

MURA: simulations of optical systems and performances

INFN and Unibo units



Istituto Nazionale di Fisica Nucleare



ALMA MATER STUDIORUM
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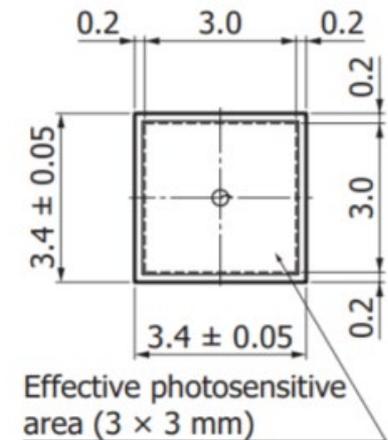


MURA optical system

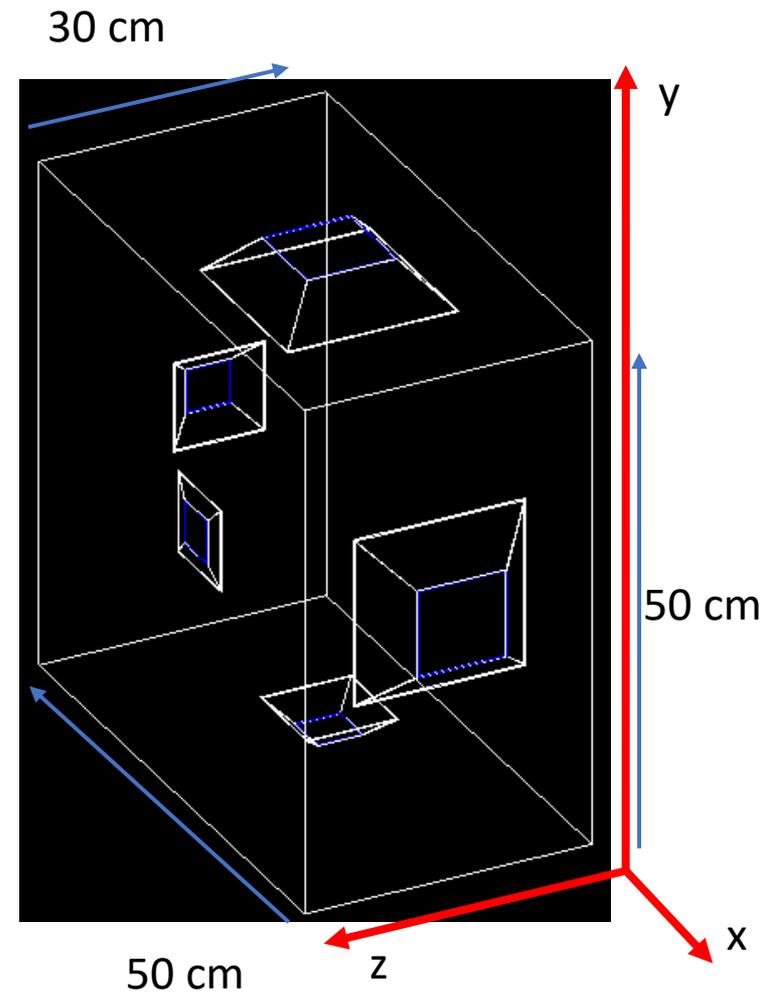
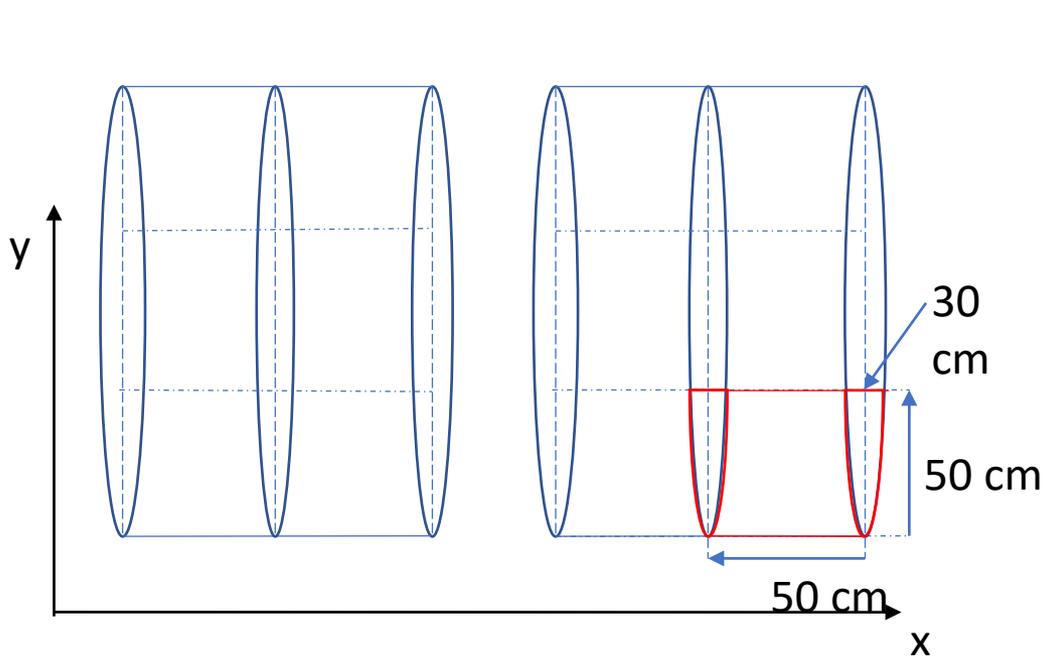
Definizione di un sistema ottico comune con Lecce, dopo vari studi, simulazioni e discussioni:

- Maschera con rango 17 (matrice di sensori di rango 16): buon compromesso tra performance e caratteristiche del detector (numero di canali, dimensioni, dissipazione di potenza)

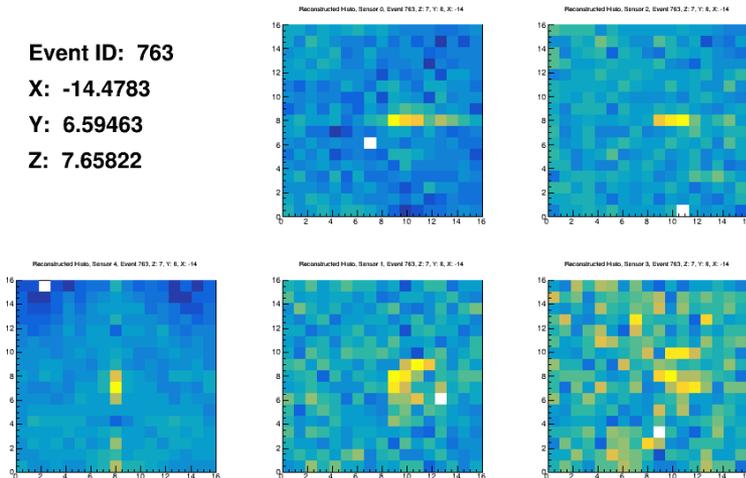
	Lecce	'Estesa'
Rango matrice	17	31
Rango maschera	17	31
Lato pixel	3.4 mm	3.4 mm
Pitch maschera	3.15 (2.95) mm	3.05 (2.95) mm
Distanza maschera-sensore (b)	20 mm	29 mm
Distanza maschera-oggetto (a)	250 mm	250 mm
FOV	723 mm	908 mm
λ	43 mm	29 mm



