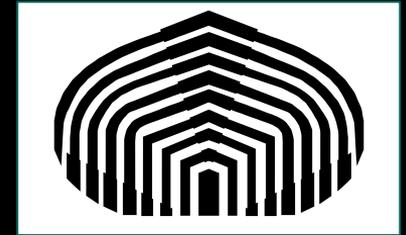


Aplicaciones de la muografía en la Ind. Petroquímica

R. A, Martinez Rivero
Tutor: C. Sarmiento-Cano UIS
Co-tutores: J. Stephany USB



Introducción y motivación

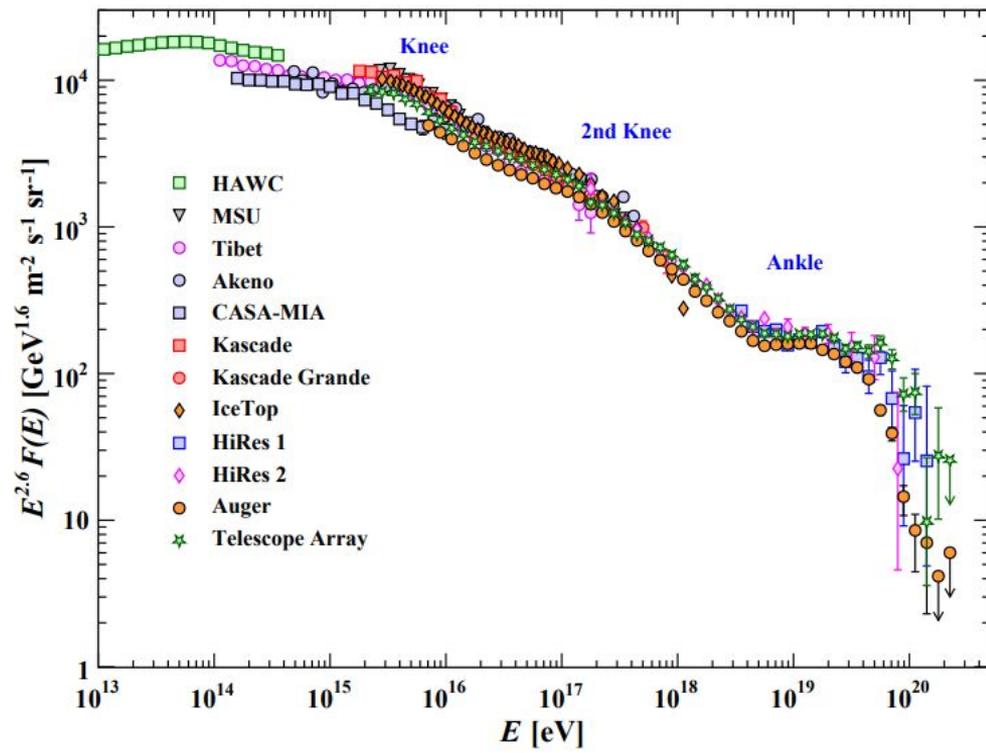
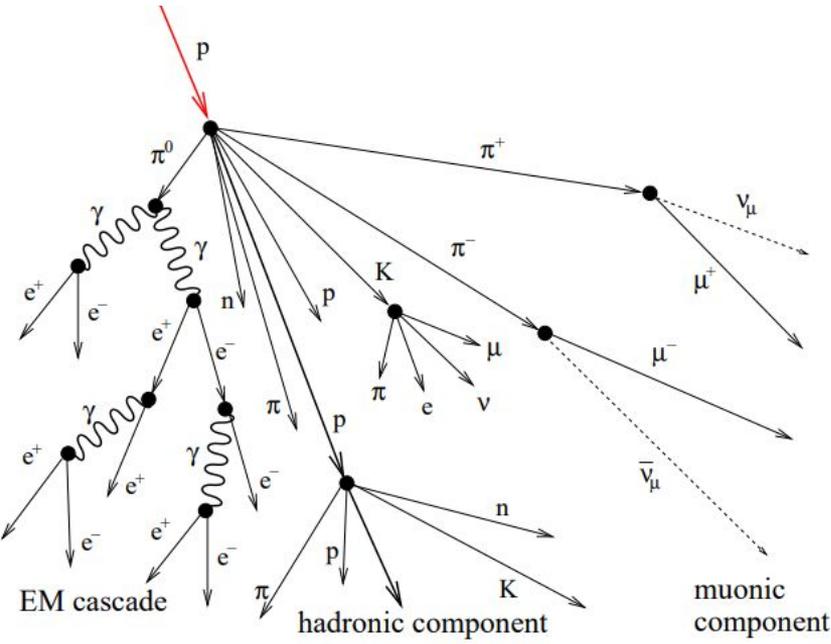
- Desafío en la extracción y refinamiento del **crudo pesado**.
- Reactores de hidrotratamiento.
- Catalizador y altas temperaturas.
- **Obstrucción:** Acumulación de material en los poros. fouling
- **Detección temprana** de la obstrucción.
- Modelos y técnicas de monitoreo.
- Espectroscopia Raman o Infrarroja, absorción de rayos X. No son viables.



¿Es factible utilizar la muografía como una técnica para medir y estudiar la dinámica de los procesos de refinamiento en reactores catalítico, con el fin de optimizar la eficiencia del refinamiento?

Radiación Cósmica

$$\frac{dN}{dAdT d\Omega dE} \propto E^\eta$$



- $K^+ \rightarrow \mu^+ + \nu_\mu$ Branching Ratio 63%
- $K^+ \rightarrow \pi^+ + \pi^0$ Branching Ratio 21%
- $\pi^+ \rightarrow \mu^+ + \nu_\mu$ Branching Ratio 99%

Pérdida de Energía en la Materia

Ionización

$$-\frac{dE}{dx} = K(\rho) \frac{Z}{A} \frac{z^2}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e \beta^2 \gamma^2 T_{\max}}{I^2} - 2\beta^2 - \frac{\delta(\beta\gamma)}{2} - 2\frac{C}{Z} \right]$$

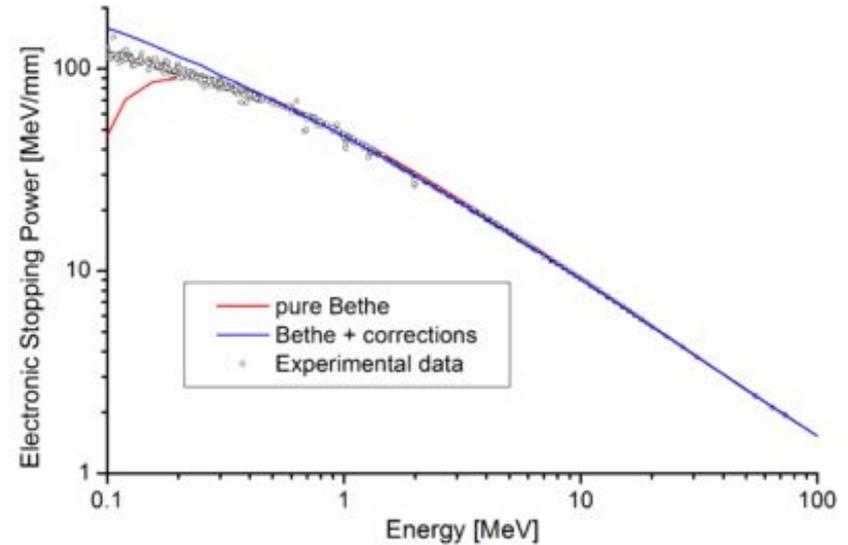
Para muones de altas energías los procesos radiativos se vuelven predominantes : *Bremsstrahlung, Pares, Int. foto nucleares.*

$E > 708 \text{ GeV}$ en SiO_2

Adair and Kasha (1977):

$$\frac{-dE}{d\rho} = a(E) + b(E)E$$

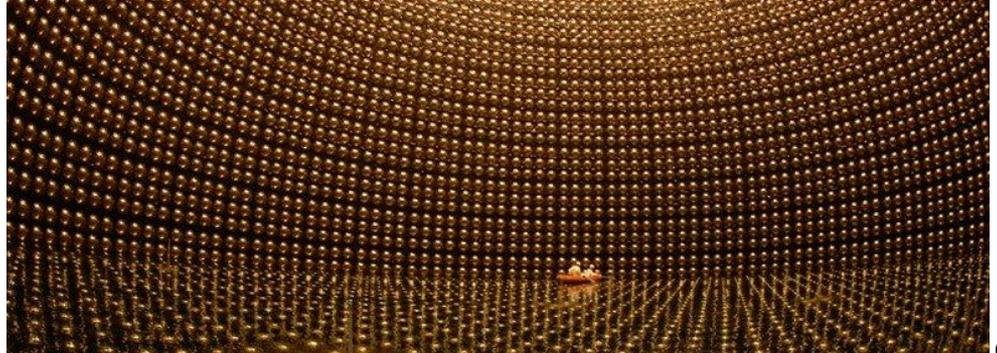
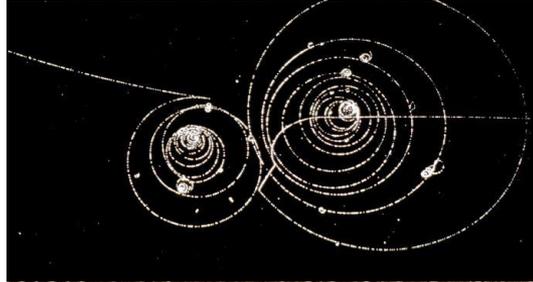
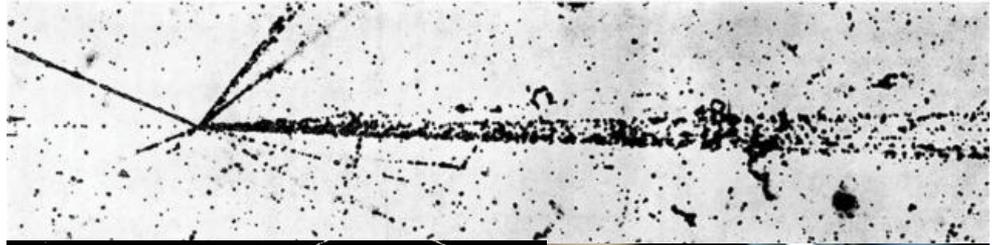
$$b(E)E < 10^{-2} a(E) \longrightarrow E < 100 \text{ GeV}$$



Groom et al. 2001 Caracterización de a y b para diferentes Materiales

Detectores de partículas cargadas

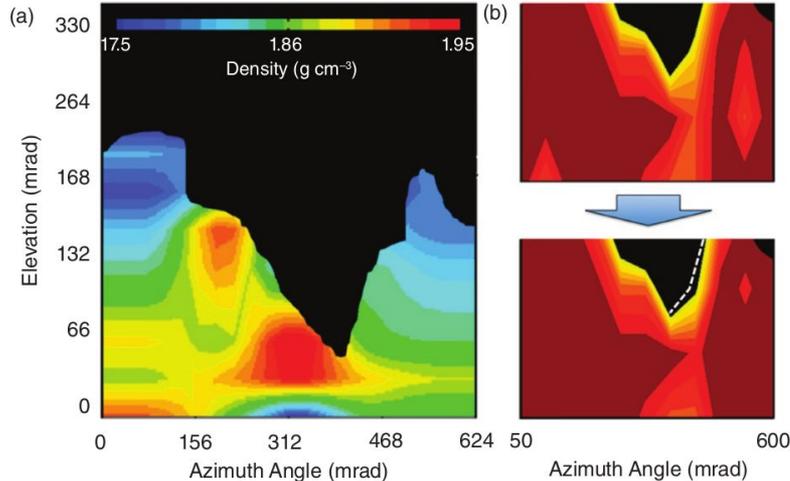
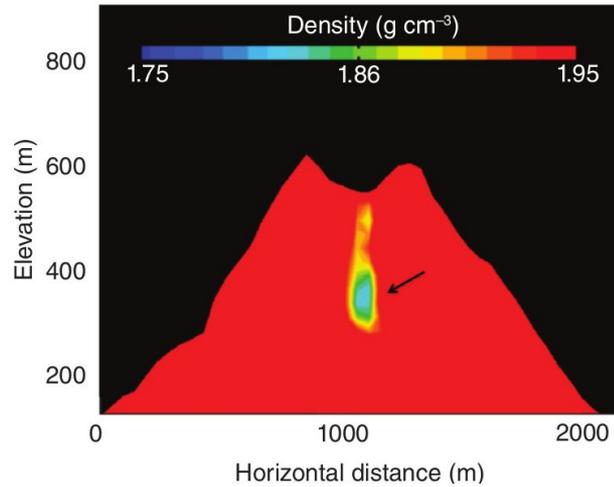
- Emulsiones Nucleares
- Gaseosos
- Centelleo
- Cherenkov



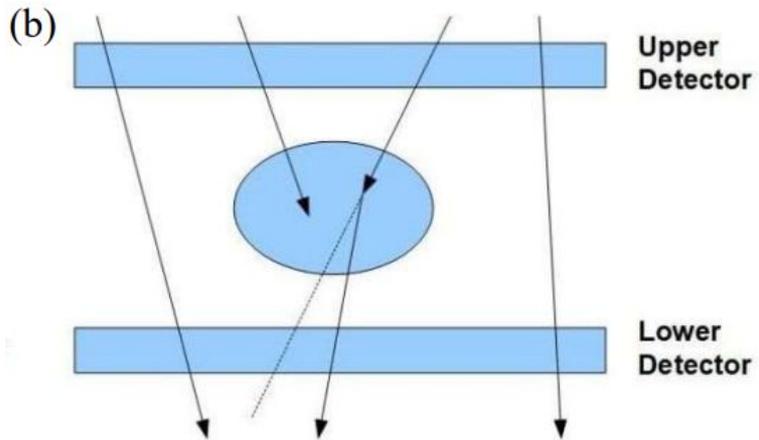
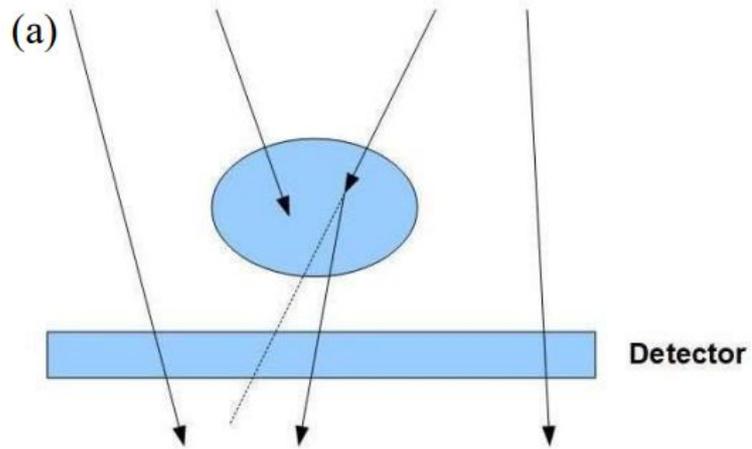
Muografía

La obtención de una imagen de una estructura por medio de muones cósmicos.

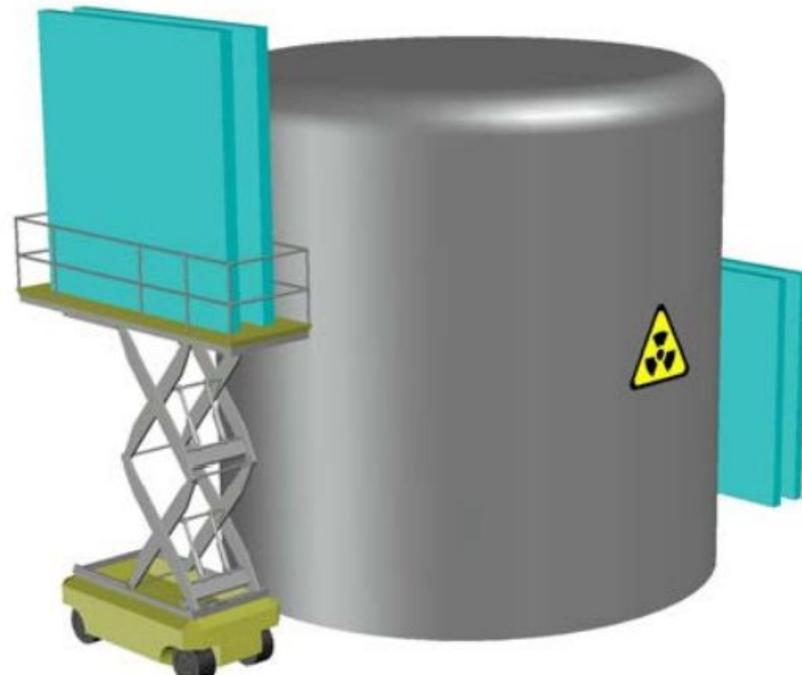
Perfiles de densidad promedio



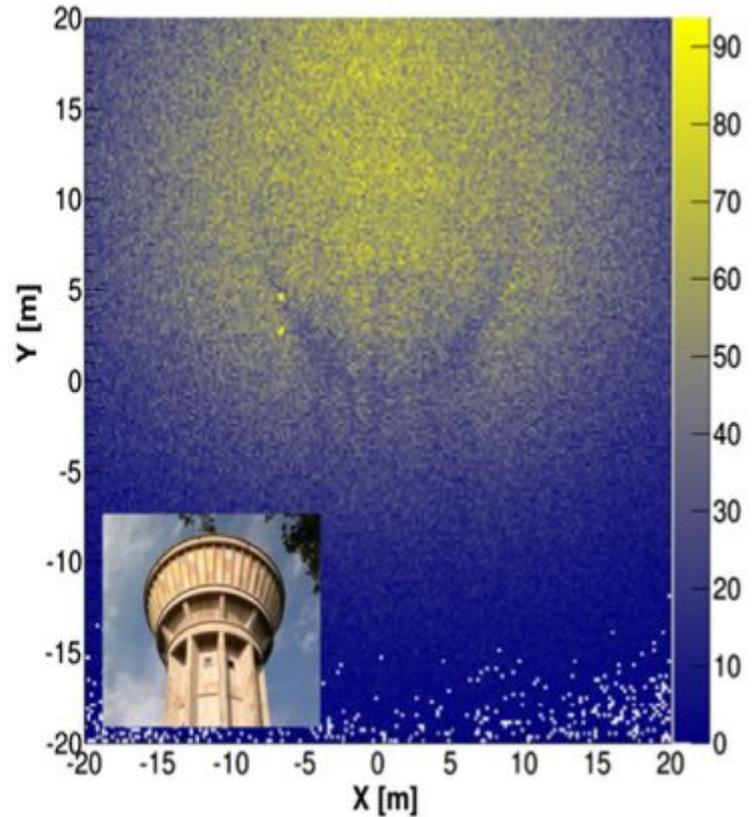
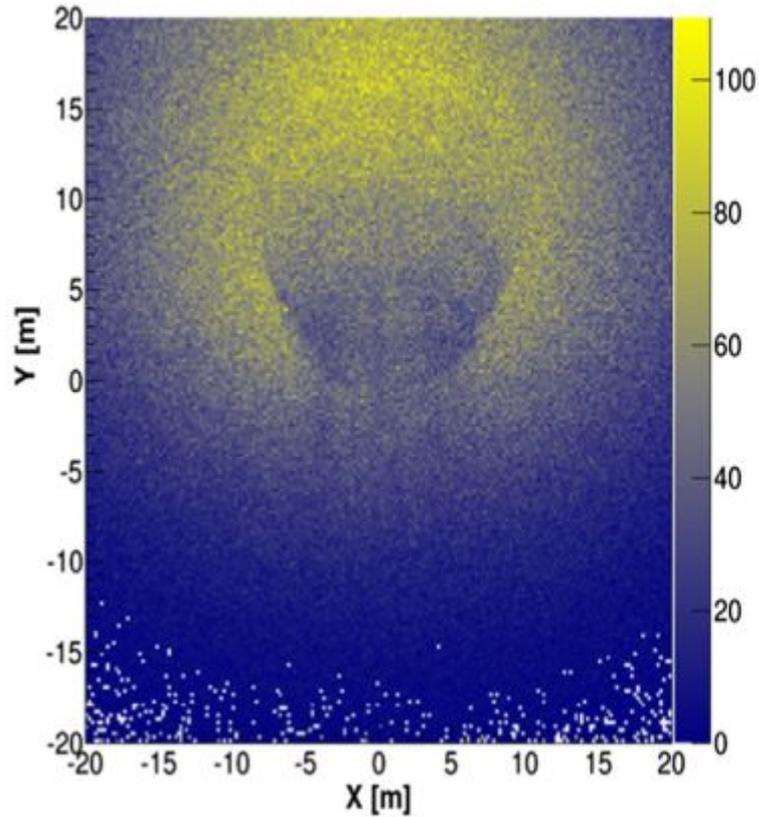
- H. Tanaka et al. Japanese volcanoes visualized with muography (2019)
E.S ~ (0.02 - 0.2) g/cm^3 a 250 m a.s.l.



