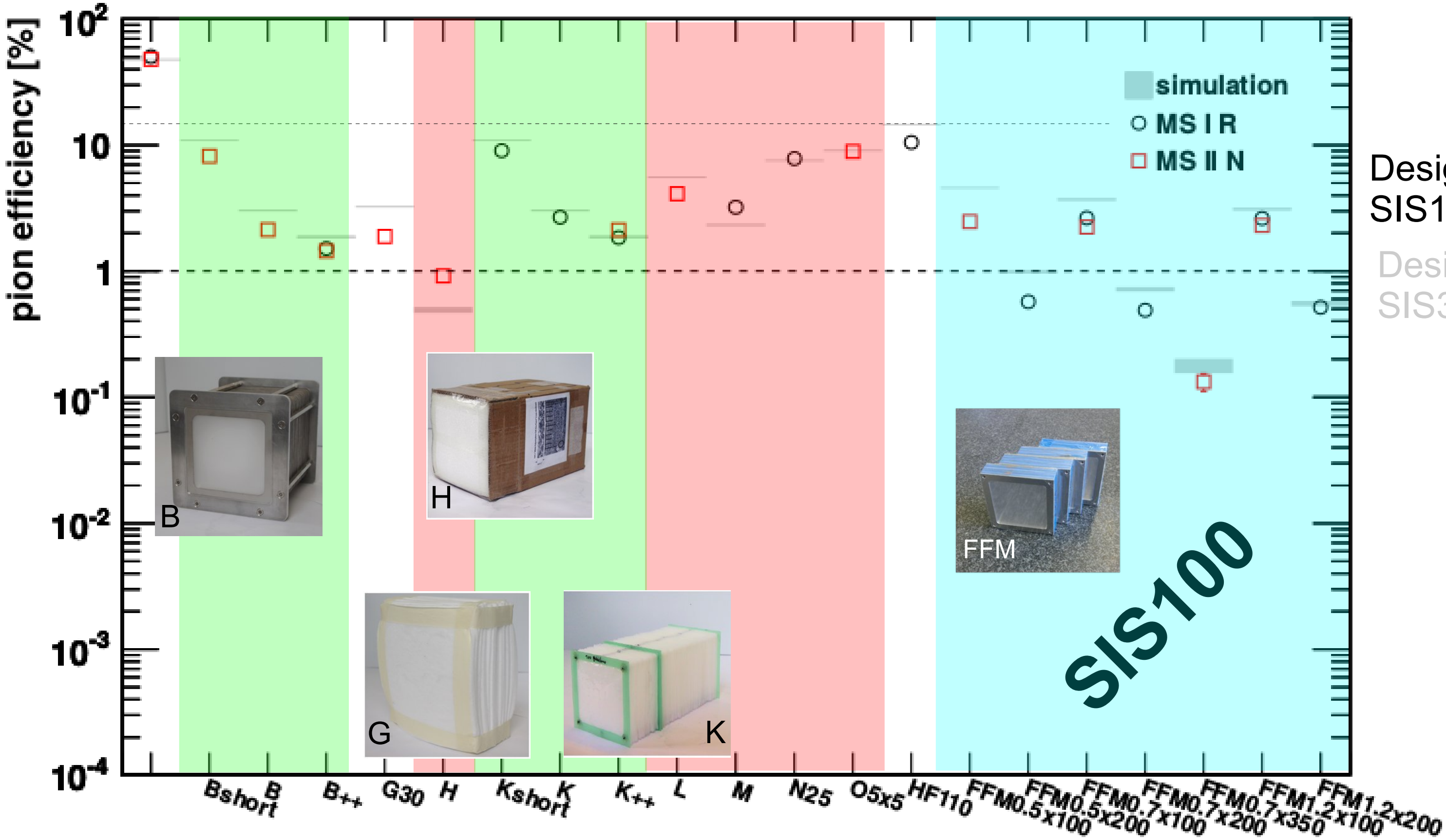
Pion Efficiency @ 3GeV/c 2012 Münster Prototype 12mm



Pokalon
PE foam
PE foil
PP fiber

Design goal SIS100

Design goal SIS300

Approximated pion efficiency with 4 detector hits per track @ 90% electron efficiency

Real-Size Prototypes

Summary

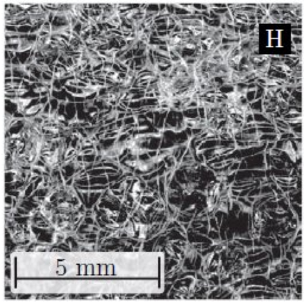
CBM-TRD radiator design:

- Evaluation of optimal radiator parameters based on simulation

- Production of radiator prototypes (regular, foam and fiber)

- In beam test and comparison to simulation (fine tuning of simulation)

→ Default radiator: Polyethylene foam foil radiator



- Mechanical “self-supporting”
- High TR-production performance
- Soft TR-spectrum → good matching to chamber absorption
- Low material budget (1.39 – 1.75% X/X_0)
- Affordable price

- First full size (57cm x 57cm x 35cm) demonstrators built