Geometria menisco: segmentazione

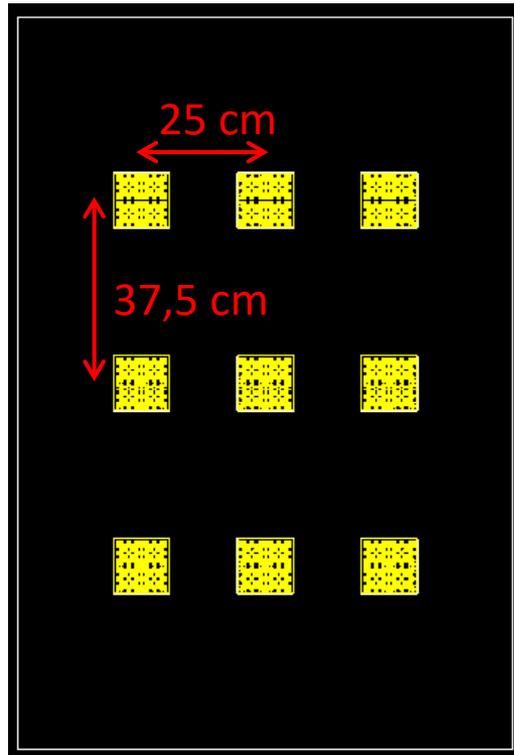


Event ID: 763
X: -14.4783
Y: 6.59463
Z: 7.65822

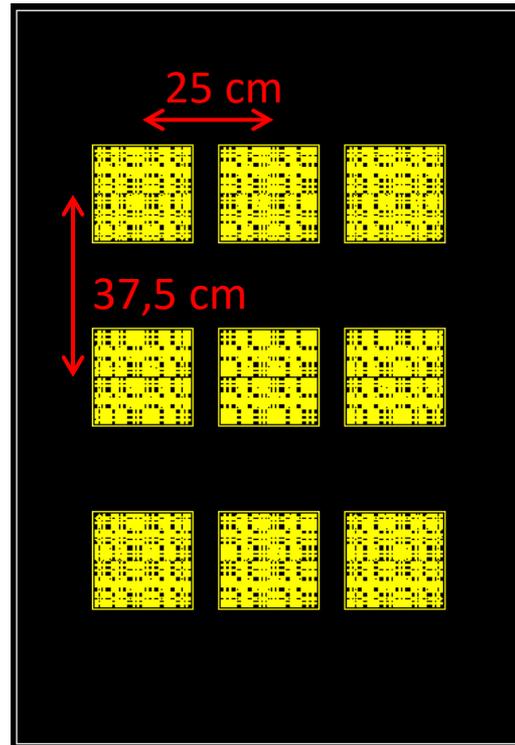


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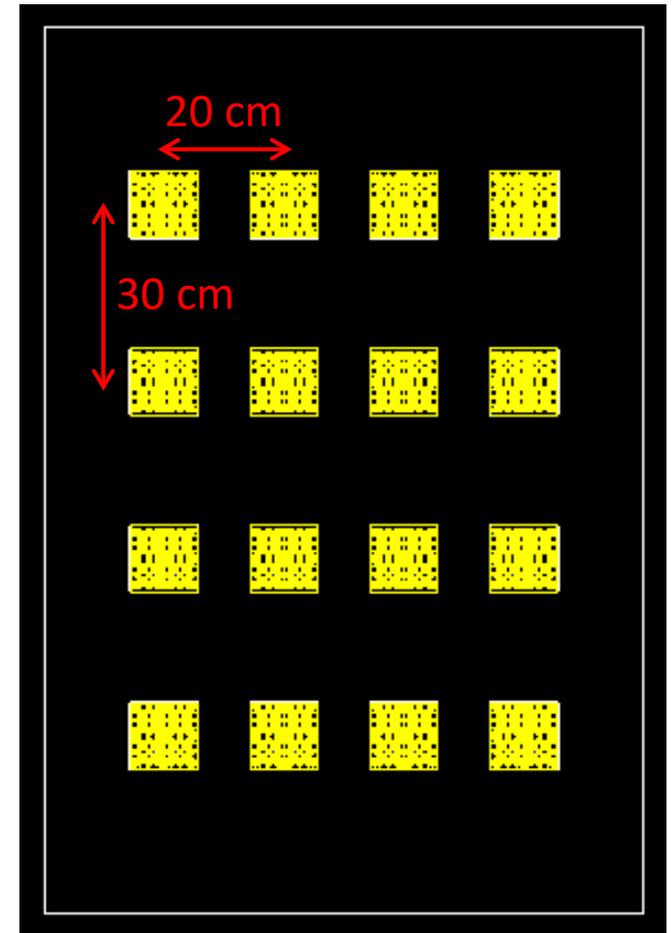
Simulazione maschere frontali



2601 canali

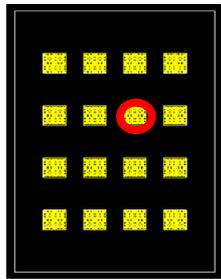
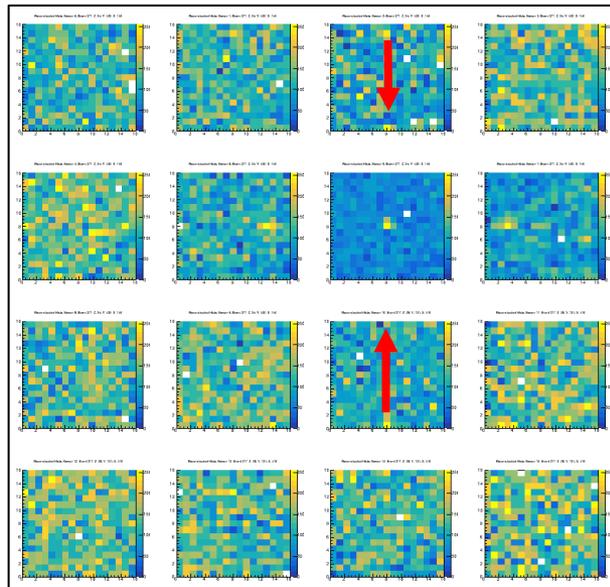


9216 canali

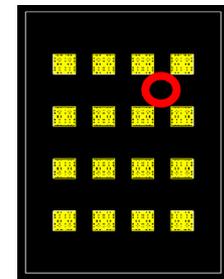
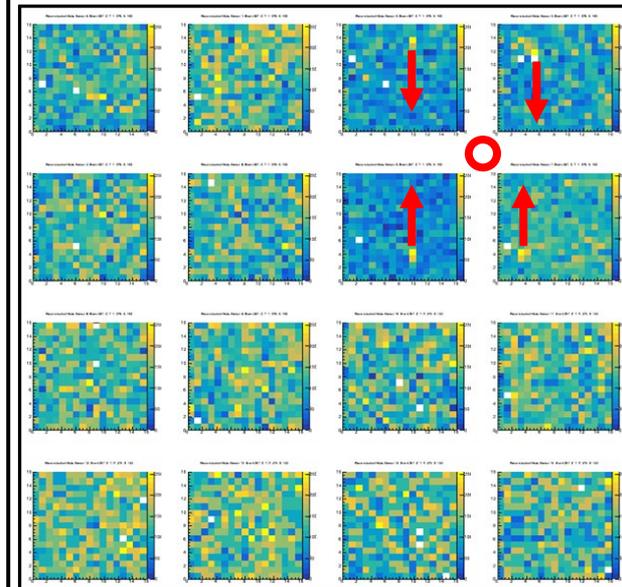
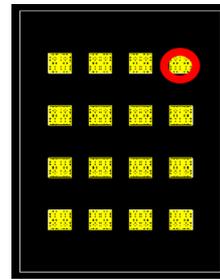
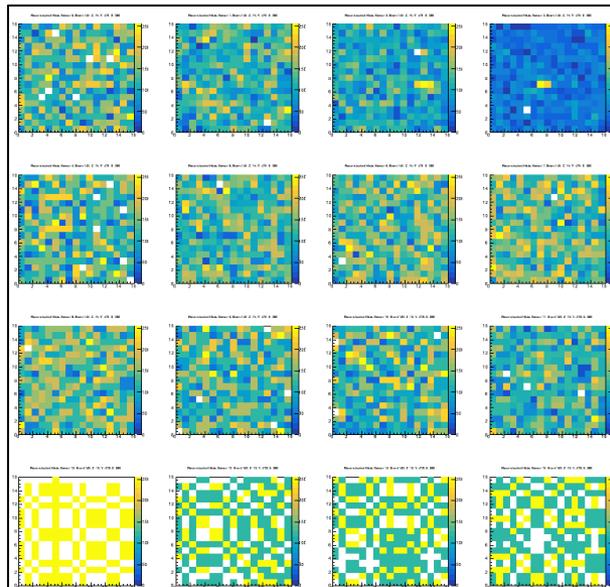