- H. Miyadera et al. imaging fukushima daiichi reactors with muons (2013)

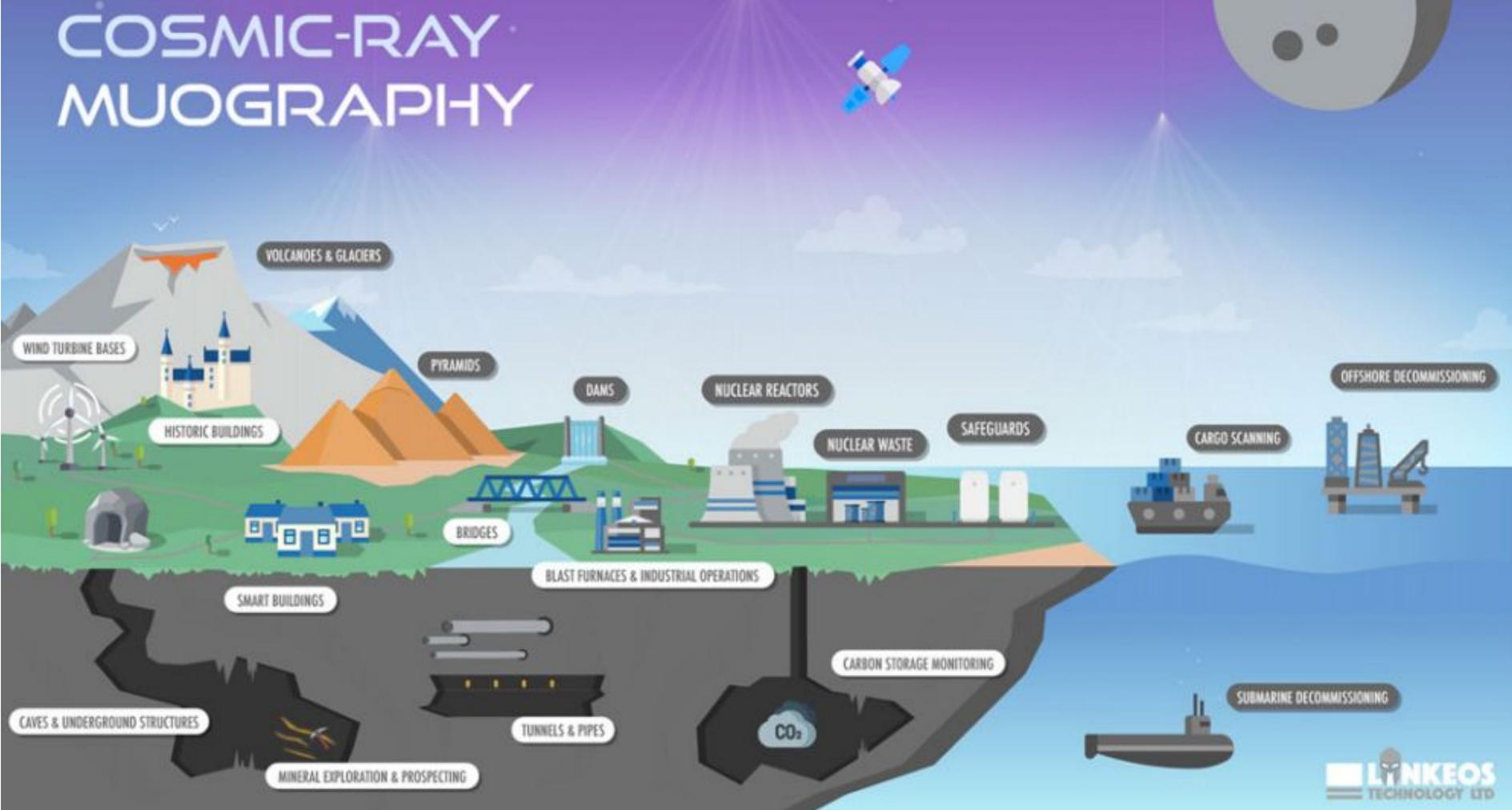


S. Bouteille, et al., Nucl. Instrum. Methods A 834 (2016) 223.

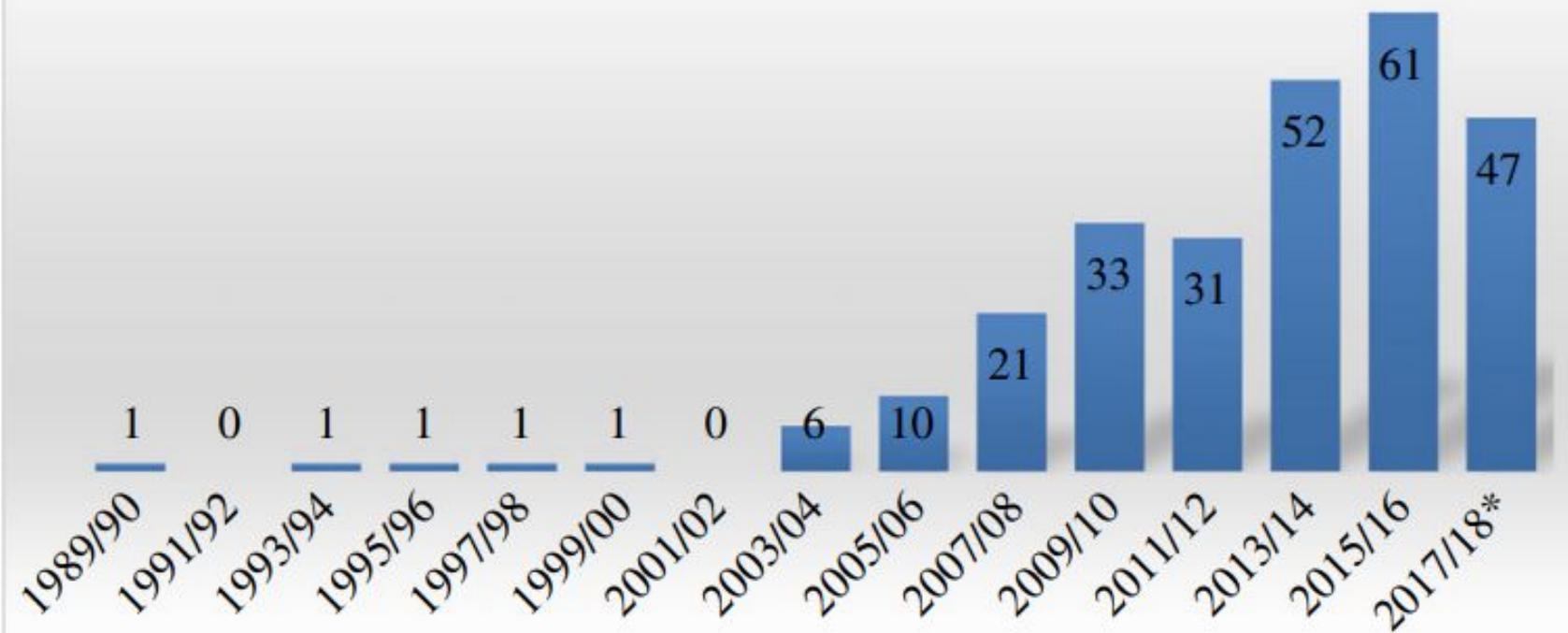


Tanque de agua, lleno Izq., vacio der. 4 días de exposicion, Hodoscopio de 0,25 m**2

COSMIC-RAY MUOGRAPHY



muography publications



Publicaciones de muografía en el tiempo, Cortesía: University of Glasgow Library

**Desarrollar un
modelo
computacional
estudiar la dinámica
en las RLF.**

*Caracterización y
simulación del Fondo
de Rayos Cósmicos.*

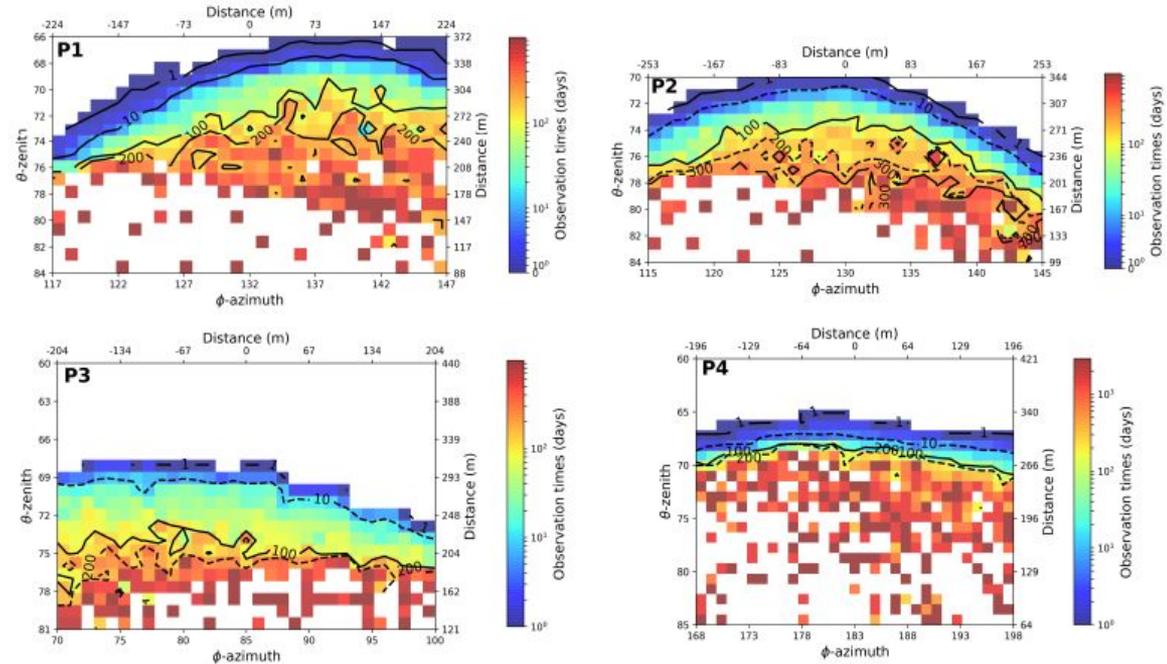
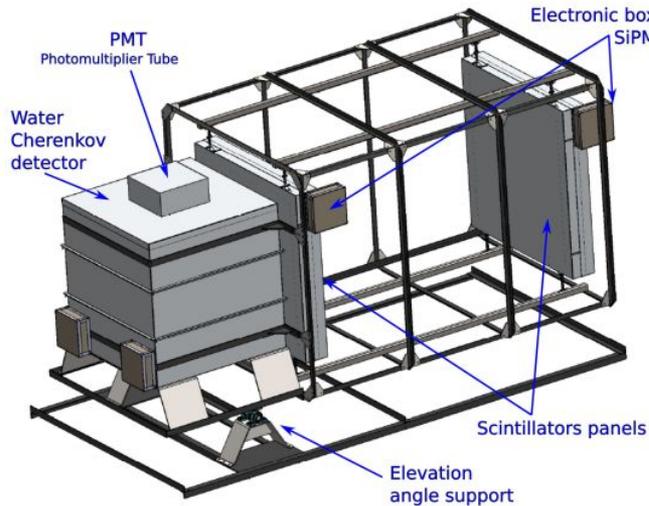
*Desarrollar diferentes
modelos de
hodoscópios.*

+

*Emular un reactor de
lecho fijo.*

*Integrar el FRC, el
hodoscópio y el RLF.*

MuTe: Muon Telescope.



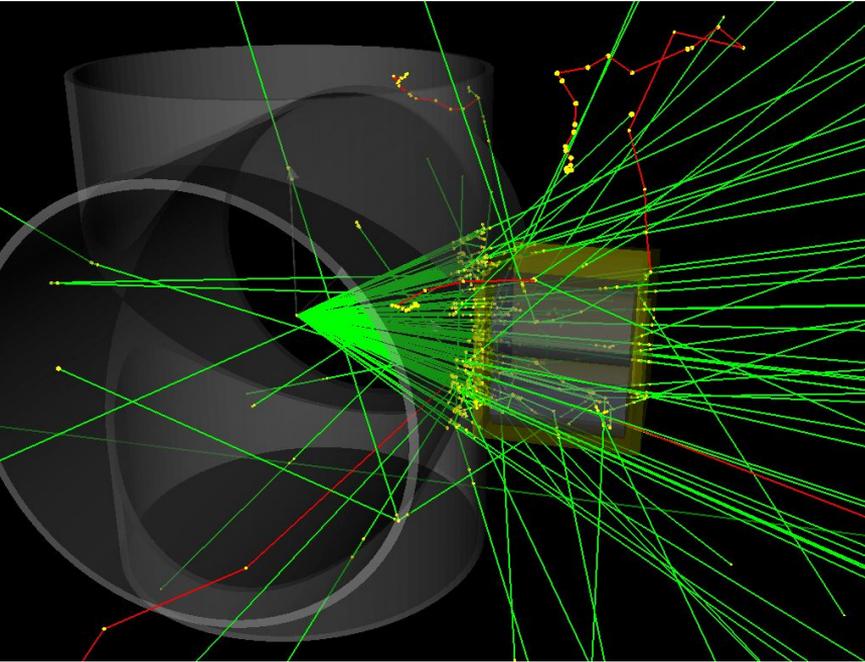
Calibration and first measurements of MuTe: a hybrid Muon Telescope for geological structures . Jesús Peña-Rodríguez, et al.

Simulated Response of MuTe, a Hybrid Muon Telescope. A. Vásquez-Ramírez et al.

MiniMuTe: A muon telescope prototype for studying volcanic structures with cosmic ray flux. H. Asorey. et al.

Simulación de Astropartículas y Detectores.

toolkit de simulación de eventos utilizado en la investigación de física de partículas y aplicaciones afines.



- Variedad de procesos: Ópticos, decaimientos, Radiativos, transporte de neutrones, etc.
- Alta Modularidad y personalización.
- Posibilidad de interfaz gráfica.
- Simulaciones Robustas.
- Alto poder de computo.
- Problemas de compatibilidad.
- Extensión no trivial para grandes proyectos.

ARTI

Framework en C++, Fortran, Bash y Perl permite la integración entre MagetoCosmics, CORSIKA y Geant4.

MAGCOS
MAGnetoCOSmics

CORSIKA
COsmic Ray SIMulations for KAscade

 **GEANT4**
A SIMULATION TOOLKIT



ARTI

Framework en C++, Fortran, Bash y Perl permite la integración entre MagentoCosmics, CORSIKA y Geant4.

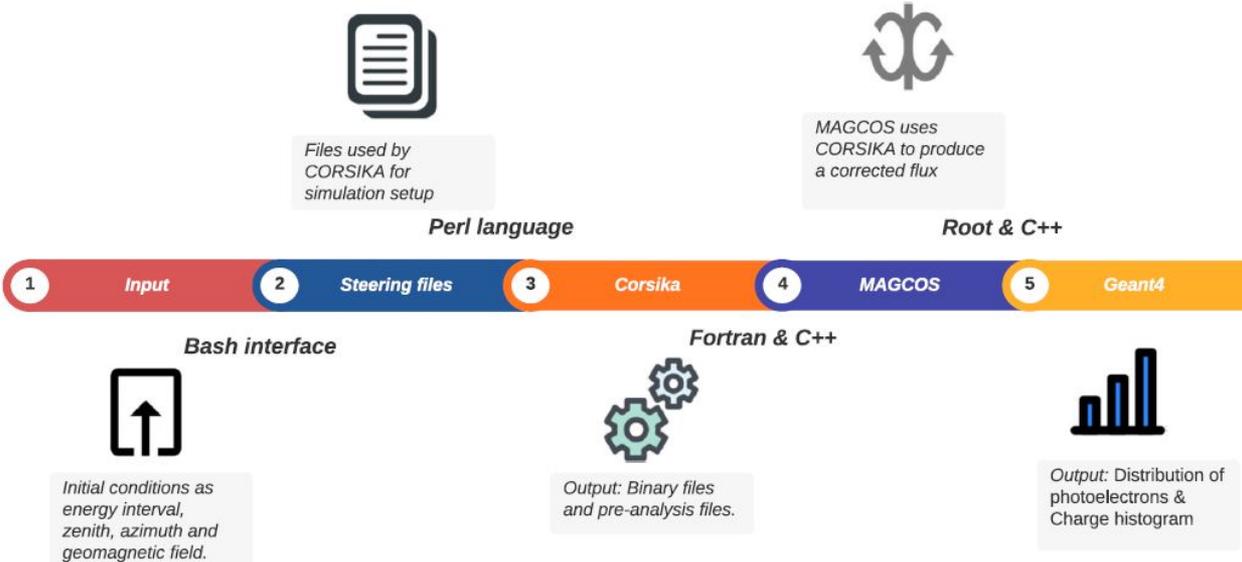
$$\Phi(E_p, Z, A, \Omega) \simeq j_0(Z, A) \left(\frac{E_p}{E_0} \right)^{\alpha(E_p, Z, A)},$$

(0.1 - 10⁶) GeV,

$$j_0(Z, A, E_0 = 10^3 \text{ GeV})$$

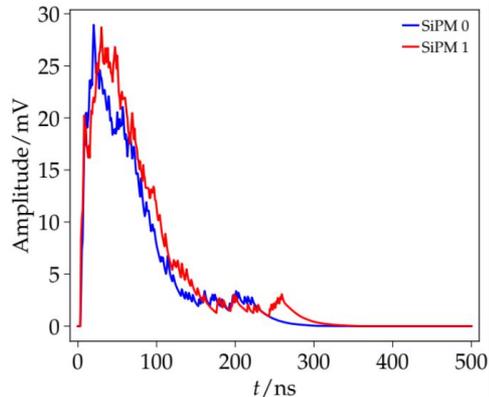
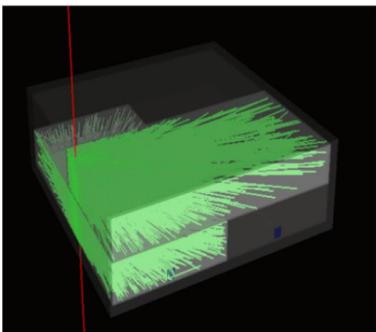
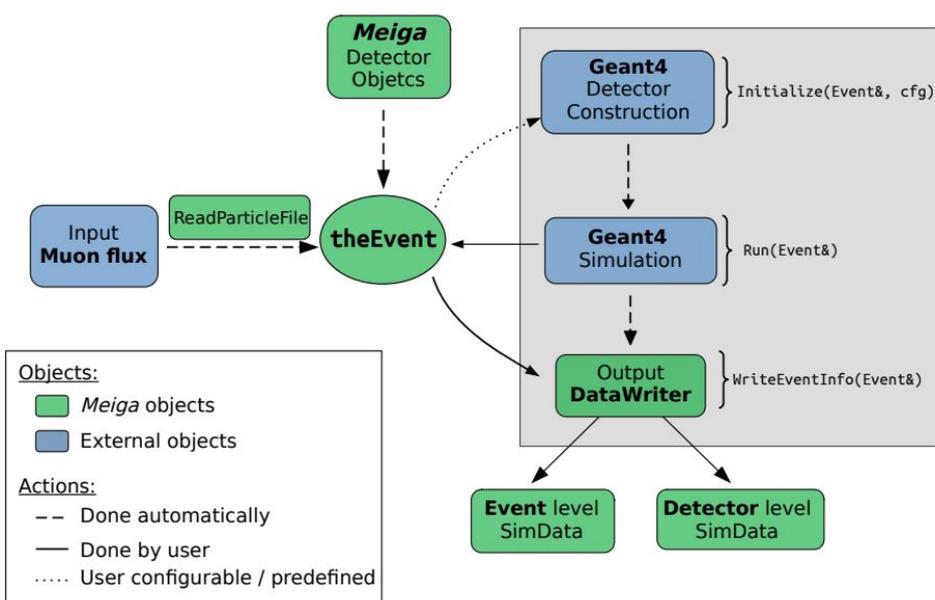
122km asl

$$1 \leq Z \leq 26,$$

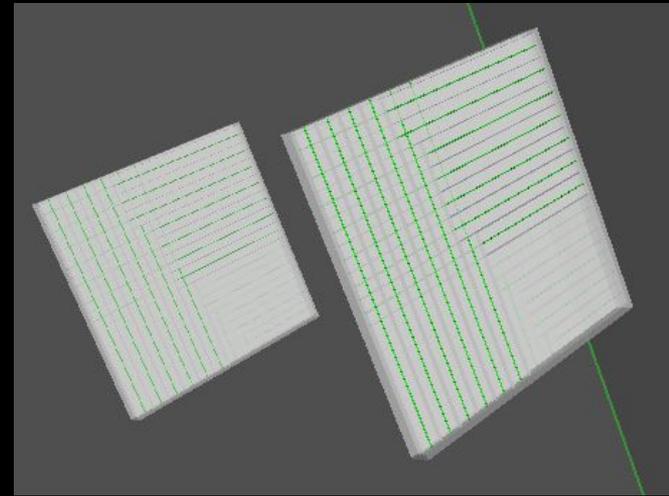


MEIGA

Integra el cálculo del **flujo** de rayos cósmicos, la **propagación** de partículas a través de materiales y la simulación de la **respuesta** del detector.



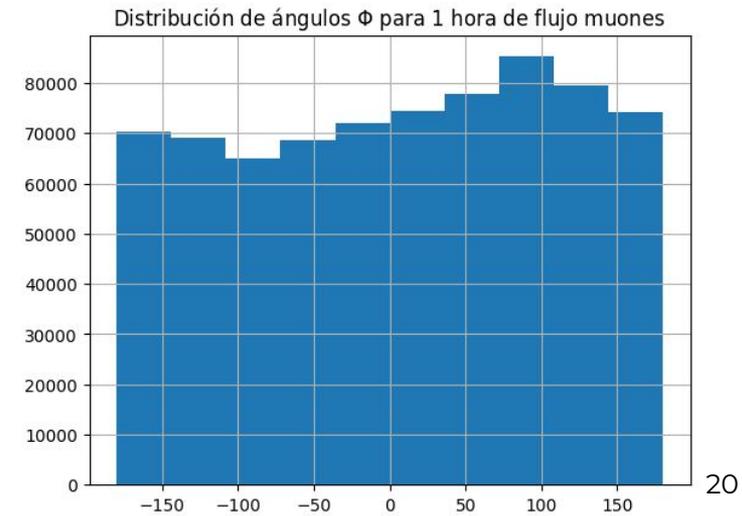
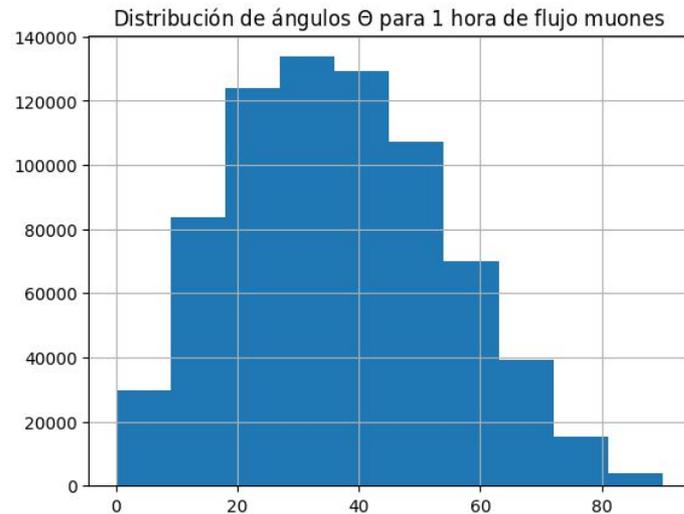
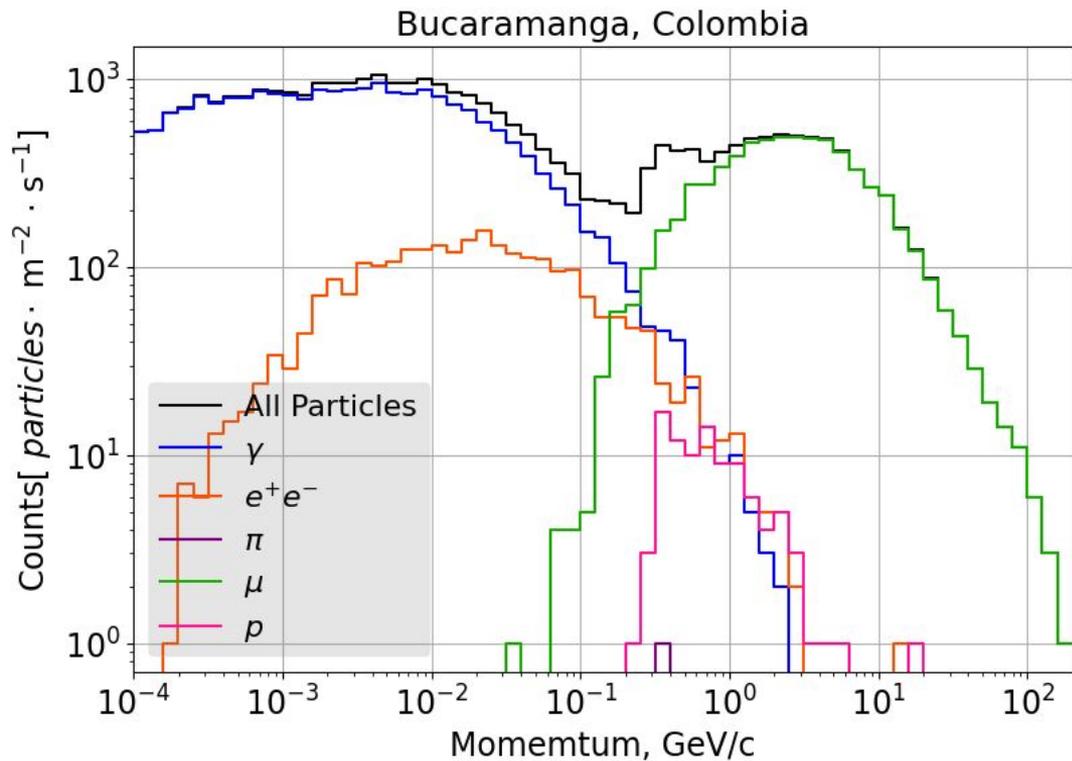
Meiga, a Dedicated Framework Used for Muography Applications A. Taboada, et al.



Physics List: QGSP_BERT_HP

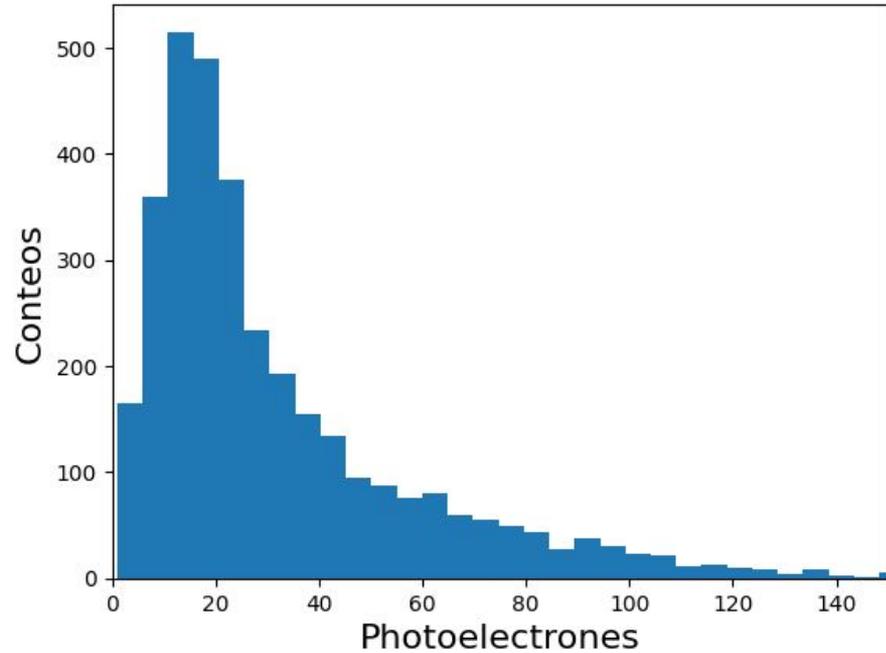
Resultados Preliminares

EAS

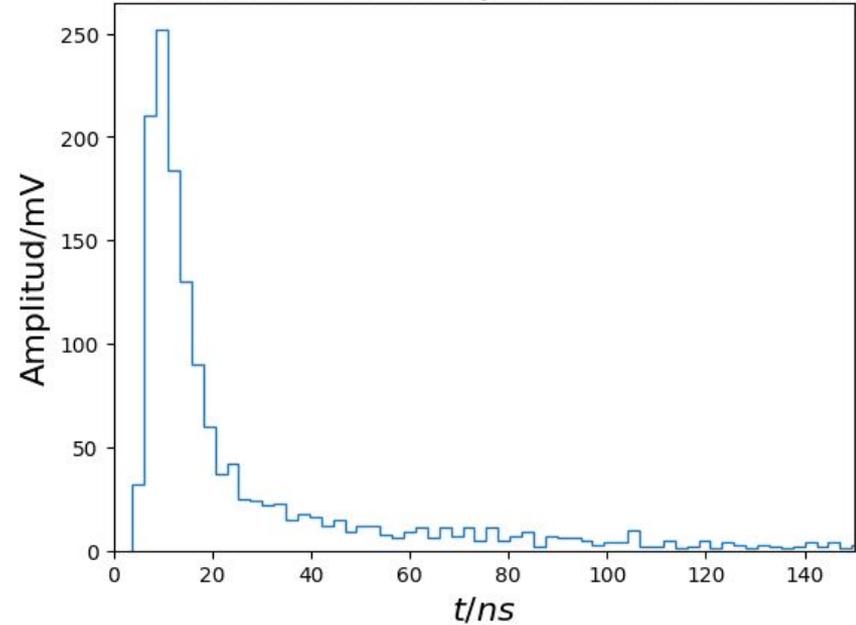


Respuesta del detector

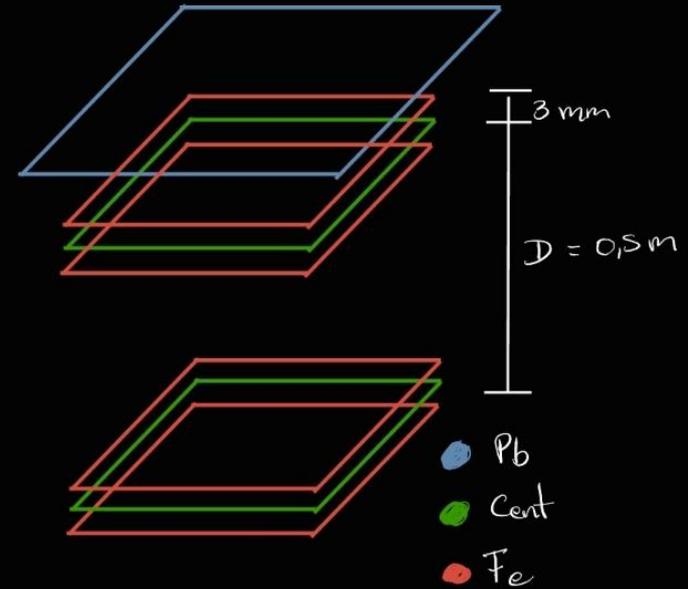
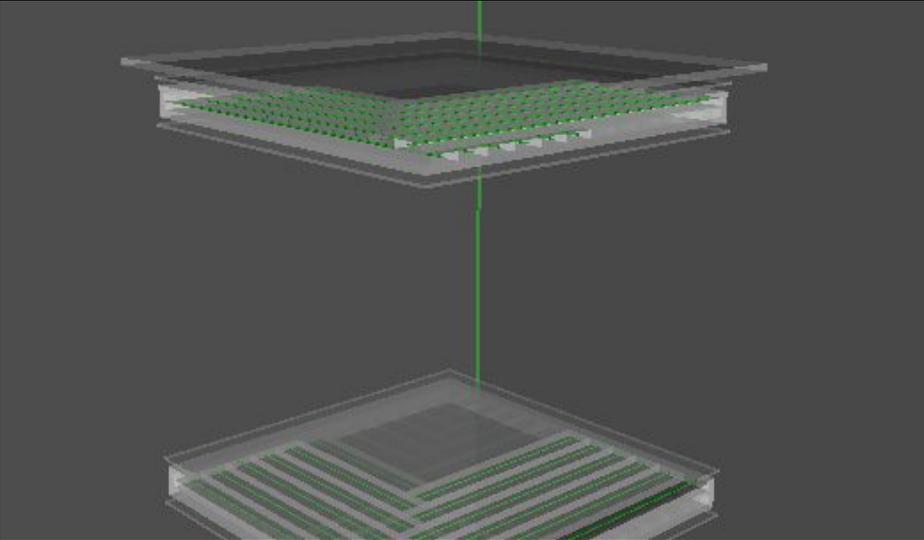
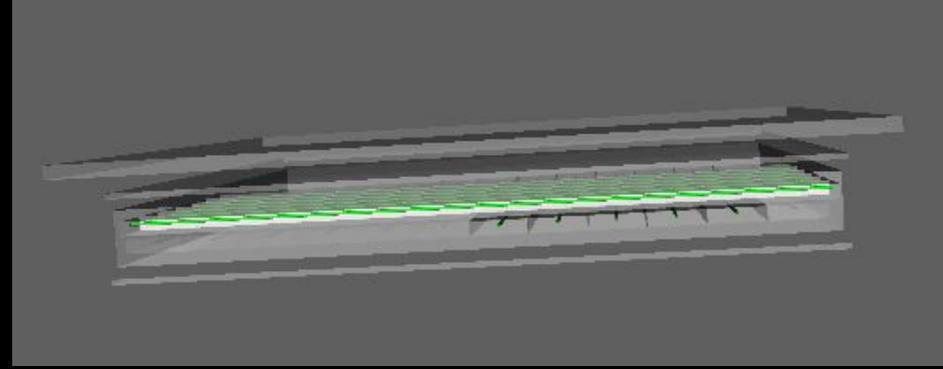
Distribucion del Numero de PE en el SiMP



Distribución temporal en los SiPM

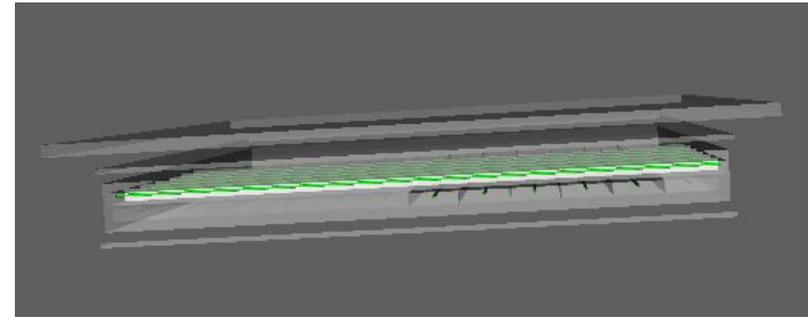
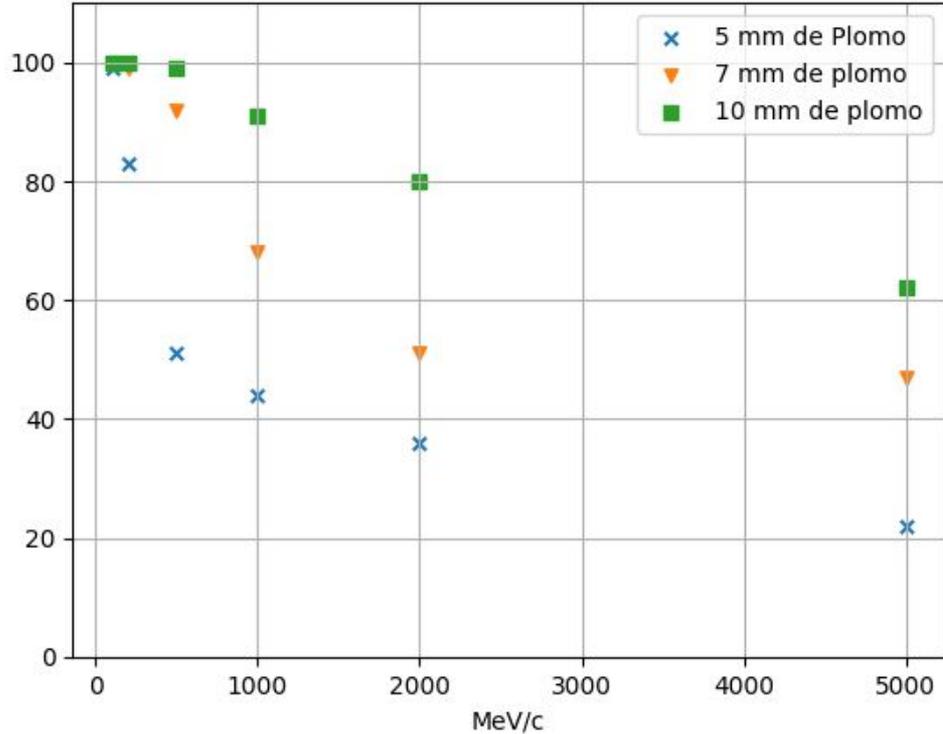


Diseño con blindaje

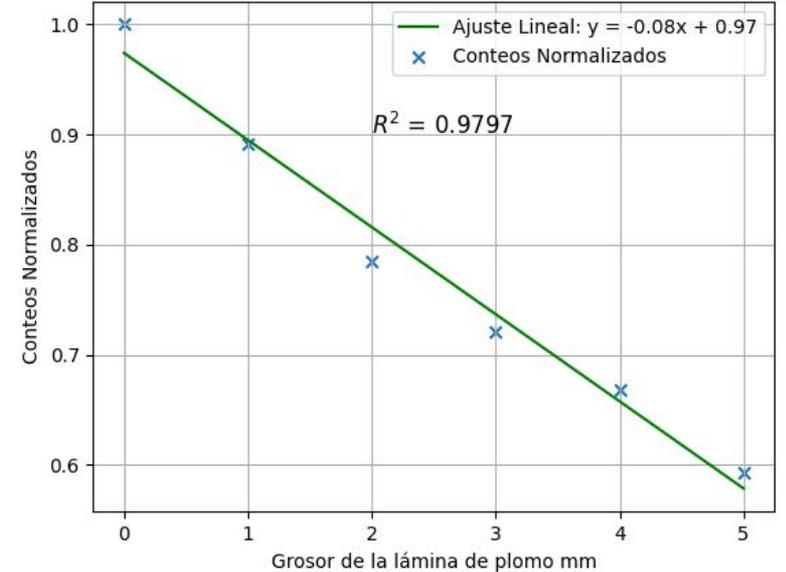


Atenuación del ruido

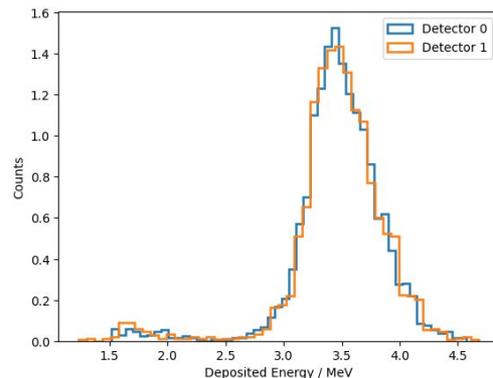
% de Atenuación Pb flujo e^- monocromatico



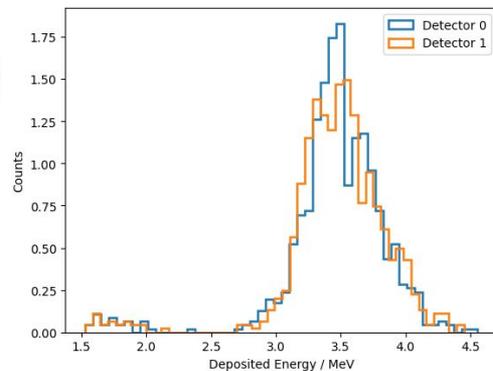
Atenuación para $[\gamma, e^\pm]$ de un flujo ARTI 30 seg



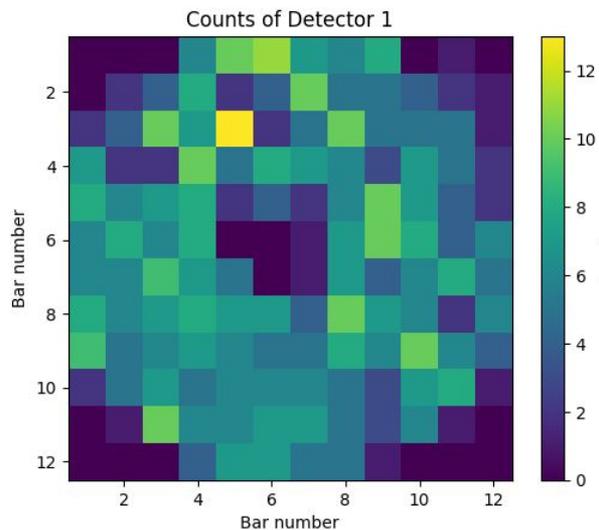
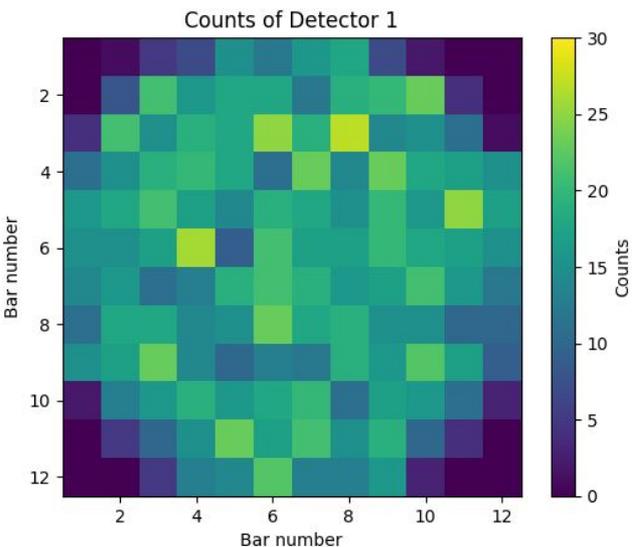
Visualización de objetivo Pb. Flujo Monocromático 1 GeV



Flujo Int=2025



Flujo Int=720



p-value 2.75×10^{-41} 24

Parámetros geométricos del hodoscopio.