4624 canali

Simulazione maschere frontali

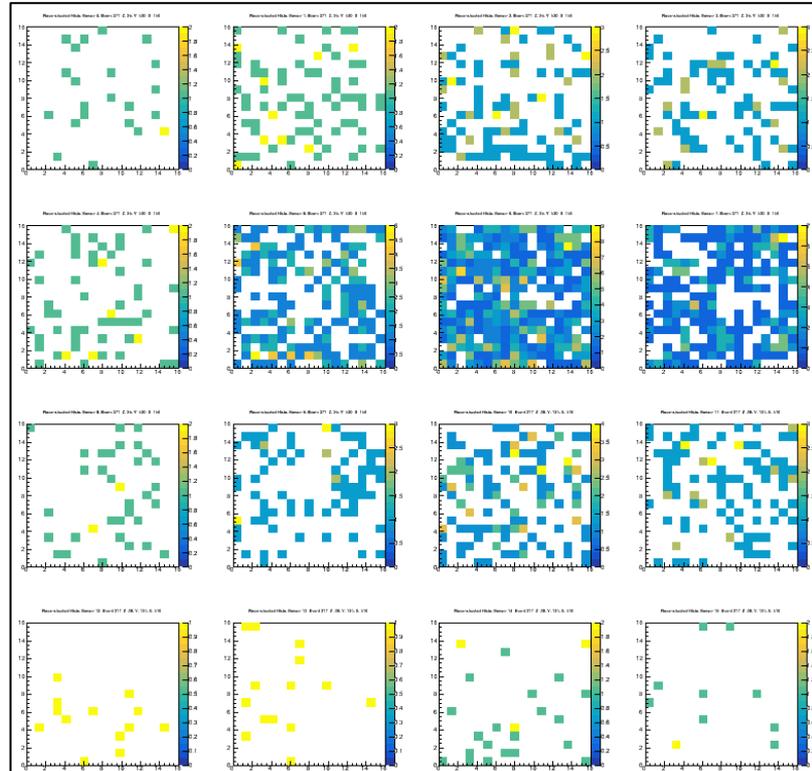
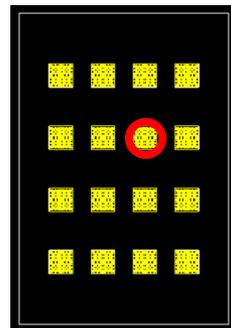
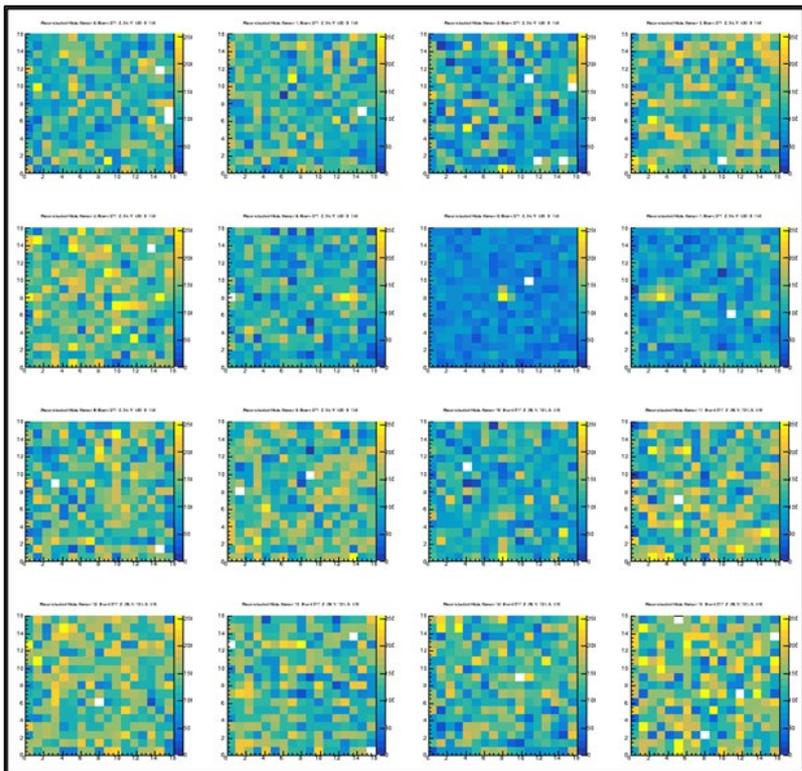


N.B.: Le immagini ricostruite vanno capovolte verticalmente!



N.B.: Le immagini ricostruite vanno capovolte verticalmente!

Griglia 4x4 rango 17



Ricostruzione
(rescaling 0-255)

Fotoni per pixel

Simulazione menisco

Facce “corte”:

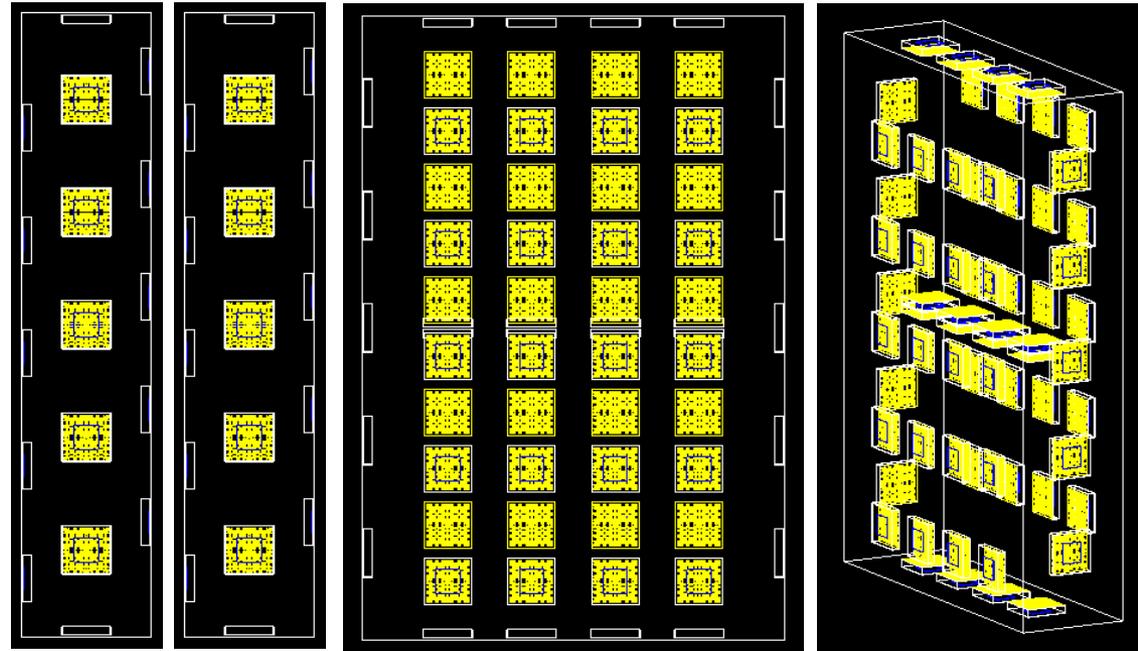
- Maschere rango 17
- Griglia 4x5 di maschere per faccia
- Maschere sfalzate lungo una coordinata

Facce “lunghe”:

- Maschere rango 17/31
- Griglia 1x5 o 4x1 di maschere per faccia

Maschere totali 66:

- 40 nelle facce corte
- 10 nelle facce verticali
- 16 nelle facce orizzontali



Menisco 100x150x30 cm³

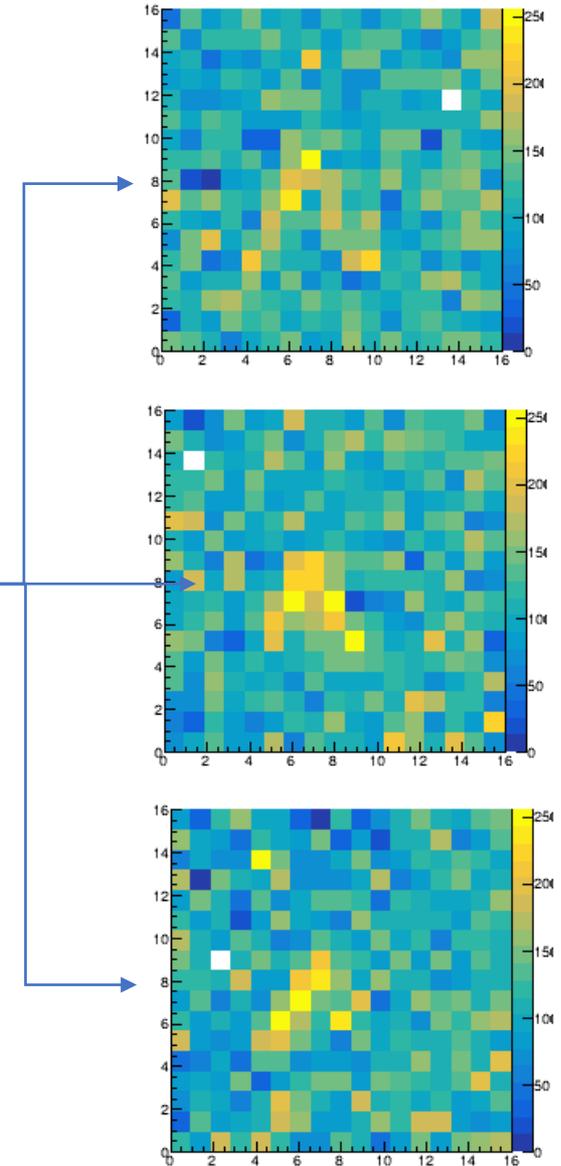
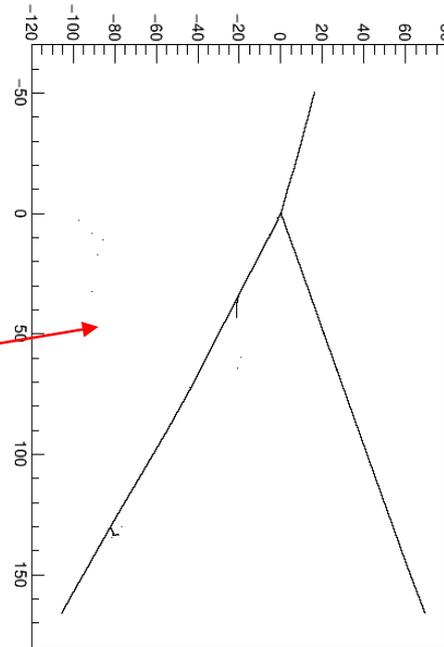
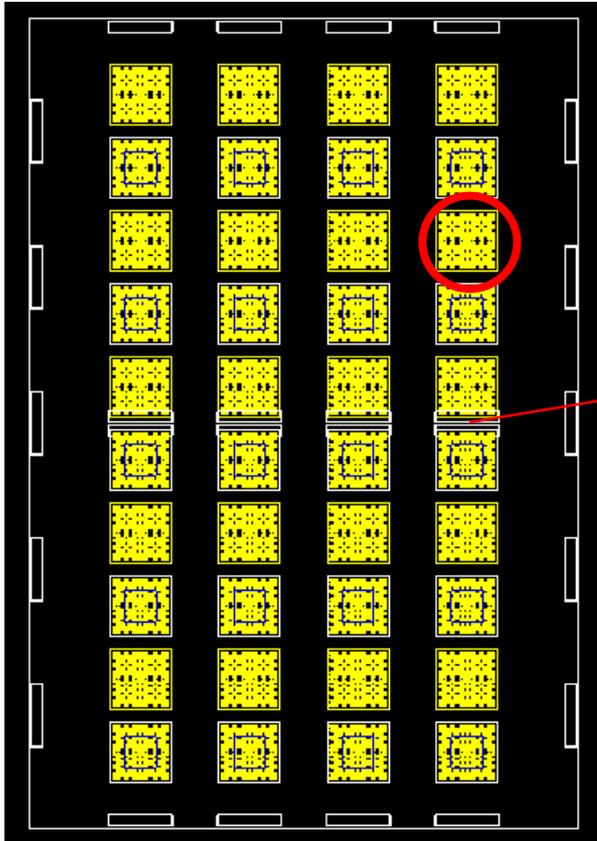
Dimensioni reali 100x146x48 cm³

Canali totali:

- $66 \times 17 \times 17 = 19074$
- $40 \times 17 \times 17 + 26 \times 32 \times 32 = 38184 \rightarrow$ potenza totale dissipata $\sim 100\text{-}200$ W

Simulazione evento di neutrino

Simulata interazione di neutrino «nota»:



Analisi eventi ricostruiti

Distinzione segnale/fondo: **Dbscan**

- input: 3 parametri (punti vicini minimi, distanza punti, intensità)
- identificazione dei cluster nell'immagine, escludendo i punti di rumore