Opacidad

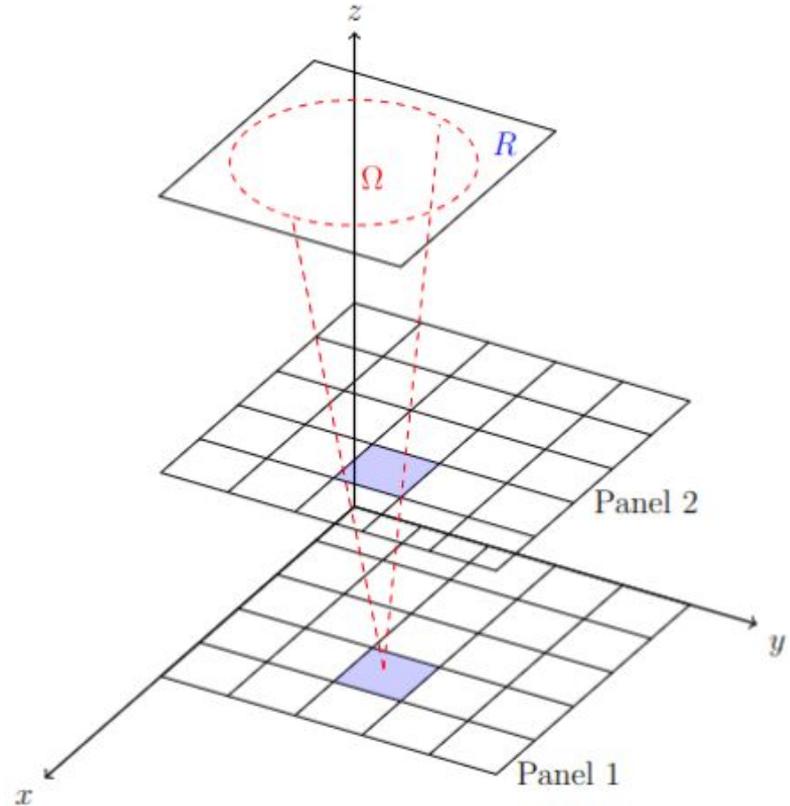
$$\varrho = \int_L \rho(\chi) d\chi = \rho \times L$$

Flujo detectado

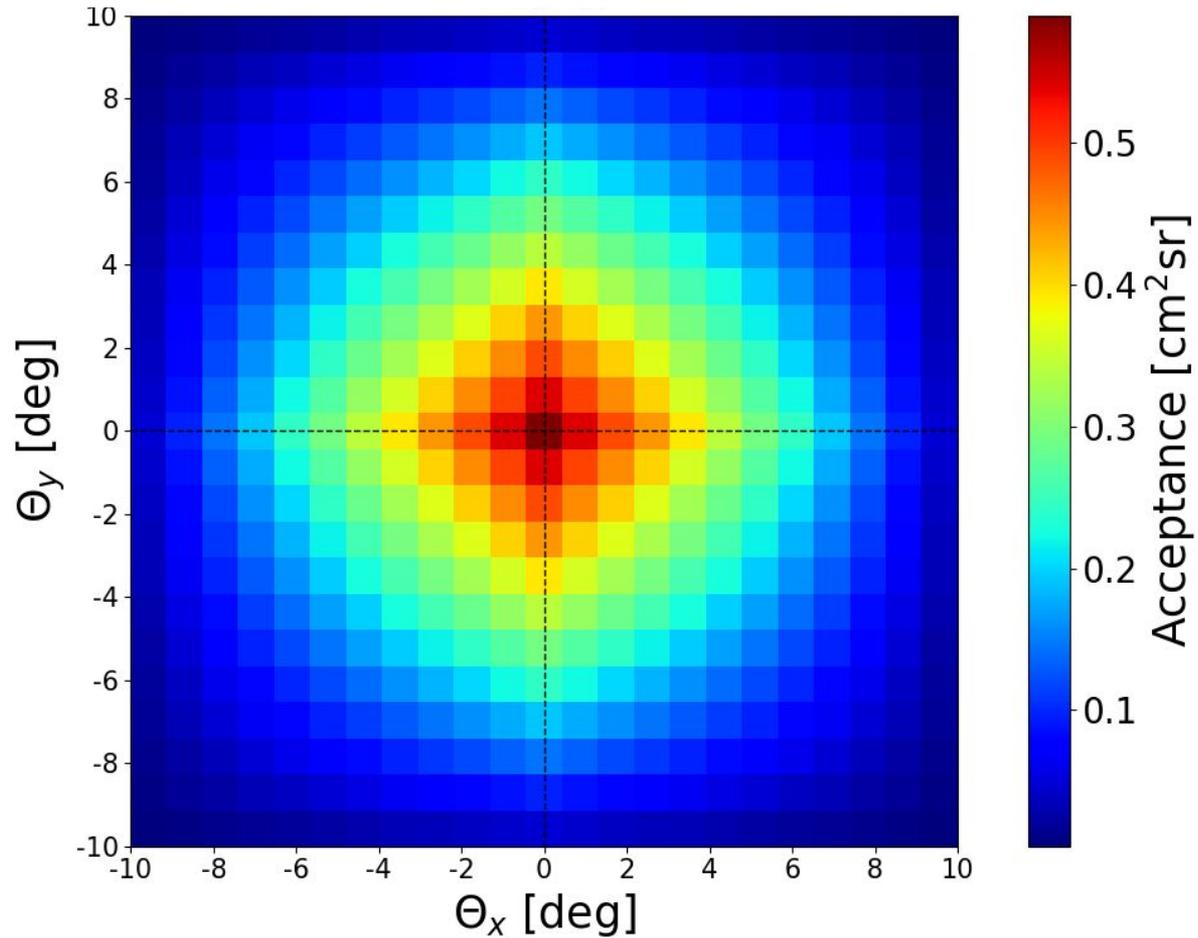
$$N(\varrho) = \Delta t \times T \times I(\varrho)$$

Aceptancia

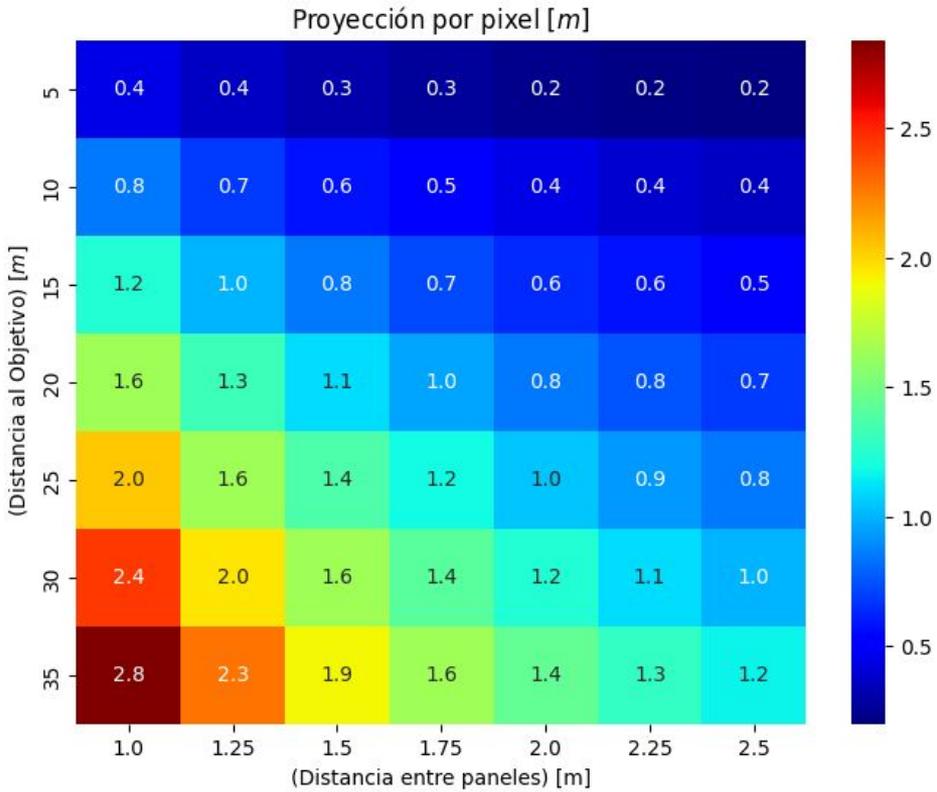
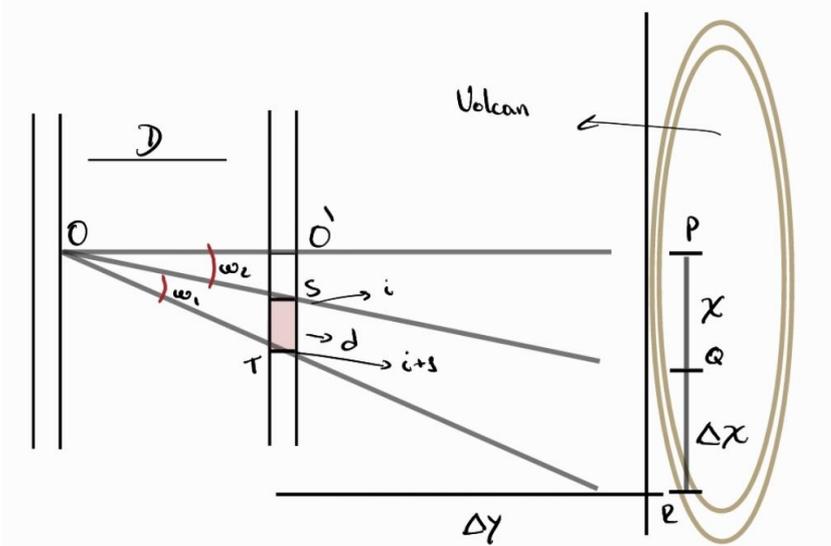
$$T(r_{ij}) = R(r_{ij}) \times \delta\Omega(r_{ij})$$



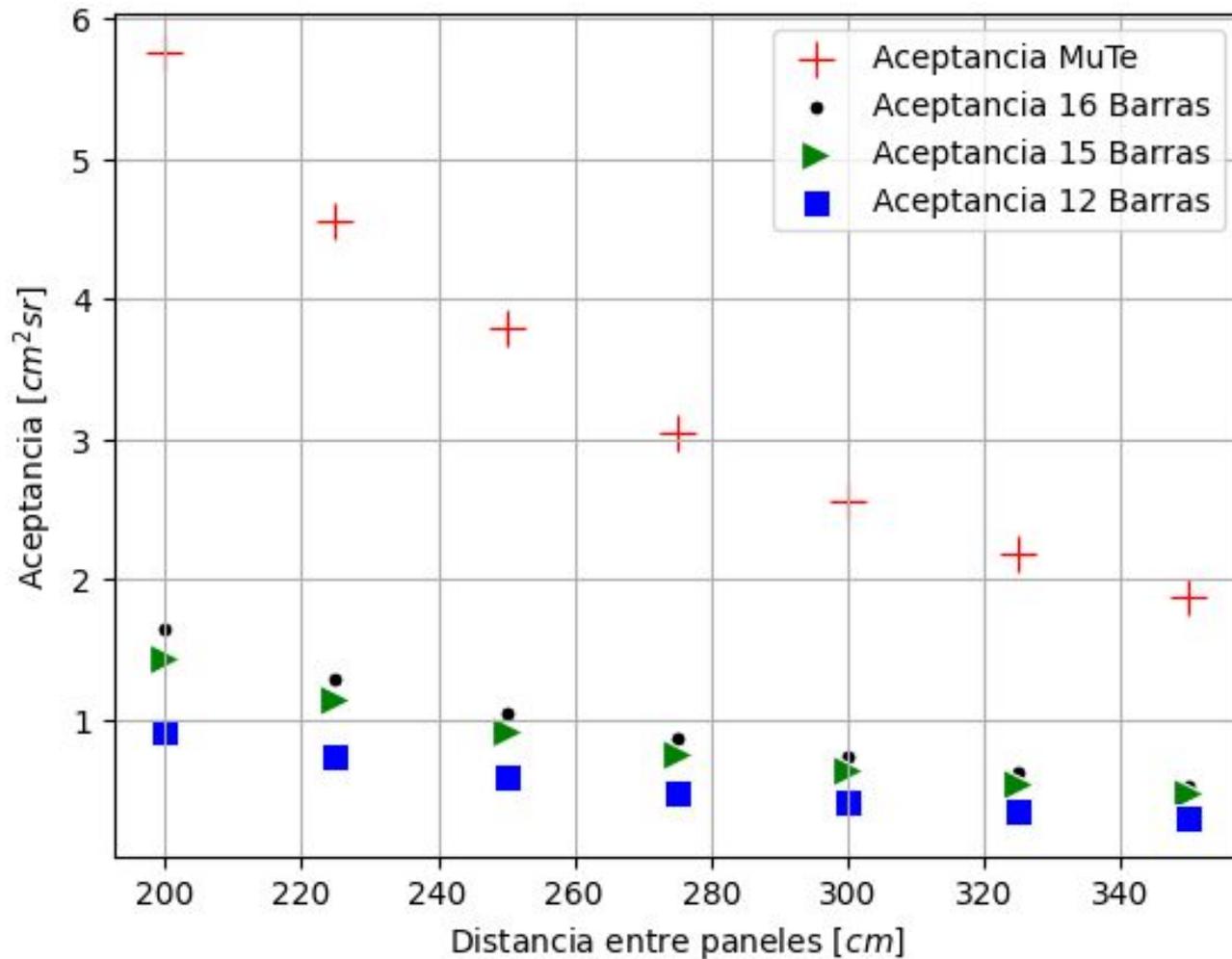
Aceptancia



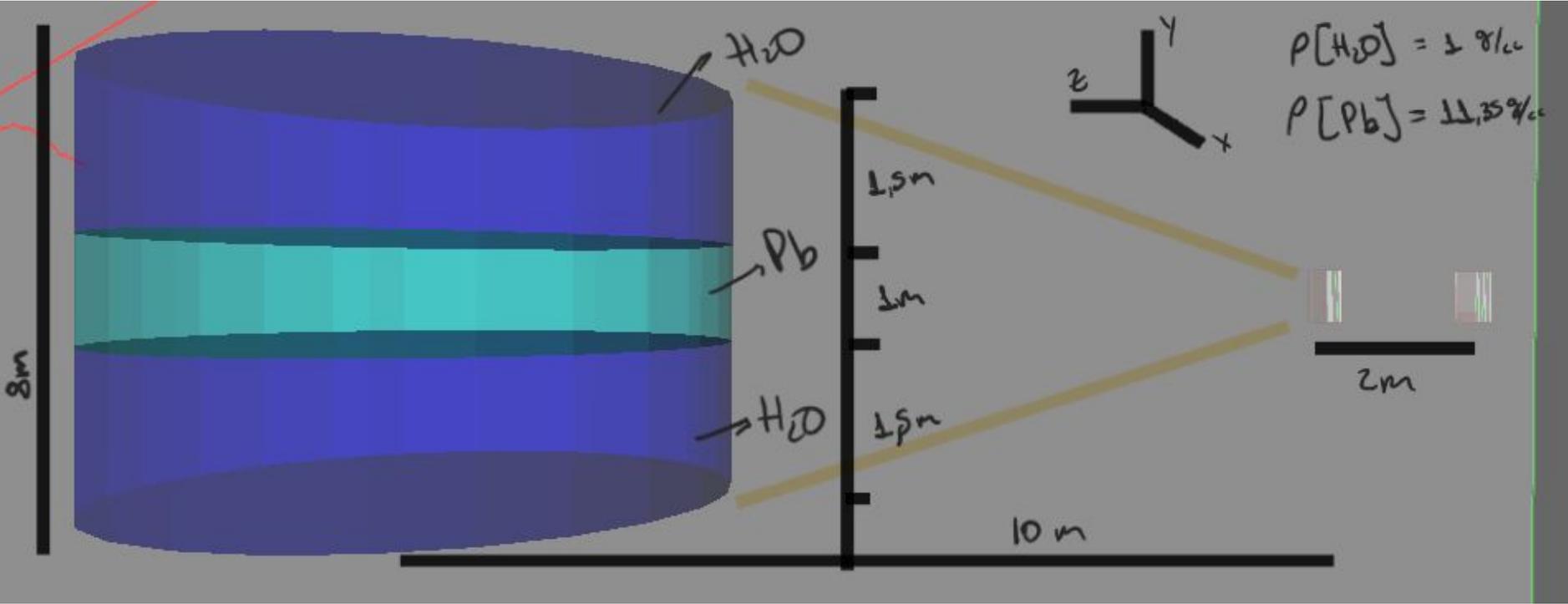
Resolución Espacial y Aceptancia 15 Barras



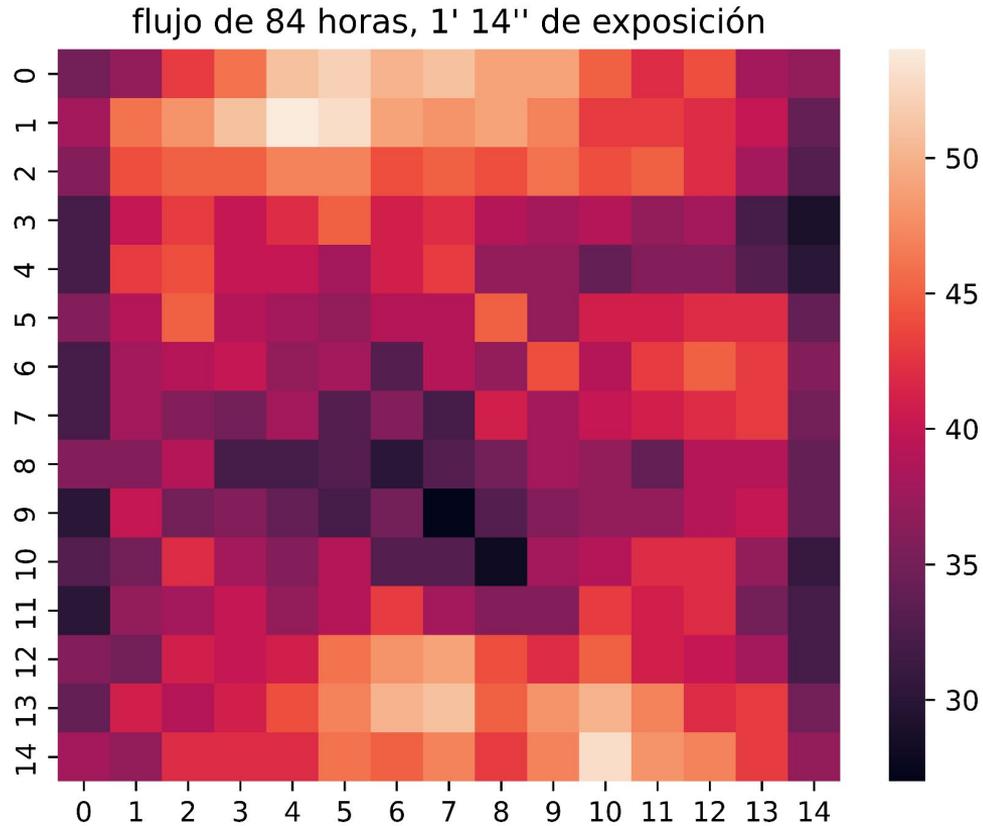
$$\Delta x = \frac{d(2\Delta y + D)}{D}$$

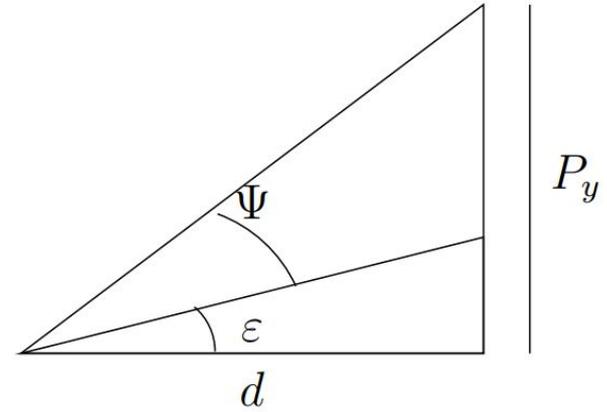
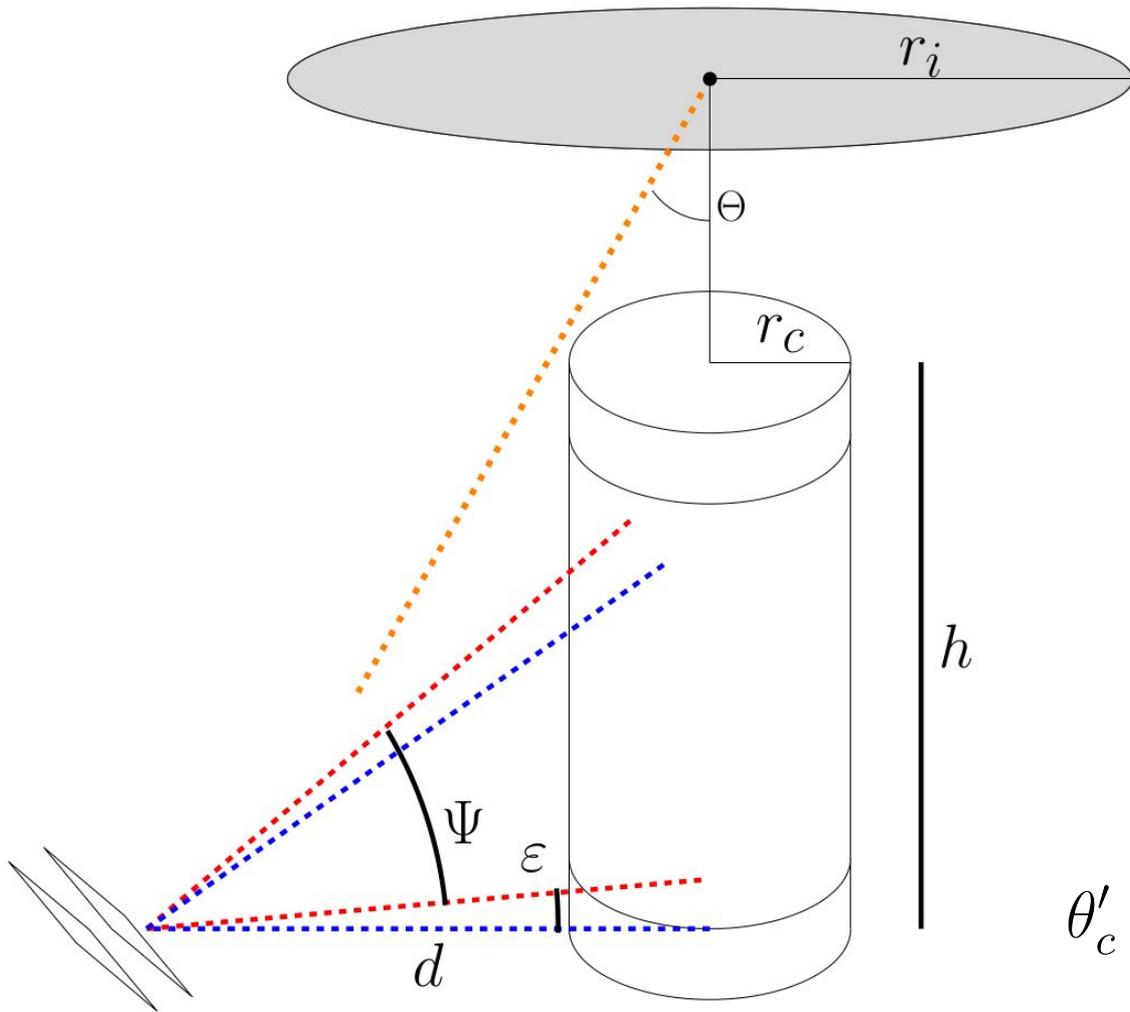