Trasformata di Hough sui pixel dei cluster + ulteriore Dbscan

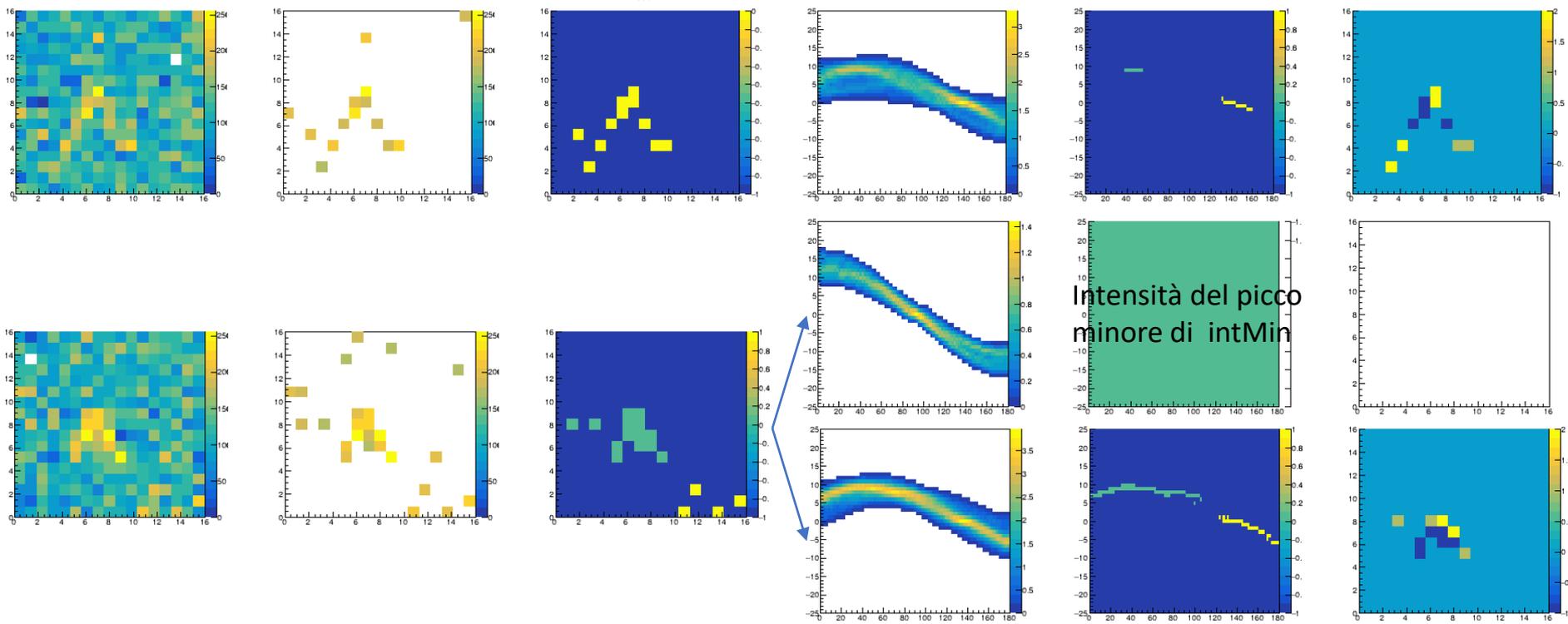


Immagine ricostruita

Pixel con intensità > intMin

Clusters

Trasformata di Hough

Clusters di Hough

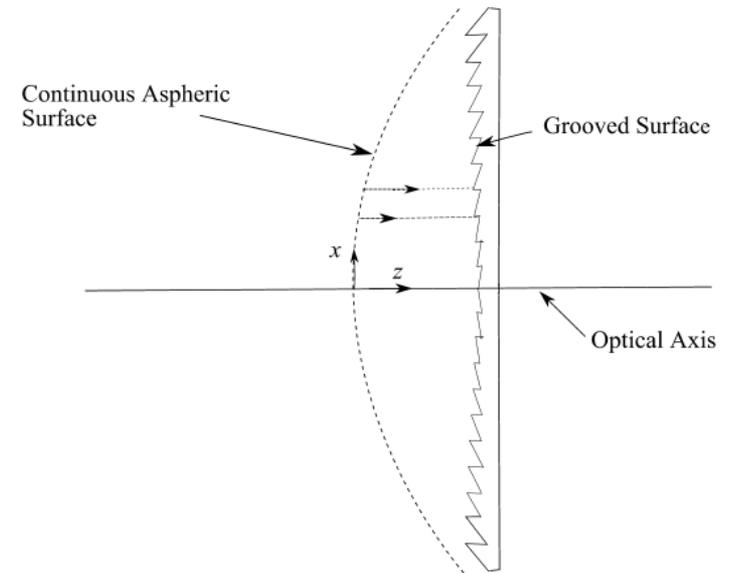
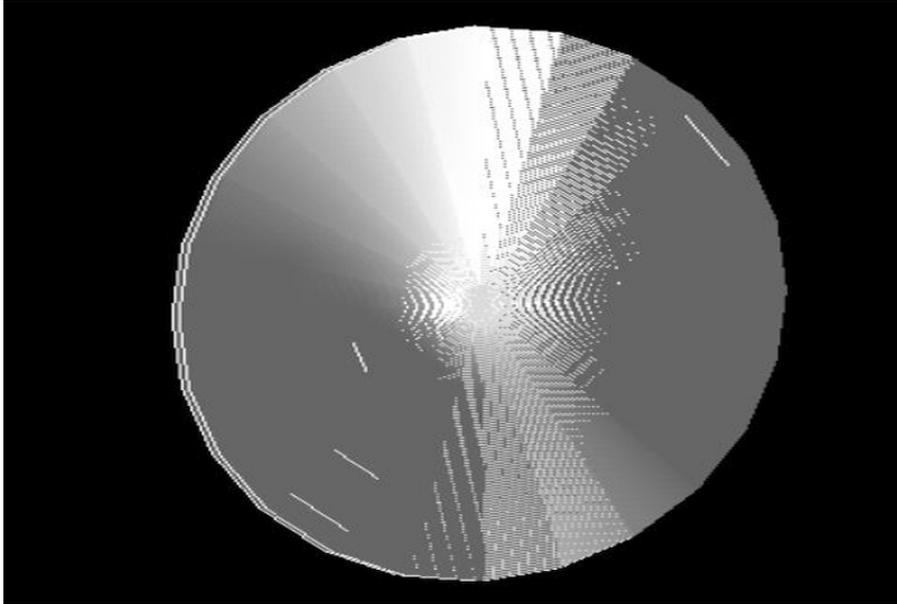
Tracce

Conclusioni sulla simulazione-MURA

Parametri stabili e conclusioni comuni col gruppo di lavoro MURA:

- Distanza massima traccia-maschera < 50 cm
- Dimensione pixel/foro maschera > 2x2 mm²
- Rango matrice < 31 (17 o 31)
- Set minimo di maschere per il menisco ha *qualche* decina di maschere
 - 40 nelle facce corte
 - 10 nelle facce verticali
 - 16 nelle facce orizzontali
- Analisi quantitativa delle immagini in corso:
 - Dbscan
 - Tracking
- Ricostruzione stereo e 3D + complementarità con informazioni temporali e intensità di fotoni

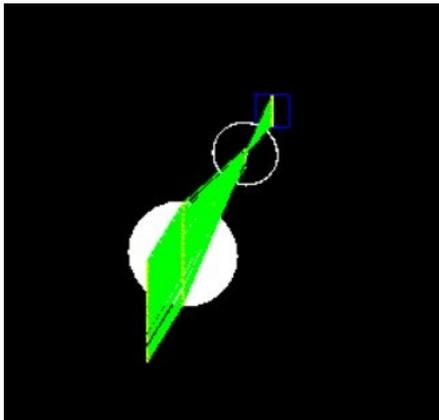
Simulazioni di sistemi non-MURA: lenti di Fresnel e specchi



equation of an aspheric surface, axially symmetric about the z axis:

$$z = \frac{cx^2}{1 + \sqrt{1 - (k+1)c^2x^2}} + a_1x^4 + a_2x^6 + a_3x^8 + a_4x^{10},$$