Esquema de simulación



Análisis de coincidencias





$$\Psi = \arctan(L/D)$$

$$\theta_c = 90^\circ - \Psi$$

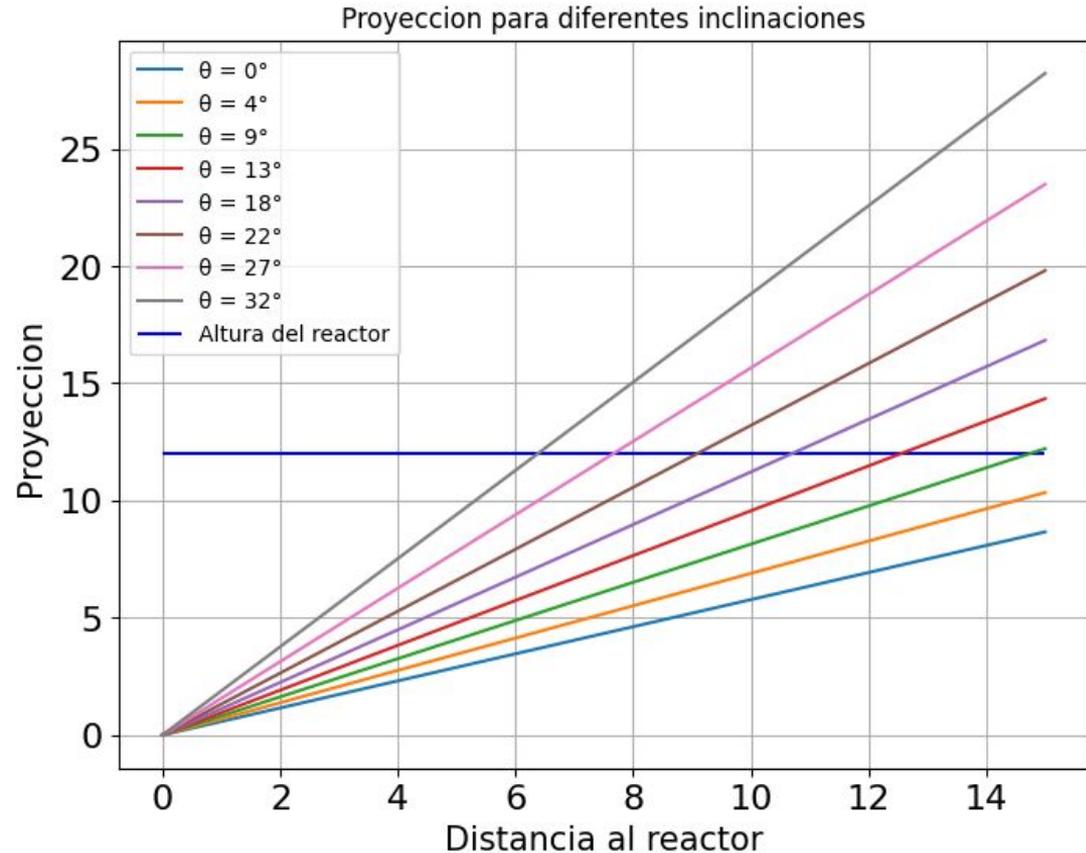
$$\theta'_c = 90^\circ - \arctan(L/D) - \epsilon$$

Configuración para atenuación de flujo

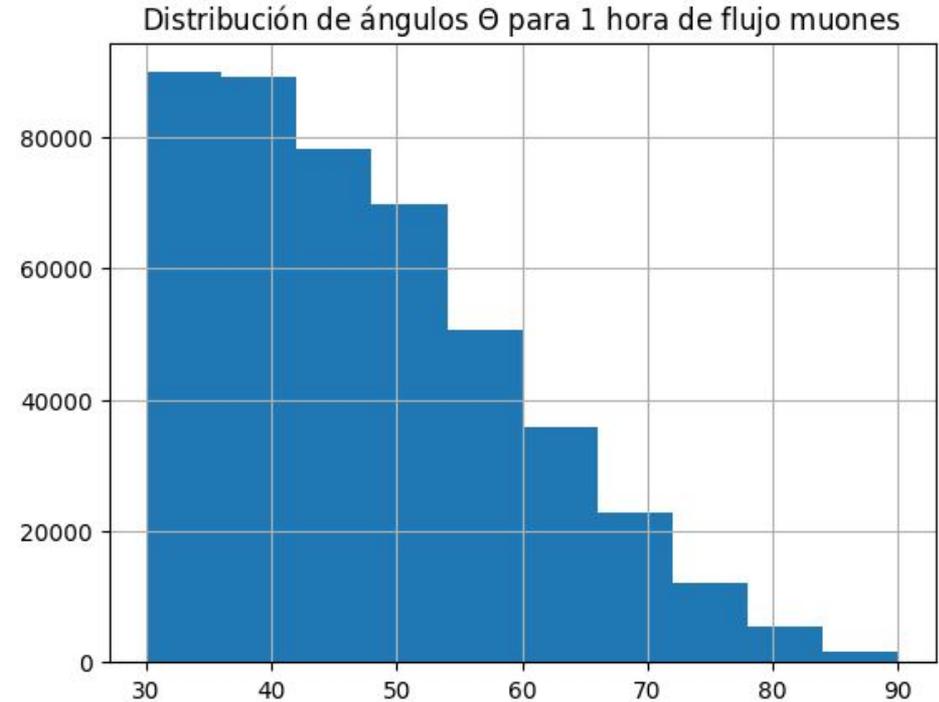
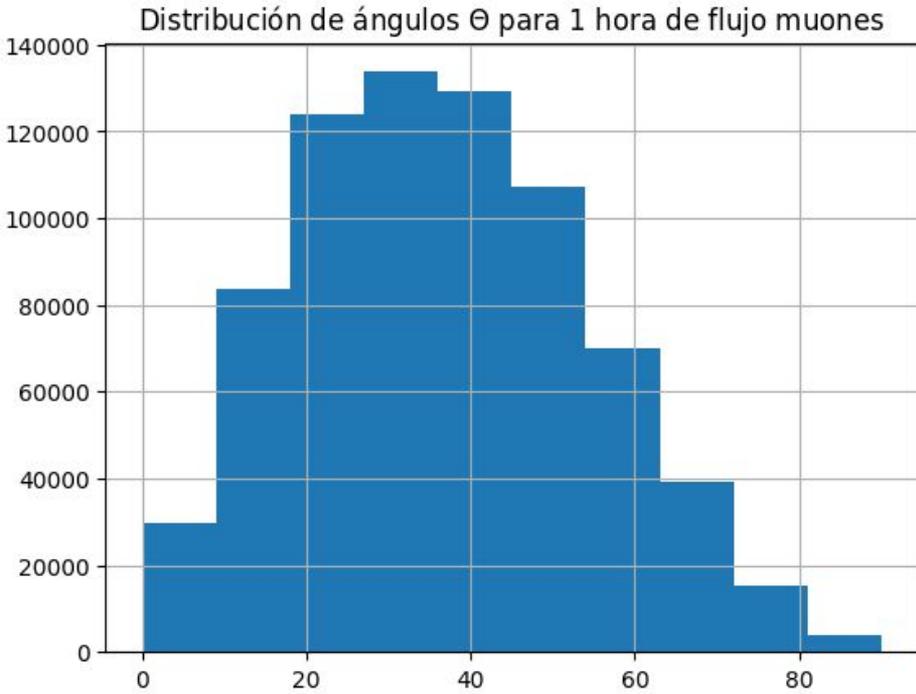
Distancia entre paneles 1m para 15 barras $\Psi \approx 30^\circ$

Al inclinar el hodoscopio se obtiene un $\varepsilon = 30^\circ$

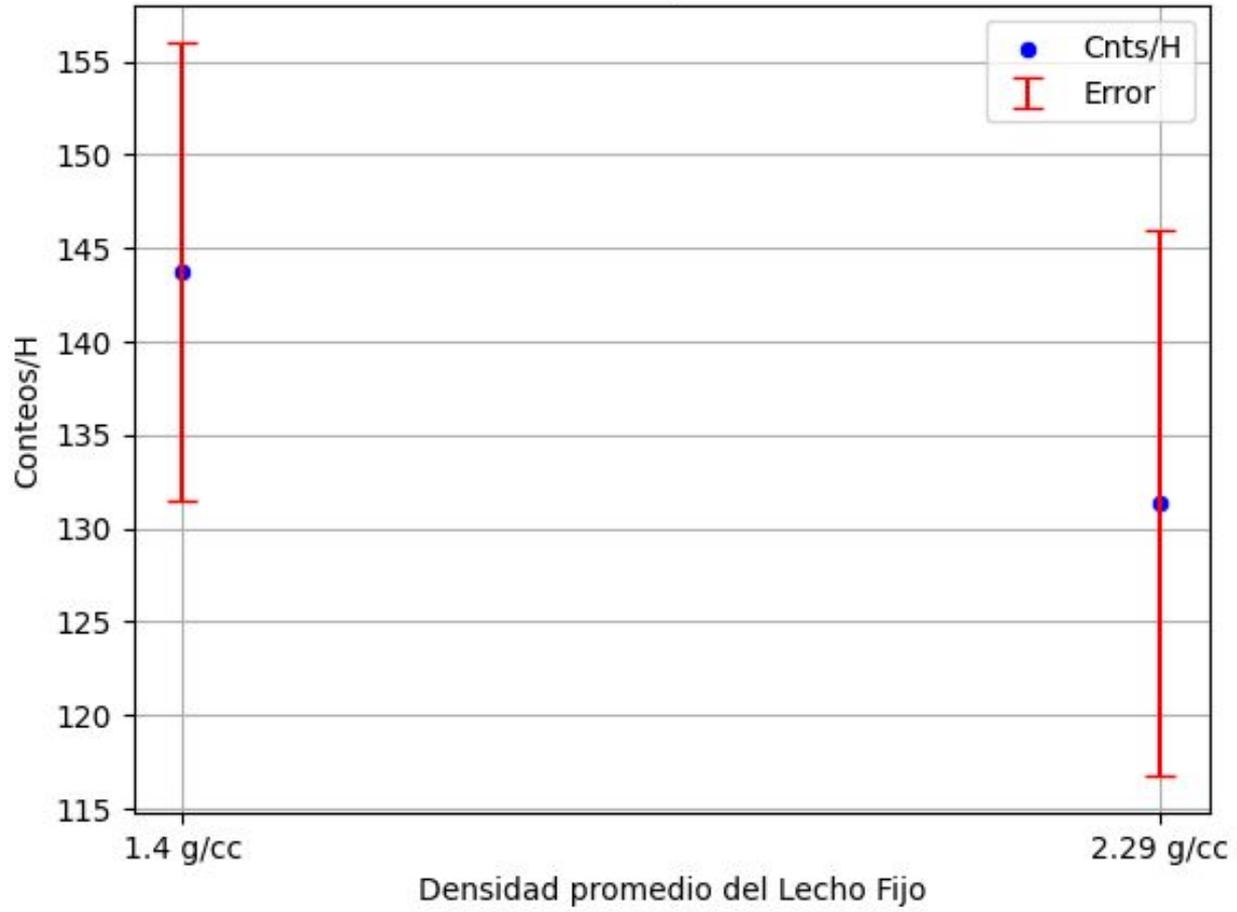
Obtenemos un ángulo de corte de $\theta_c = 90^\circ - 30^\circ - 30^\circ = 30^\circ$



Filtrado de la inyección



Conteos por Hora



Distancia entre paneles
1m para 15 barras

30 grados de inclinacion

5 metros de la torre

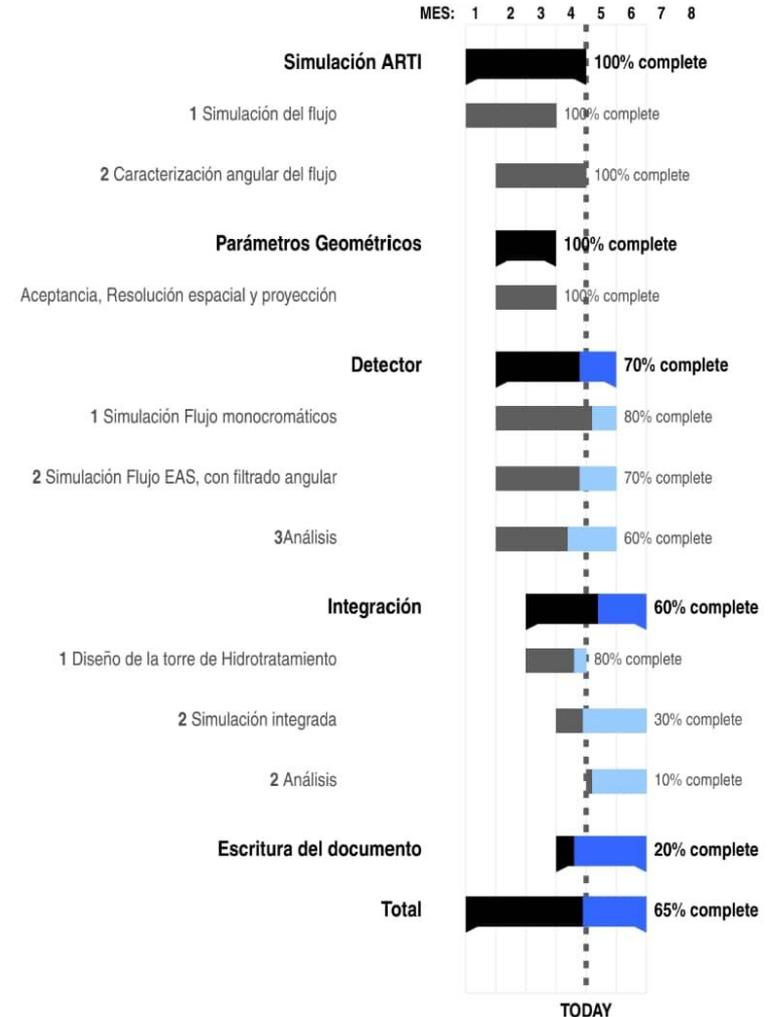
96 horas de flujo

Aprox 9 horas de
exposición

- Flujo monocromático electrones, hasta 5 cm de Pb.
- Flujo monocromático de muones, hasta 5 cm Pb.

❖ Simulación con y sin filtrado angular.

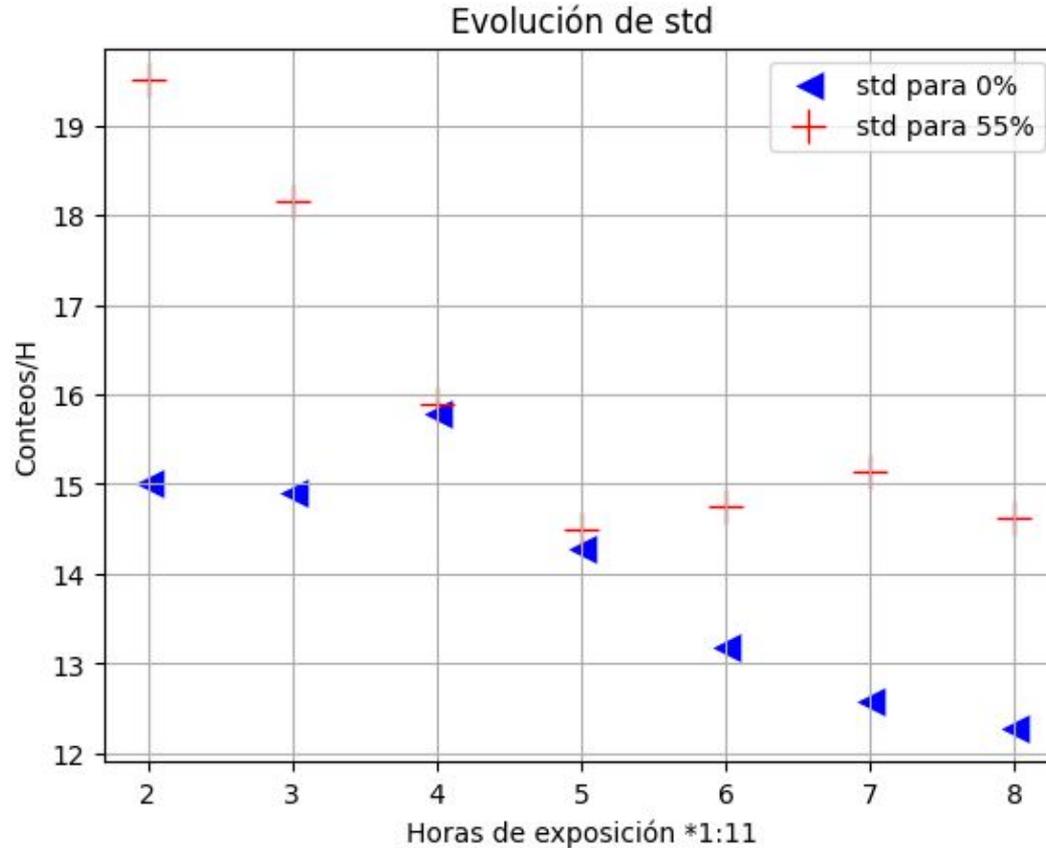
- Revisión del repositorio de la torre de hidrotreamiento.
- Simulación Integrada.



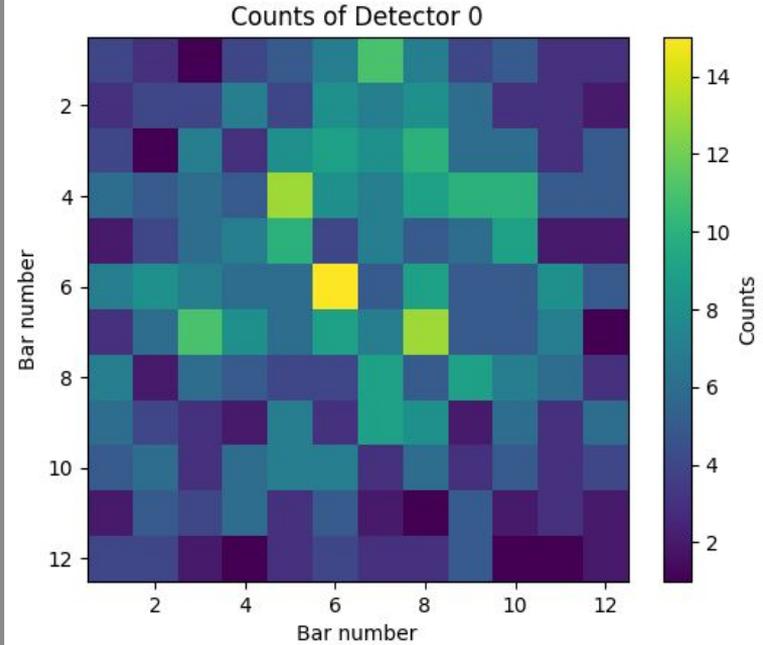
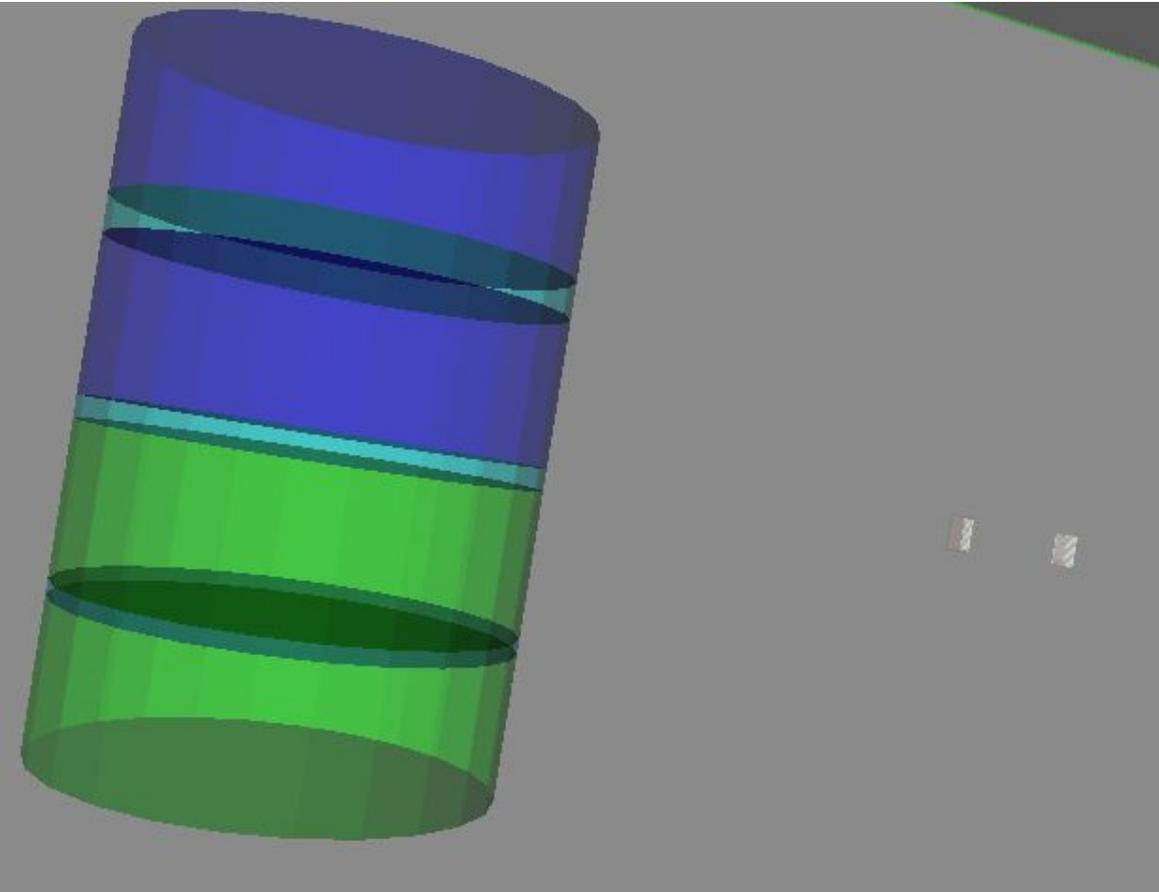
Backup