Geant4



Implementata in Geant4

→ Da studiare / ottimizzare con ray tracing software

Lenti di Fresnel

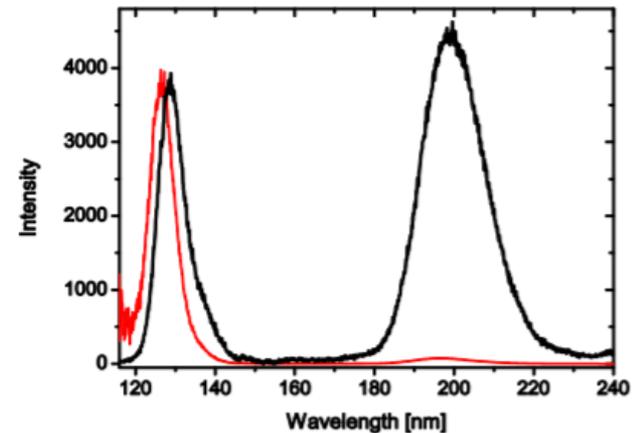
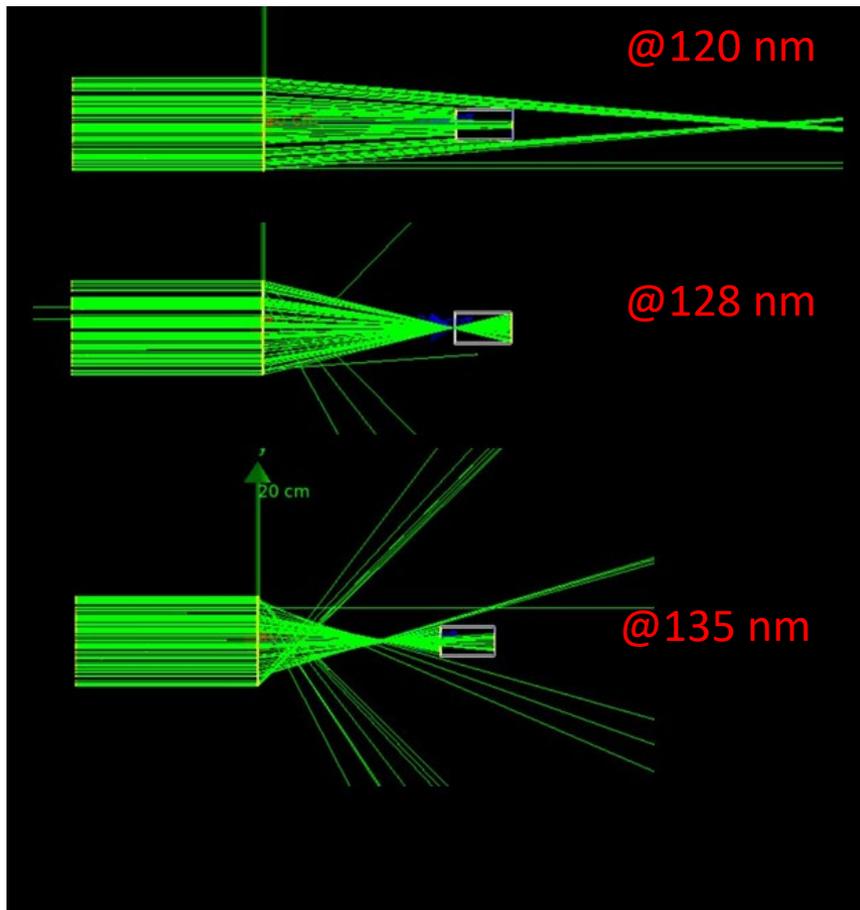


Fig. 5. Emission spectrum of unpurified liquid argon (85K) with (thin line) and without (thick line) sensitivity correction of our setup. The broad emission structure around 197 nm may be attributed to an oxygen impurity [12, 24].

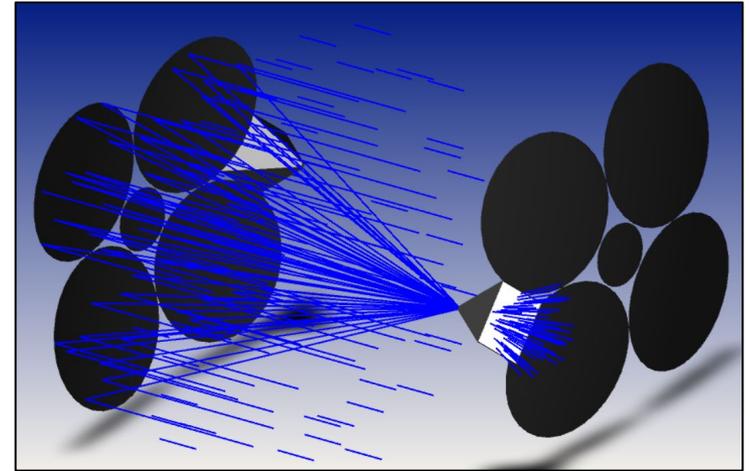
- Materiale usato: LiF (indice di rifrazione alto; resistenza a shock termici?)
- Focale: 20 cm@128 nm
- Diametro lente 10 cm

Tenendo conto dello spettro di emissione del Lar
→ Focalizzazione problematica

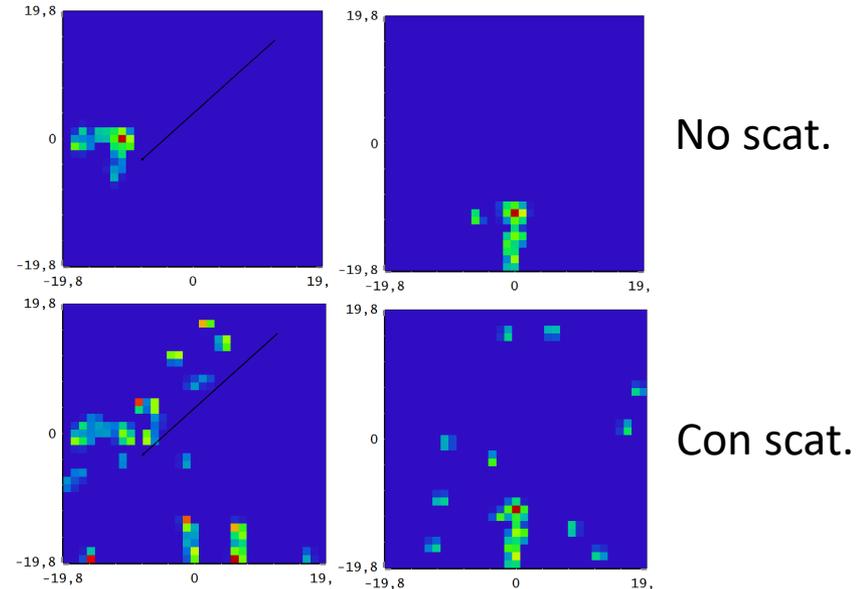
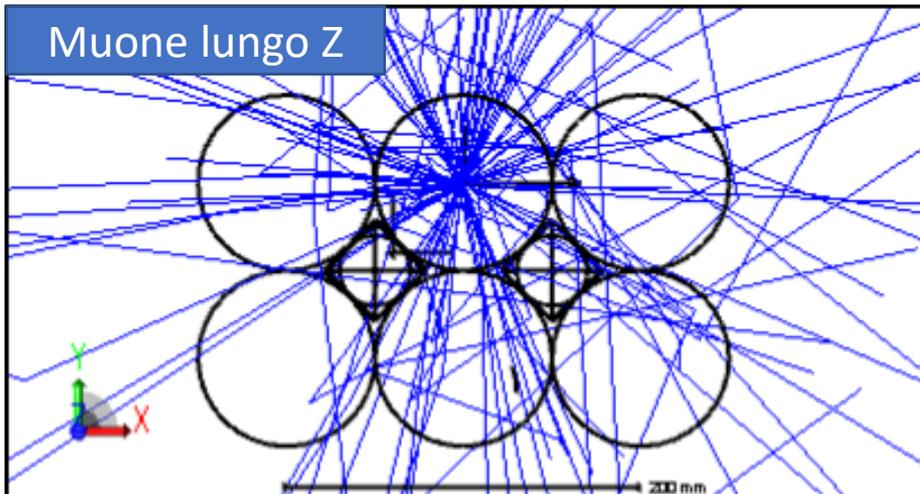
Configurazione con specchi

Sistema di 4 specchi che focalizzano la luce su un sensore posto sulla faccia opposta del menisco (facce up- e downstream)

Raggio specchio singolo circa 10 cm.
35 sistemi di specchi (150 specchi) per ricoprire una faccia → 35 sensori per una faccia del menisco.
Consumo sensore 5.4 W → 200 W per una faccia del menisco.