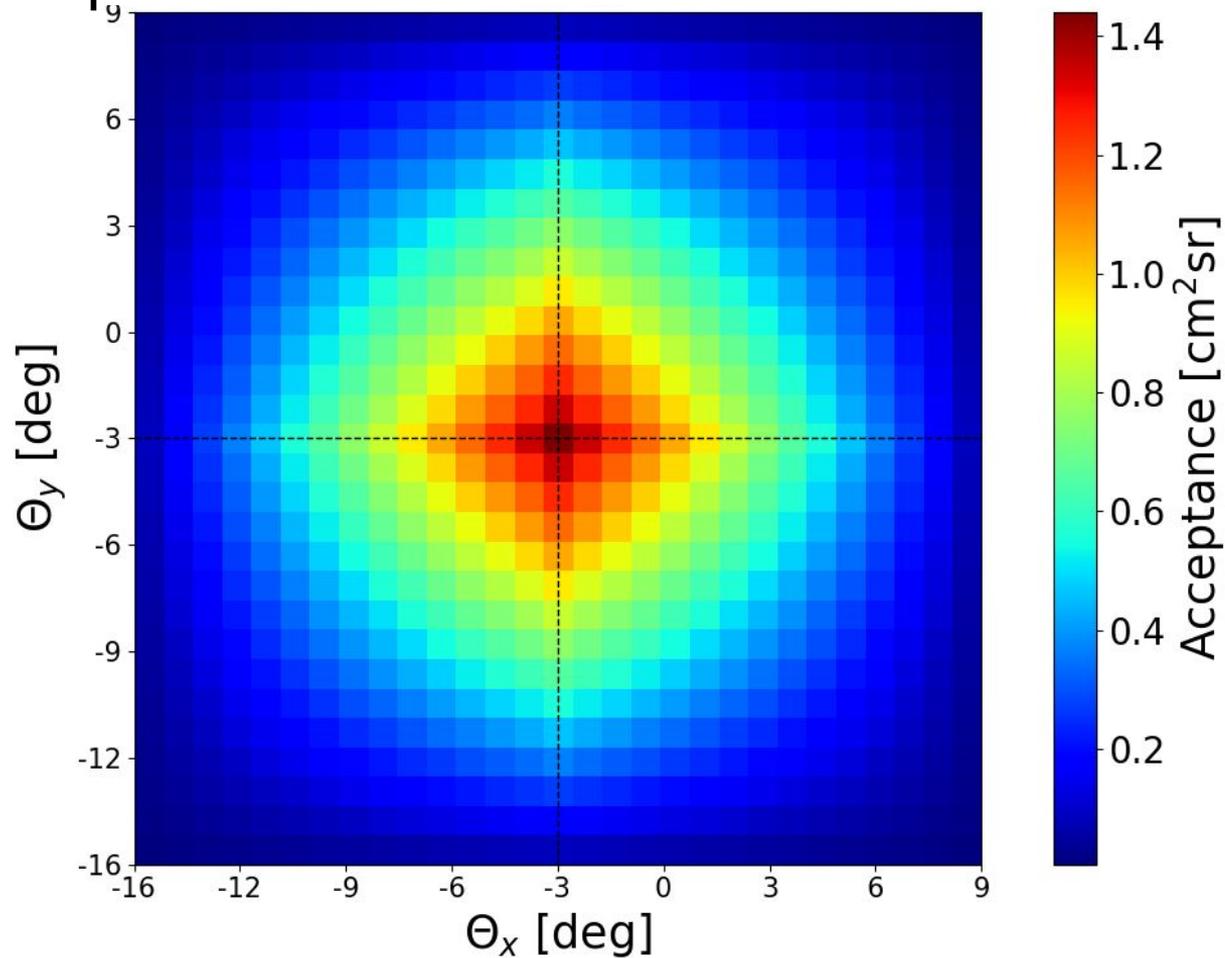
Comportamiento de la estadística

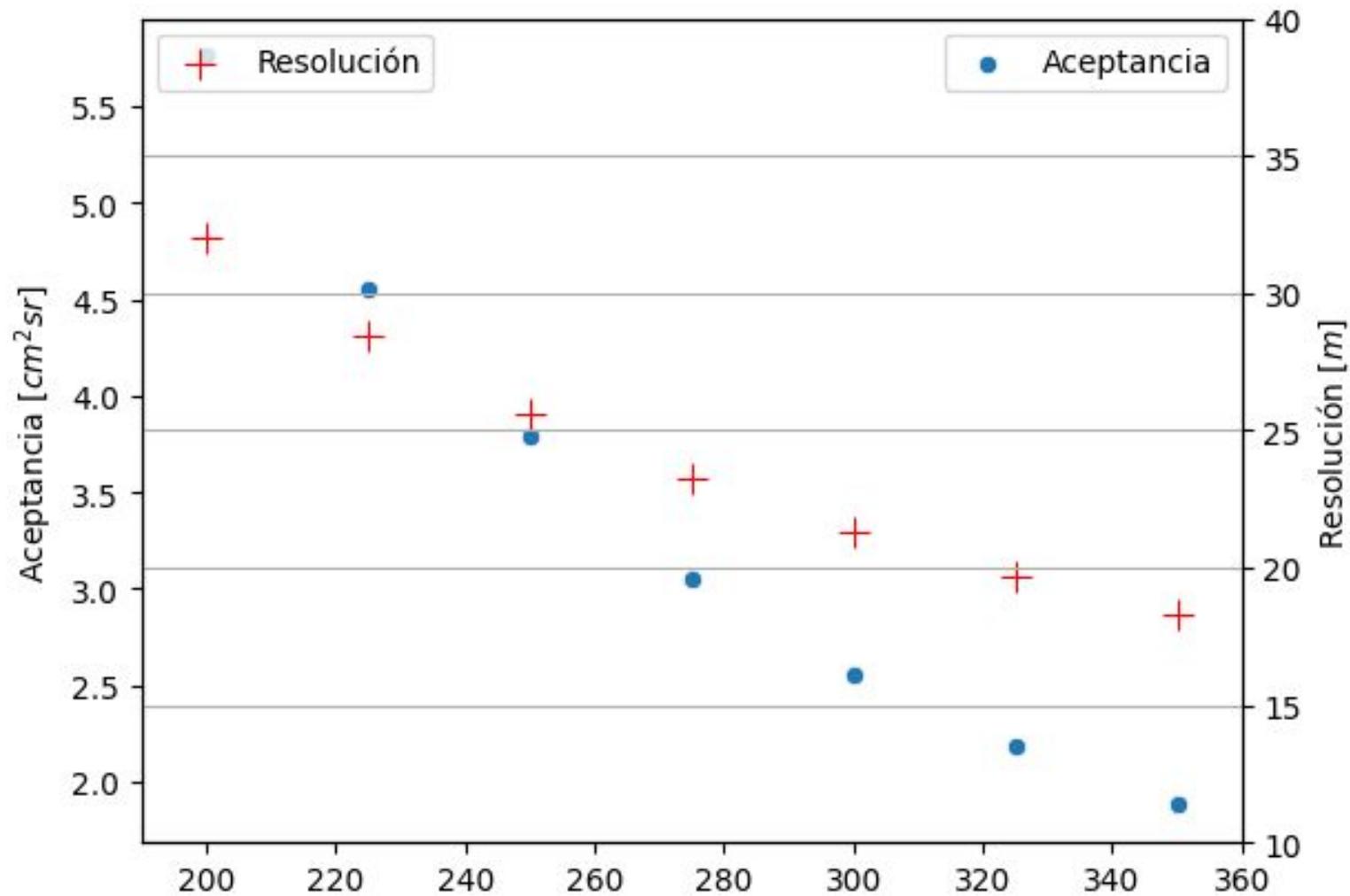


6 Horas de Flujo 12 Barras

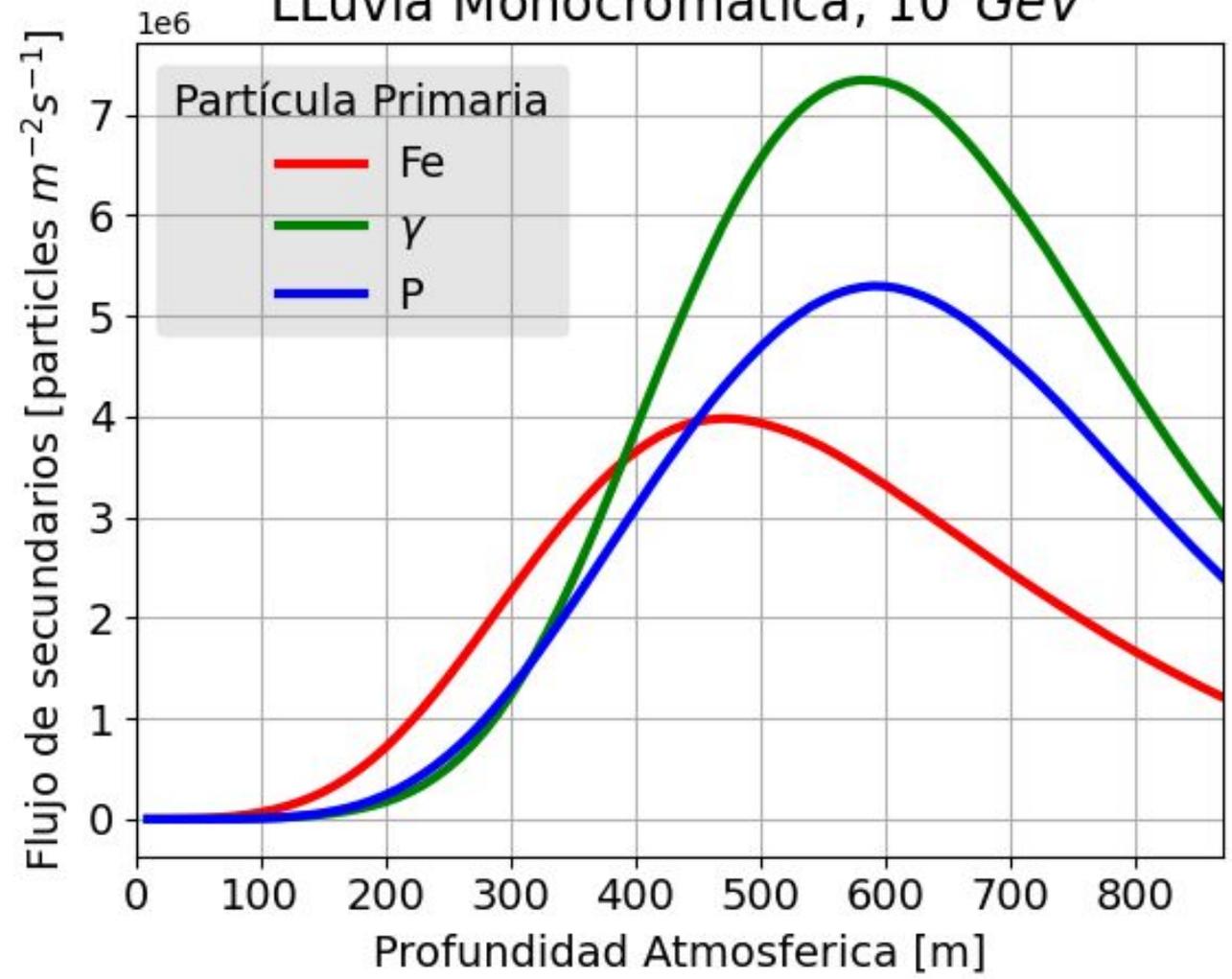


Aceptancia 15 Barras

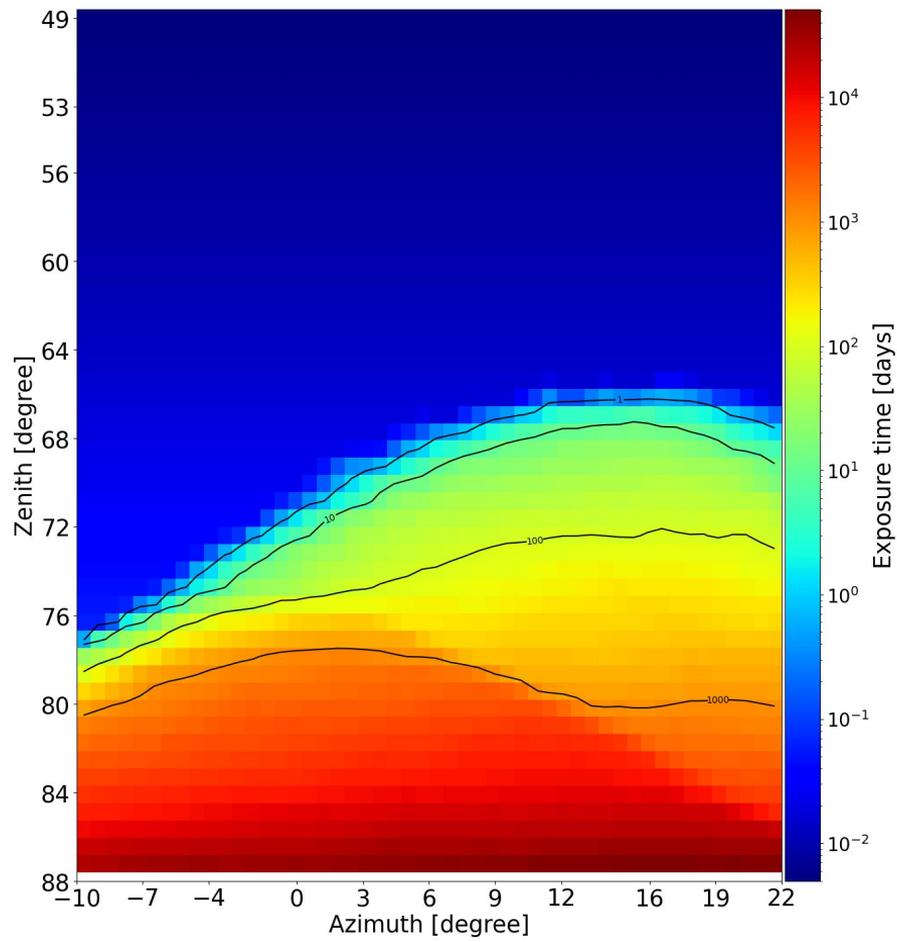
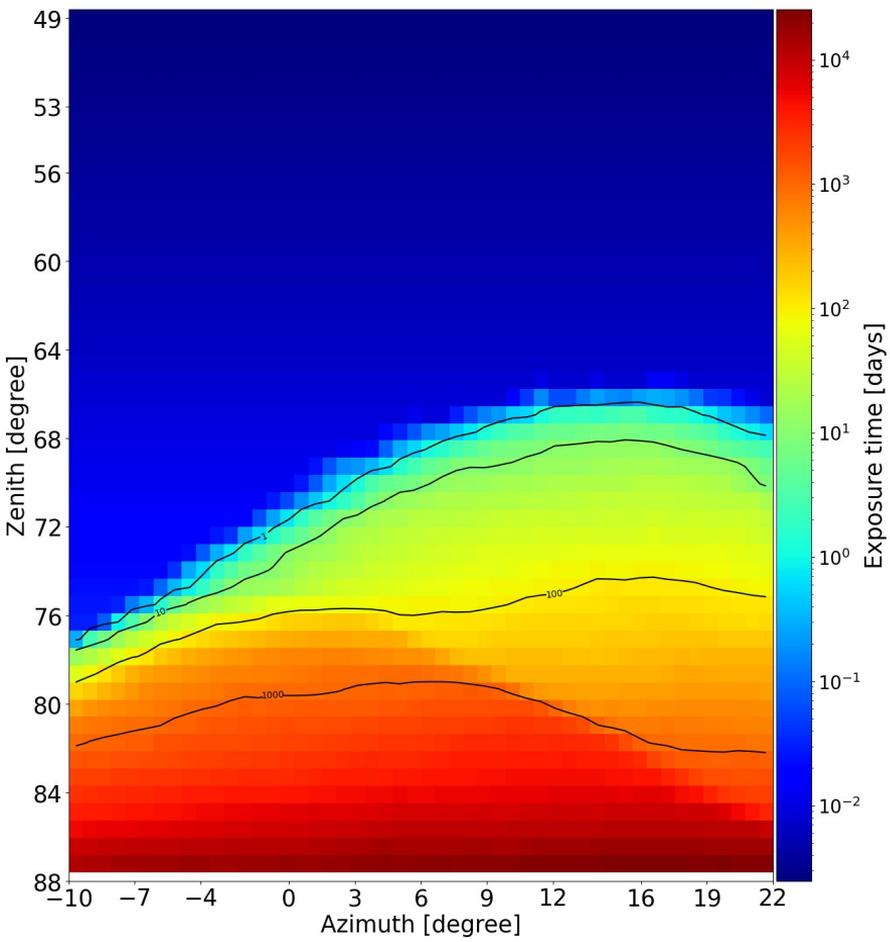




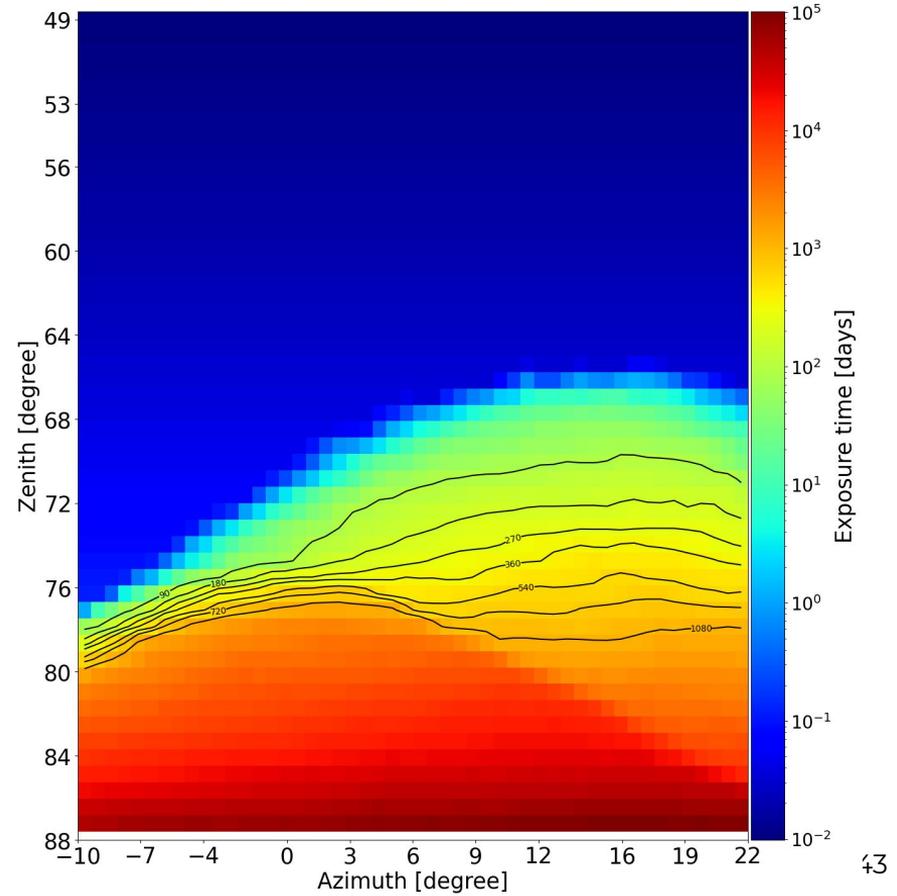
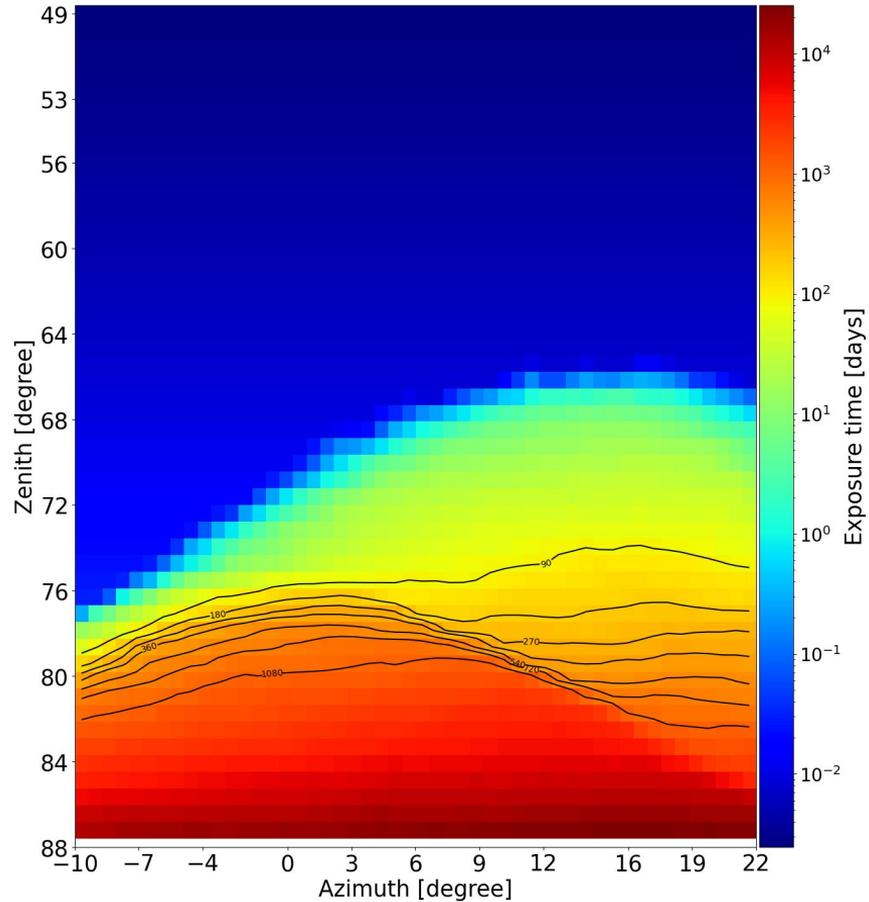
LLuvia Monocromática, 10^6 GeV