Lo scattering sembra essere problematico già nella vista «corta».



Warm demonstrator and plans for Cold demonstrator

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Warm demonstrator goals

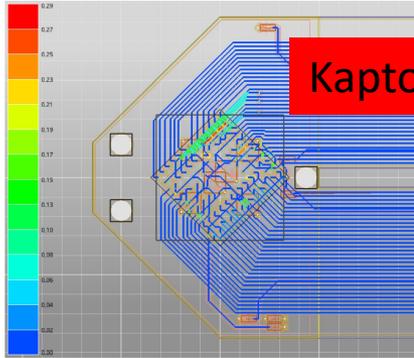
Build a very simple system to test:

- simple pattern reconstruction with **MURA masks in reality**
- Use standard **SiPMs matrix**
- Test **readout ASIC** on the market
- Verify eventually **signal transmission in Liquid Nitrogen**
- Verify **mechanical robustness of SiPM matrix** in LN
- Make the first exercise of **coupling the sensor to the mask**
- How to build the **mask**?

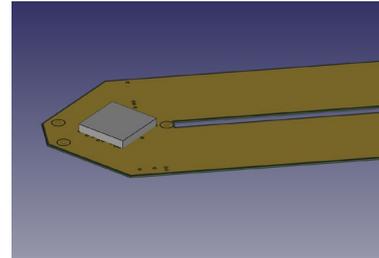
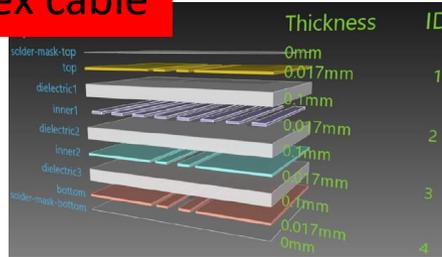
A **lot of work** done by (despite Covid limitations):

- *Alessandro Badiali, Valentina Cicero, Ignazio Lax, A.M., Valerio Pia, Michele Pozzato, Nicolo' Tosi*

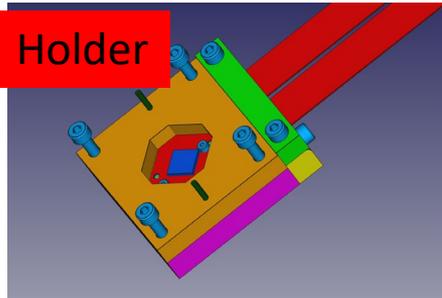
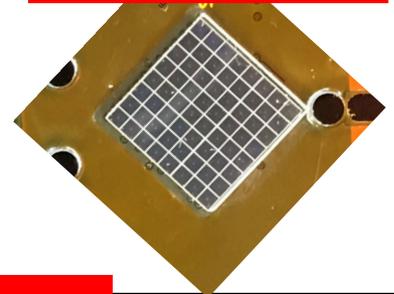
Some piece of hardware..



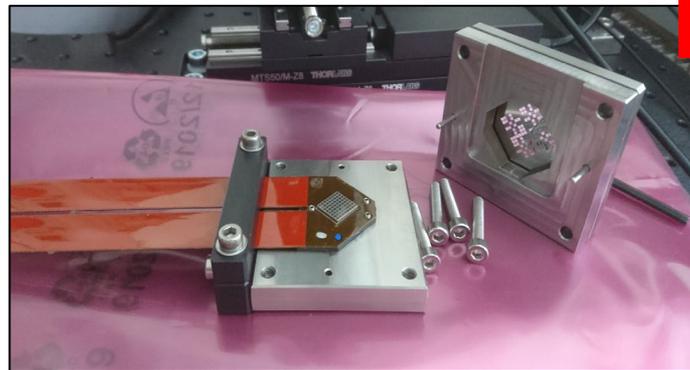
Kapton flex cable



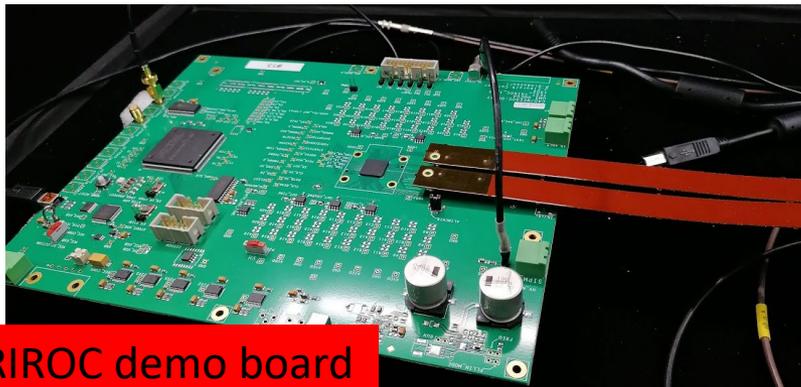
8x8 SiPM matrix



Holder

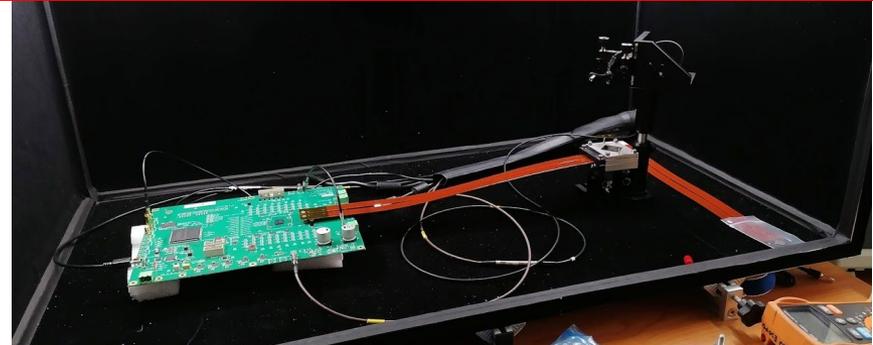


MURA mask 7x7



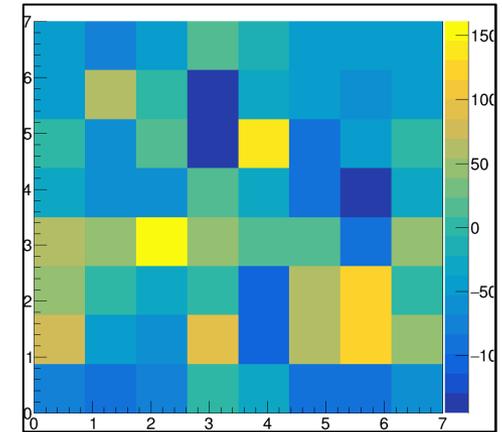
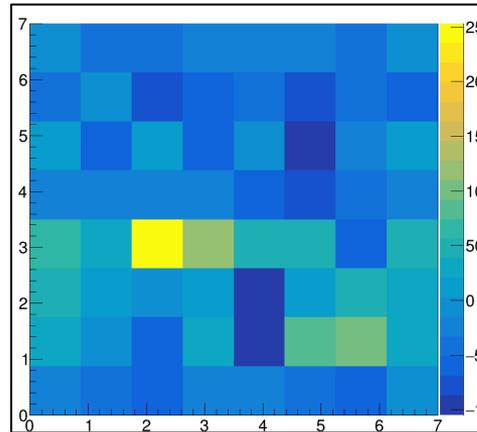
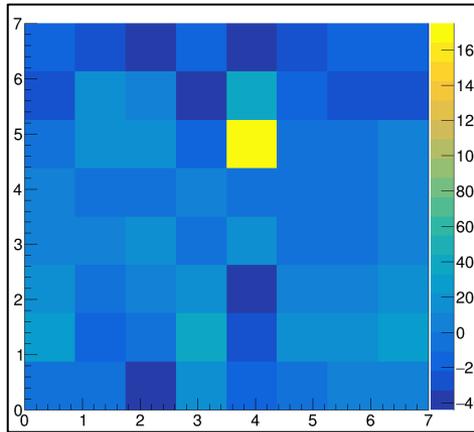
TRIROC demo board