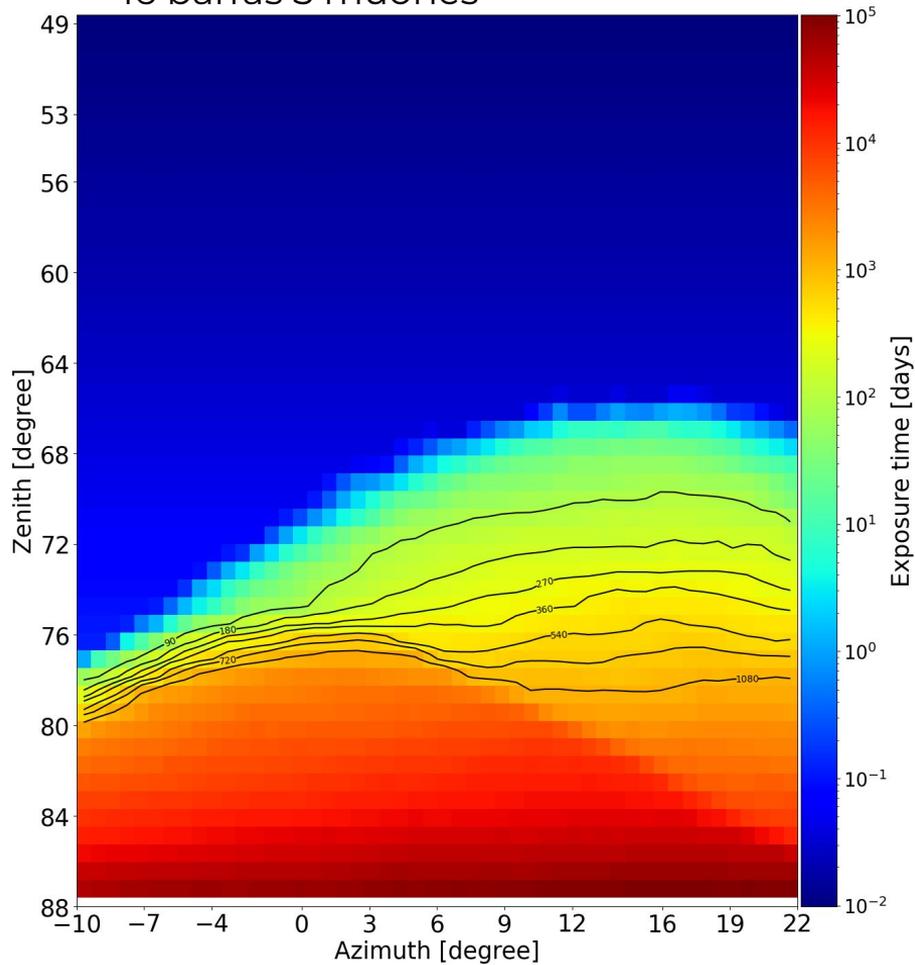
30 Barras, 10 y 5 Muones Machi



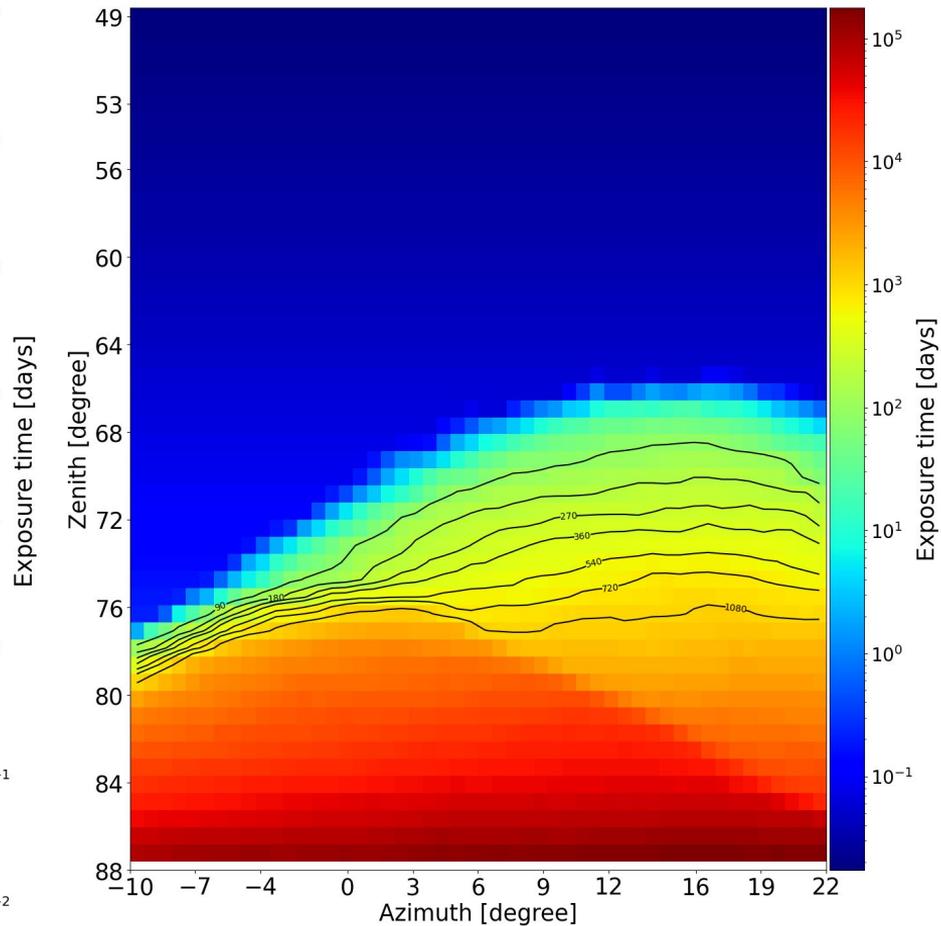
30 Barras y 15. A 5 Muones



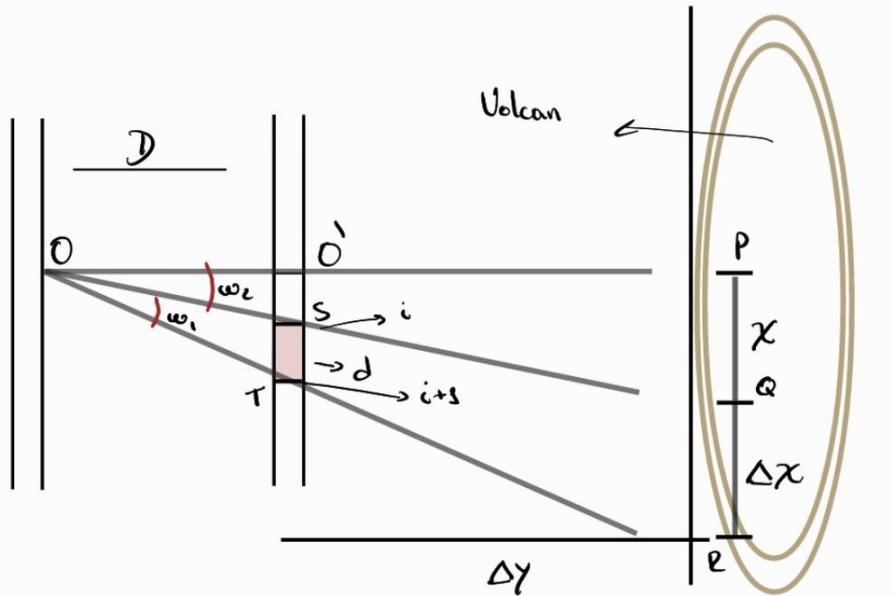
16 barras 5 muones



16 barras 10 muones



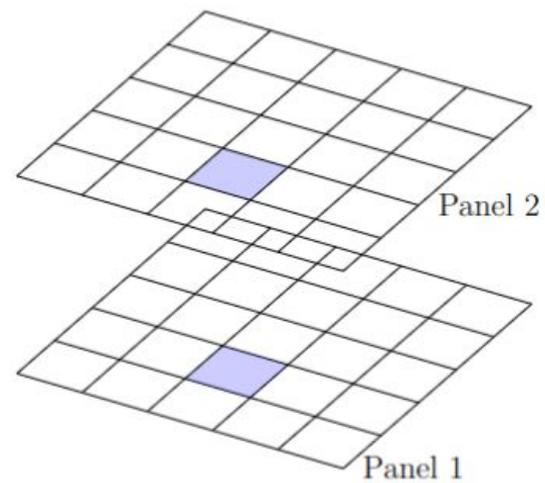
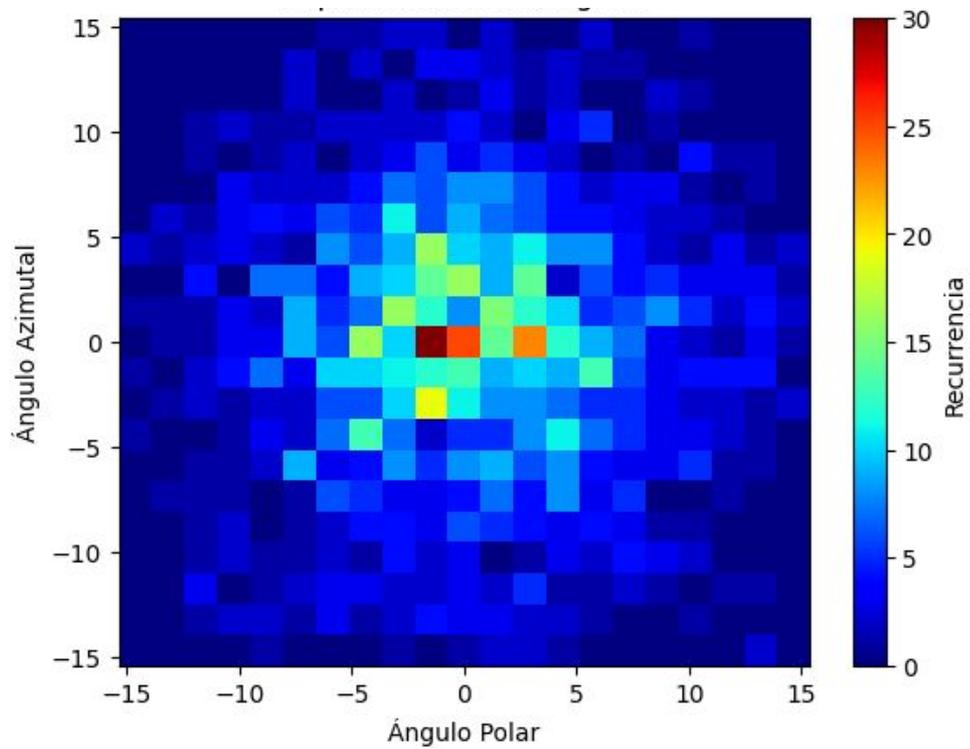
RESOLUCION ESPACIAL

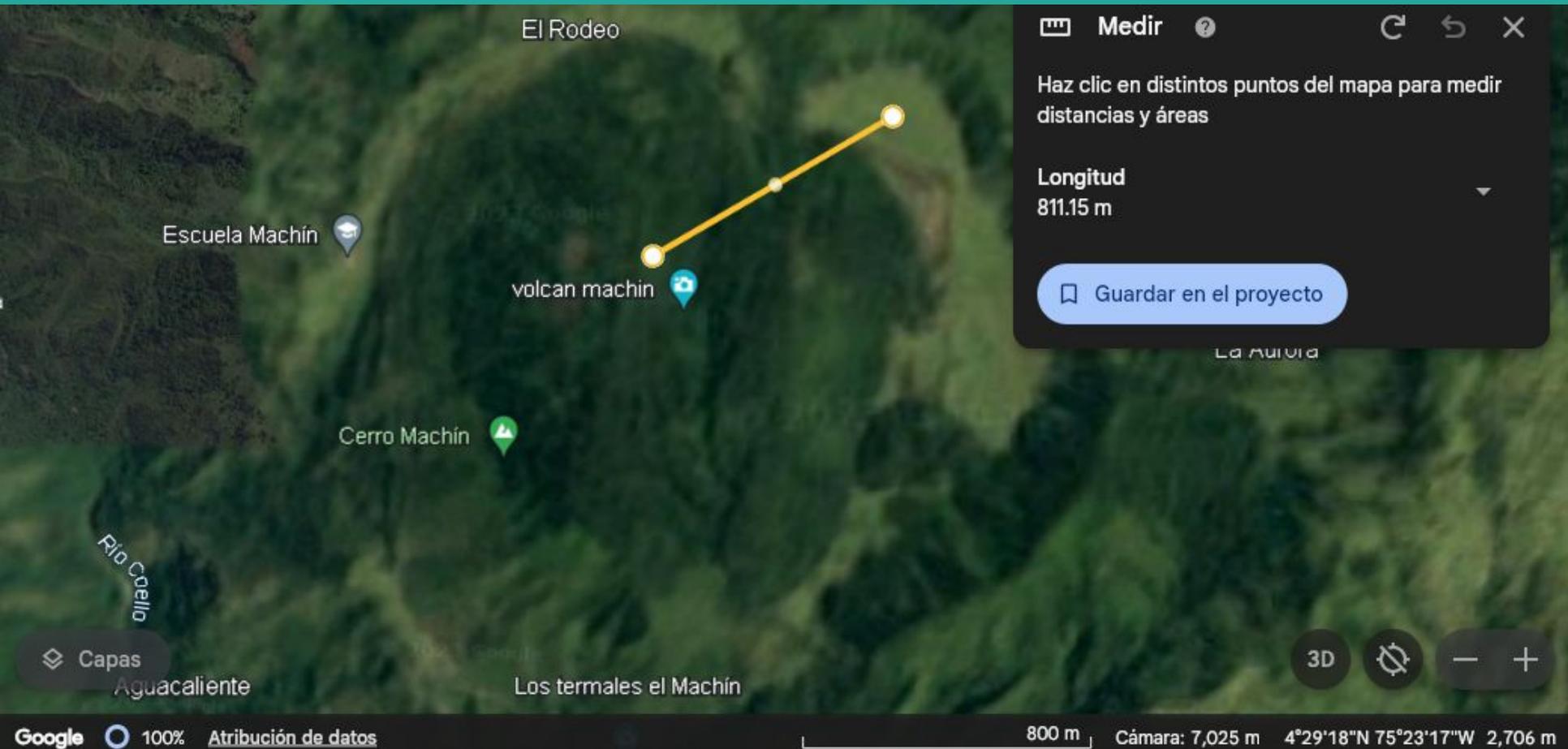


$$\tan(\omega_1 + \omega_2) = \frac{|PR|}{|OP|} = \frac{d(N - (i + 1))}{D} = \frac{x + \Delta x}{\Delta y + D}$$

$$\tan(\omega_2) = \frac{|QP|}{|OP|} = \frac{d(N - i)}{D} = \frac{x}{\Delta y + D}$$

$$\Delta x = \frac{d(2\Delta y + D)}{D}$$

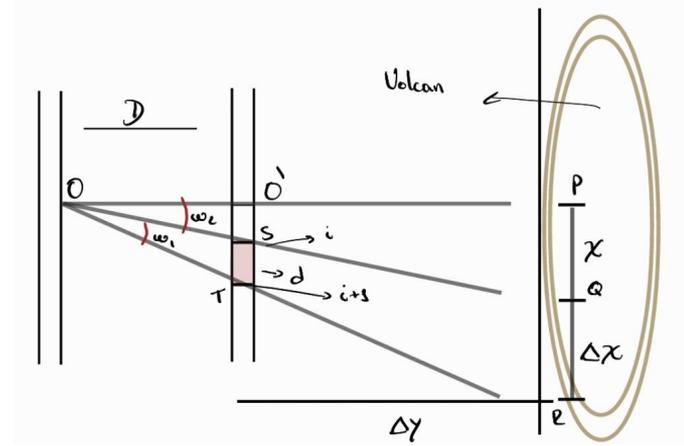
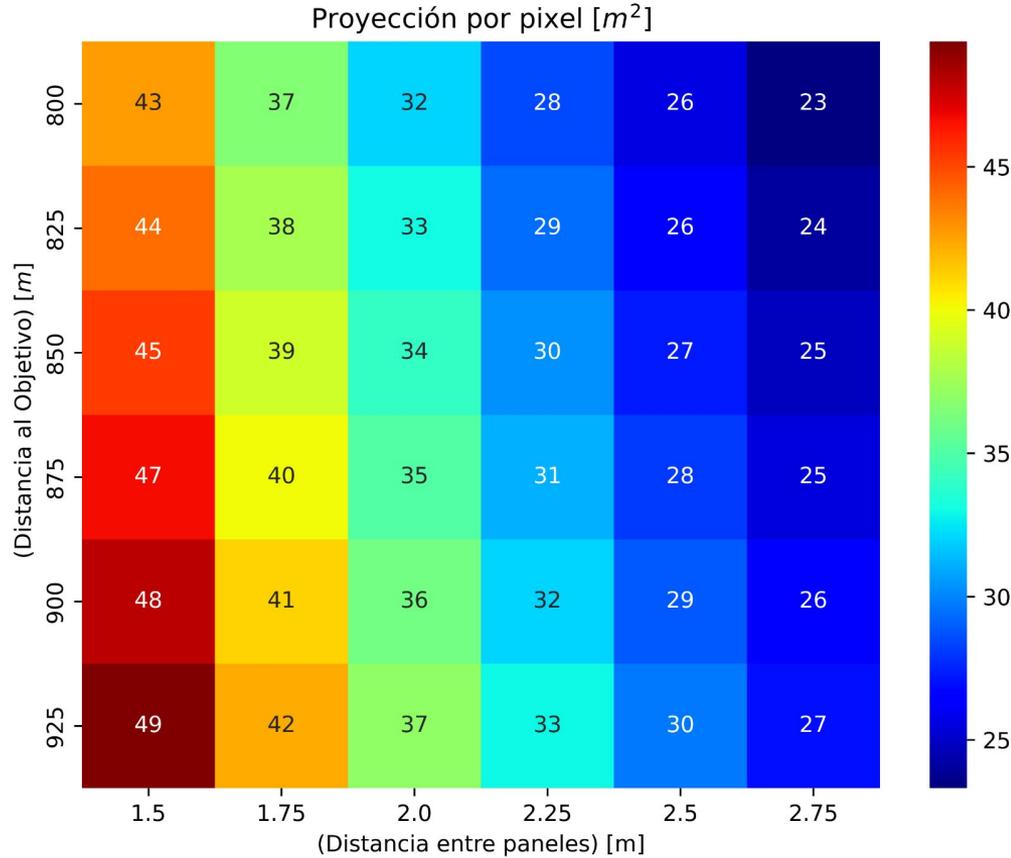




$$D \sim (800 - 900)m$$

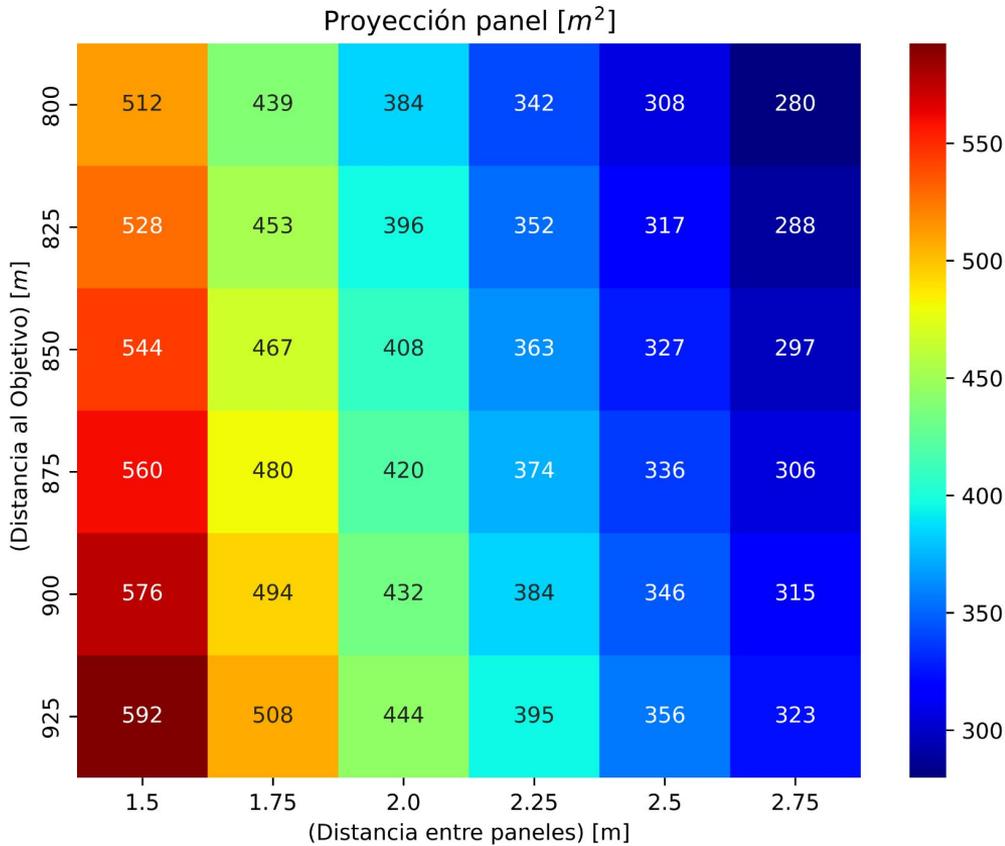
$$2(x + \Delta x) \sim (200)m$$

PROYECCIÓN ESPACIAL

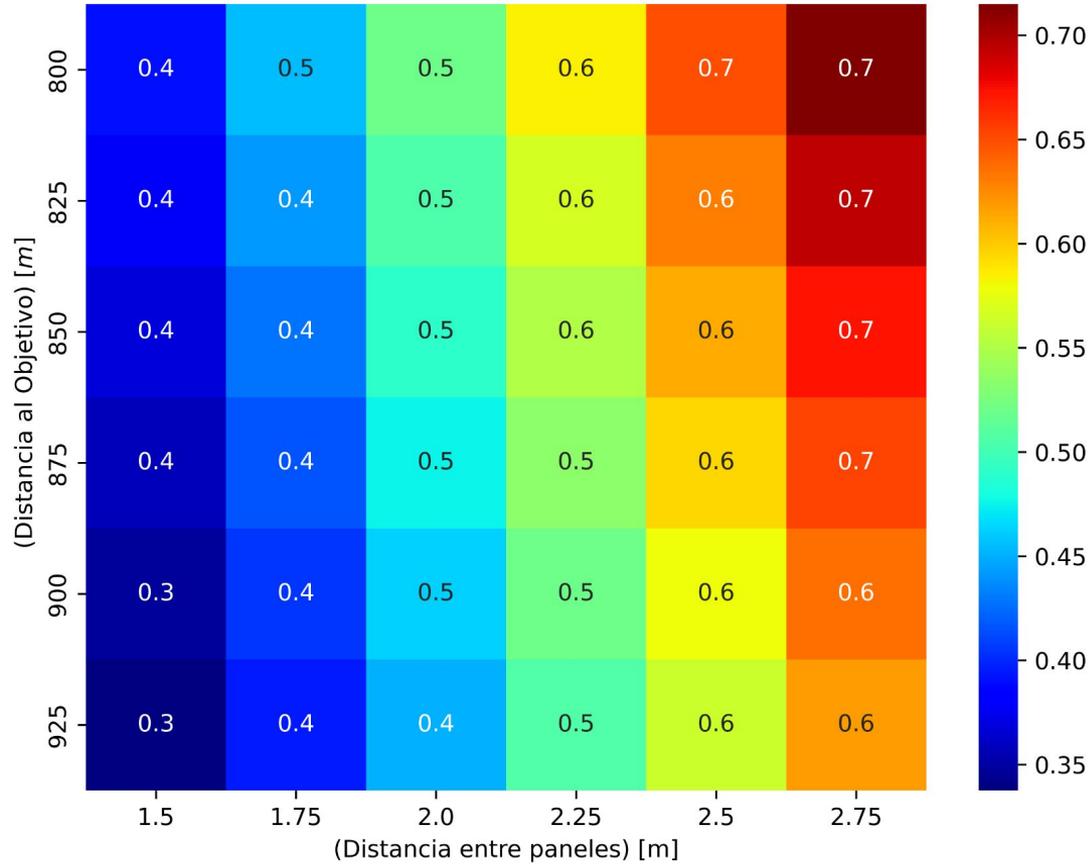


$$\Delta x = \frac{d(2\Delta y + D)}{D}$$

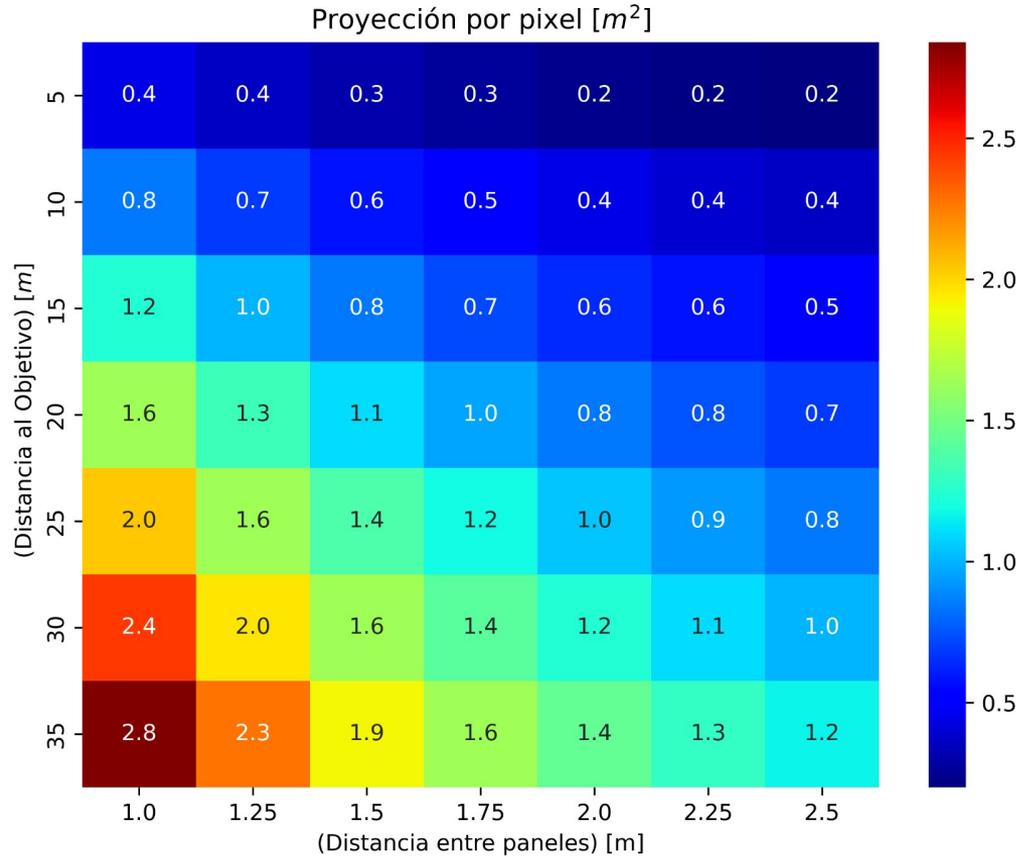
PROYECCIÓN ESPACIAL PANEL

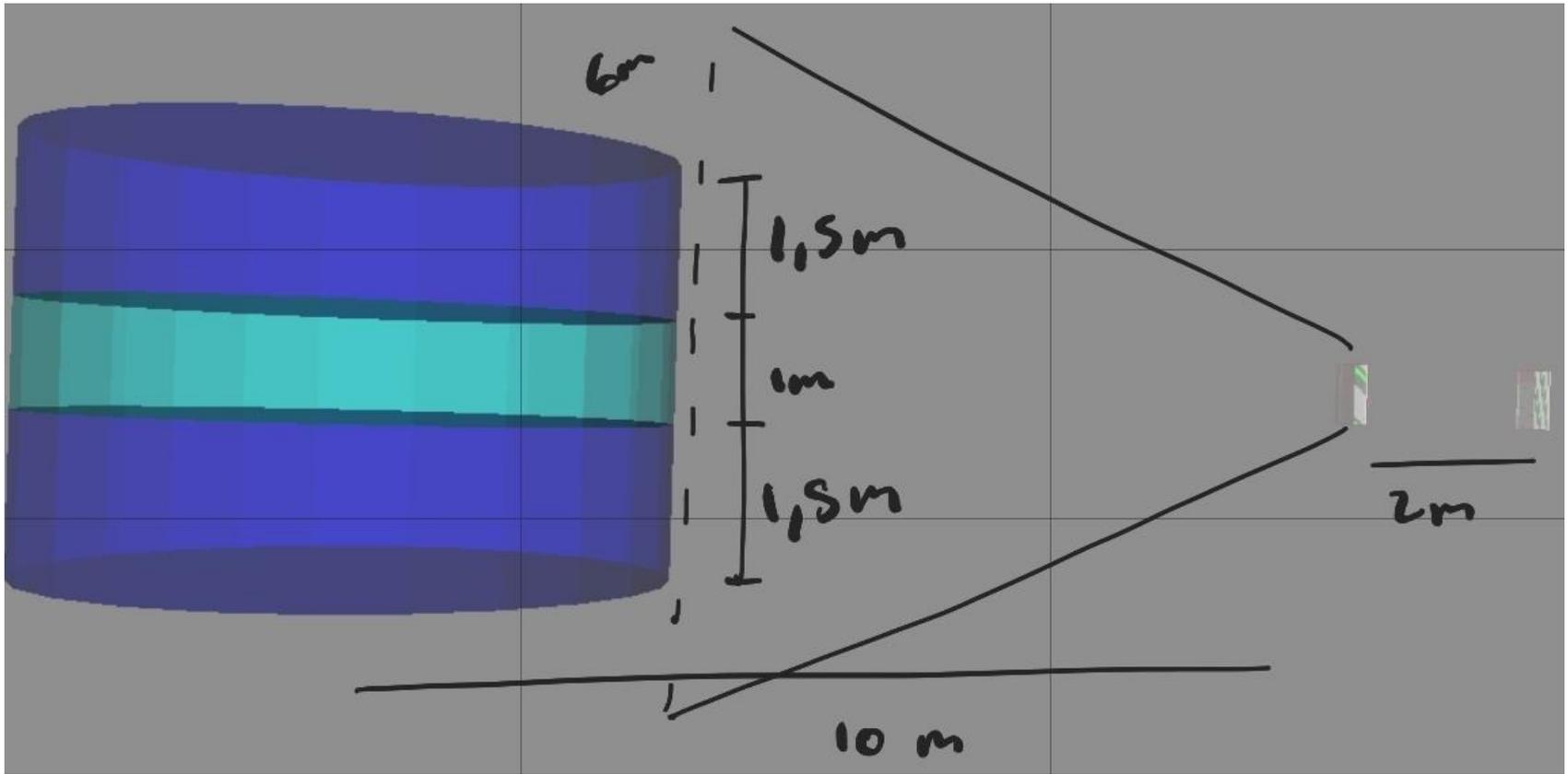


Proporcion de altura cubierta para 200 m



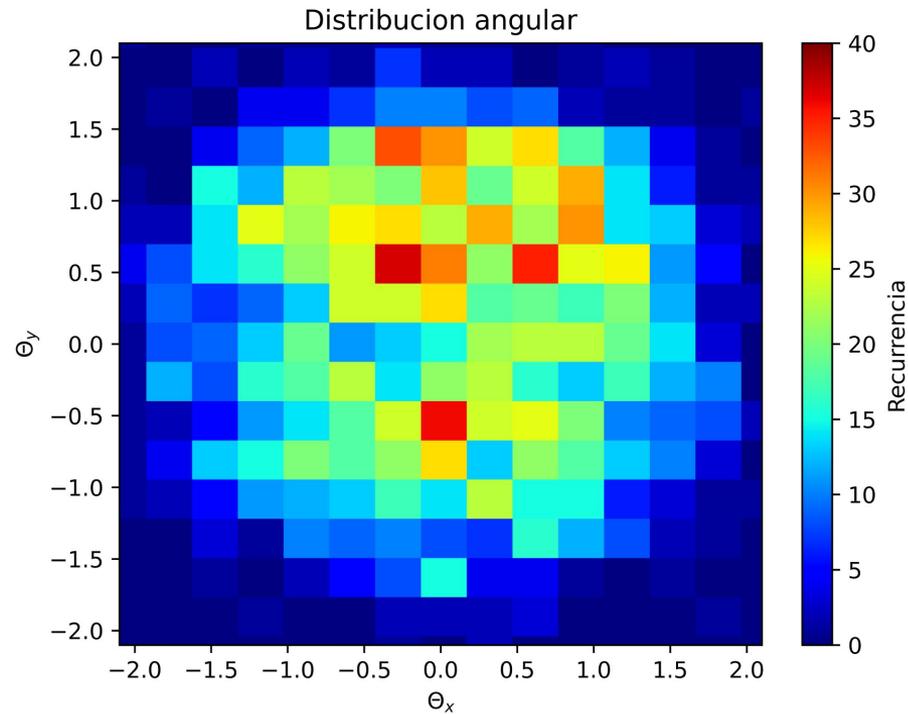
Para la TCC



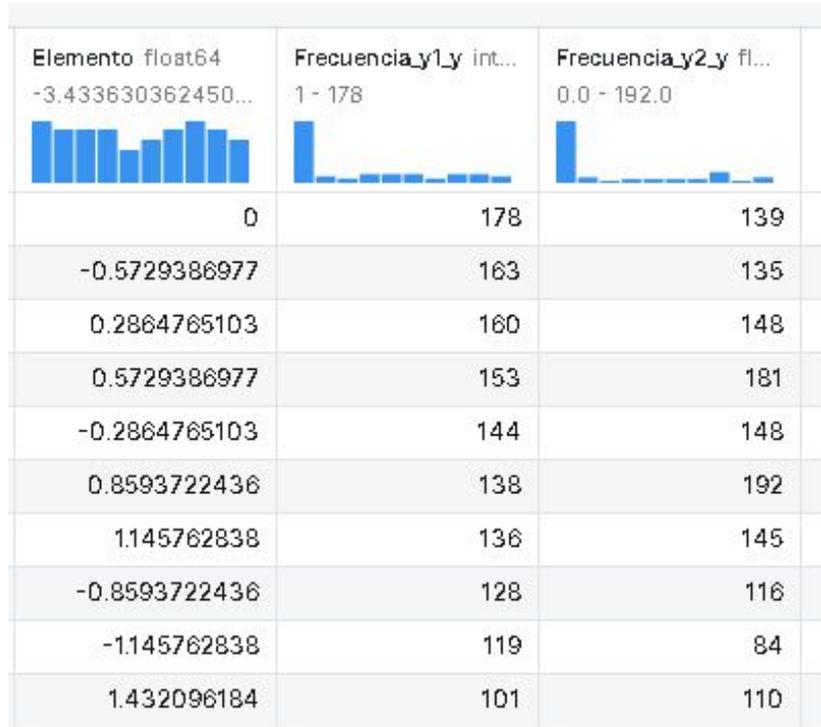


Distancia entre Paneles 2 m Distancia al Obj 10 m, Resolución Espacial 0,4 m, Proyección de 6 m, Aceptancia Max: $1,44 \text{ cm}^2 \text{ sr}$, radio de inyección 4 m.

Distribucion angular de conteos, 16 Horas



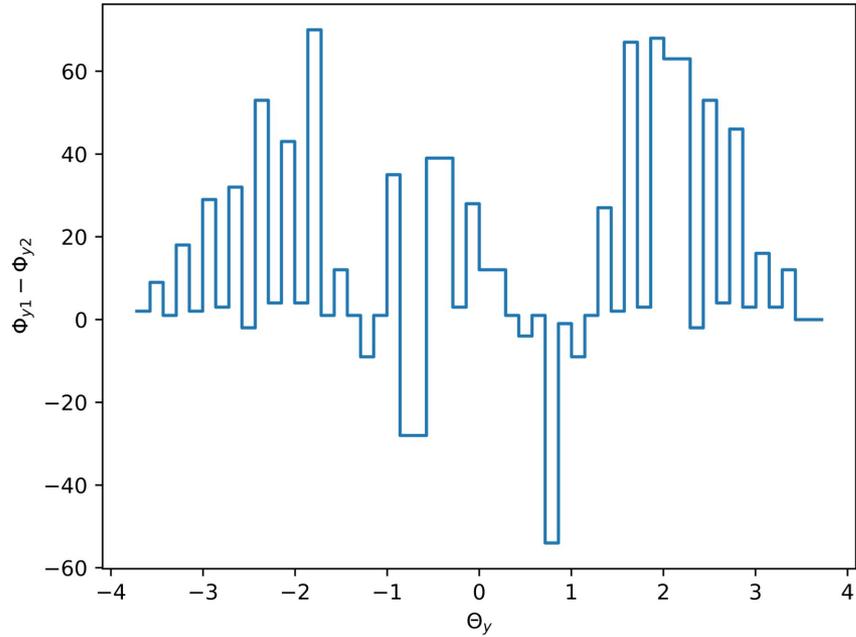
Misma configuración, pero sin el cilindro (Fondo)



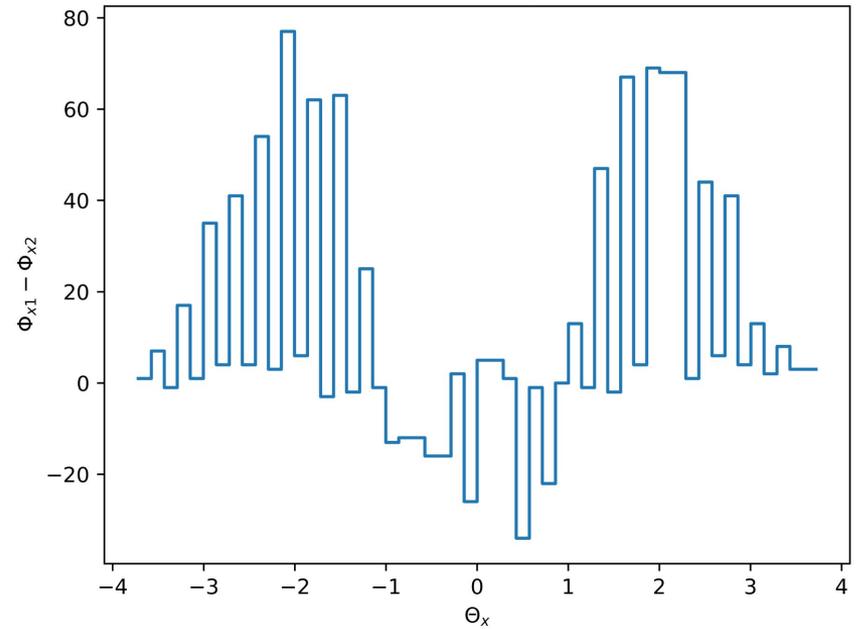
$$y_1 = \theta_{fon}$$
$$y_2 = \theta_{obj}$$

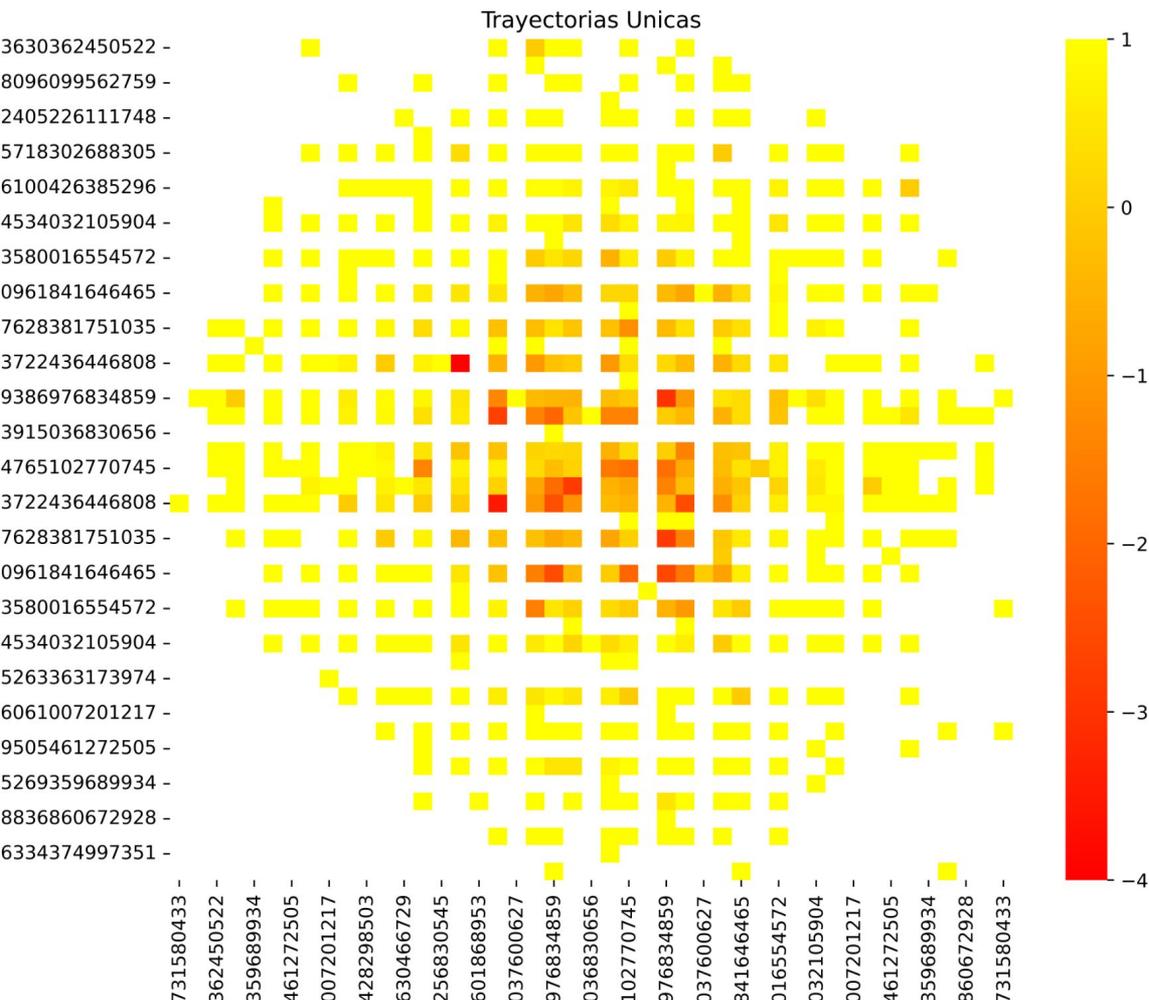
Disminución del flujo angular

Diferencia de flujo en Θ_y



Diferencia de flujo en Θ_x





$$\frac{\Phi(F) - \Phi(O)}{\Phi(F)}$$

Condición de viabilidad.

$$\Delta T \times \mathcal{T} \times \frac{\Delta I^2(\varrho_0, \delta\varrho)}{I(\varrho_0)} > 1$$

$$\Delta I(\varrho_0, \delta\varrho) = \Phi[E_{\min}(\varrho_0)] \times \left. \frac{dE_{\min}}{d\varrho} \right|_{\varrho=\varrho_0}$$

E_{\min}	GeV	minimum muon energy to cross a given opacity
Φ	$\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1} \text{GeV}^{-1}$	differential flux of muons
γ	$\in \mathbb{R}$	power-law exponent of differential spectrum
A		scale factor (i.e. amplitude) of differential spectrum
I	$\text{cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$	integrated flux

Hydrotreating Unit