Black box (calibration SiPMs & LED patterns)

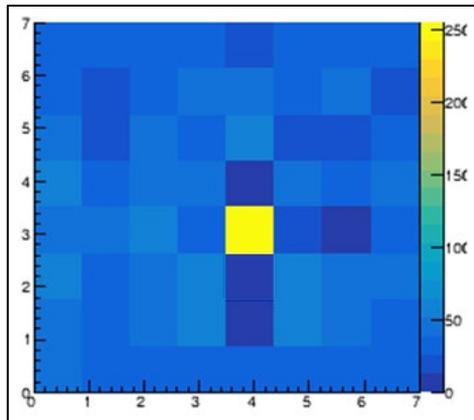


First real reconstruction of simple patterns

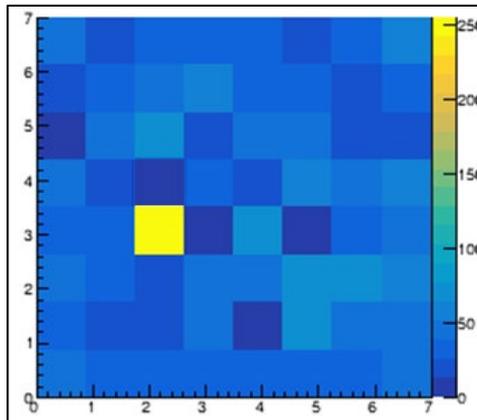
Misure
con prototipo
a T ambiente



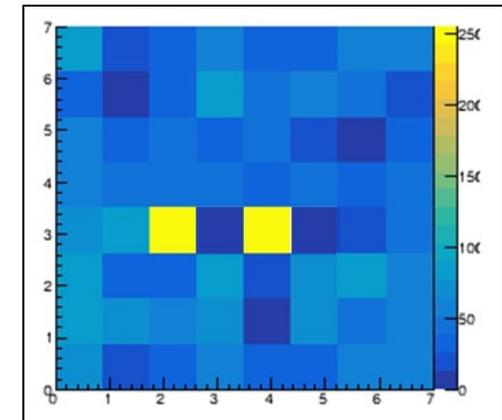
Simulazione



LED A



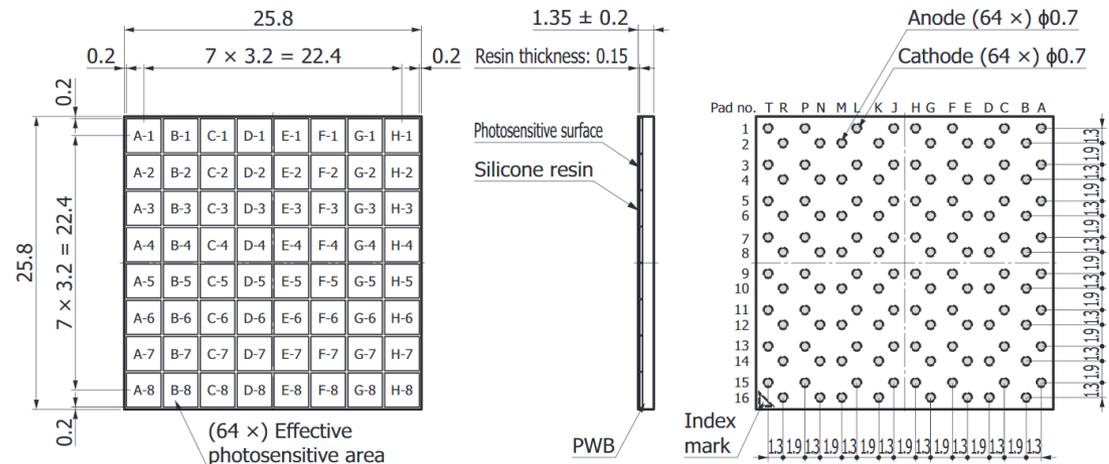
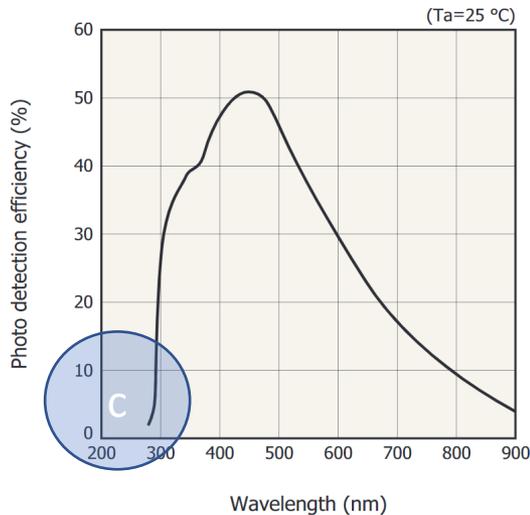
LED B



LED A+B

Plans for Cold demonstrator (1)

- After some iteration with simulation we arrived to the following compromise (considering time schedule and available budget)
- Use SiPM 3x3 mm² assembled to form a matrix 8x8:
 - *Hamamatsu 14161-3050HS-08*

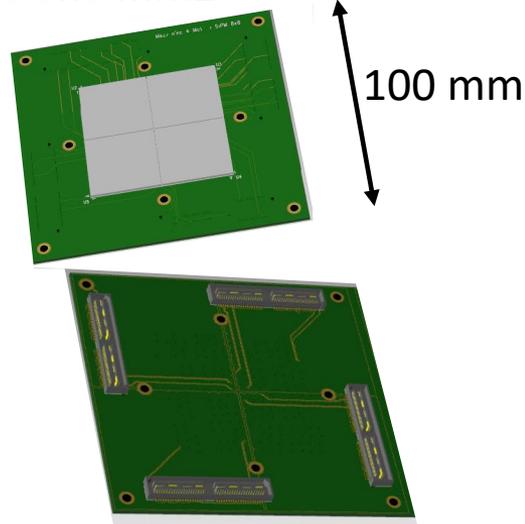


Plans for Cold demonstrator (2)

- Assemble 4 of these matrix on a mezzanine board to form **one «sensor unit» 16x16 of SiPMs 3x3 mm²**:
 - Samtec high density connectors, Q series, 0.8mm pitch, 50 Ohm (board to board or board to cable)
 - Tried automatic layout: possible
 - **3 cameras** (for 3 orthogonal views), 12 matrix

16x16 = 256 ch

SiPMs 3x3 mm²



Plans for Cold demonstrator (3)

- The optimal approach for the readout of SiPM matrix is through a **cryogenic ASIC** in order to reduce the number of connections through feedthrough flanges
- ALCOR 32 ch?? Question for Torino group....



Backup

