Access to particle-particle emitting source at intermediate energy

E.V. Pagano[2,4], T. Minniti[1,2], G. Verde[3], L. Acosta[2] and Exochim Collaboration

[1]Dipartimento di Fisica, Università di Messina, Ctr. Papardo 31, 98166 S. Agata, Messina, Italy
[2]INFN-Laboratori Nazionali del Sud, via S. Sofia 44, Catania, Italy
[3]INFN-Sezione di Catania, Via Santa Sofia 64, Catania, Italy.
[4]Dipartimento di Fisica, Università di Catania, Via Santa Sofia 64, Catania, Italy

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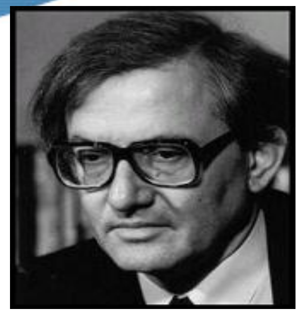

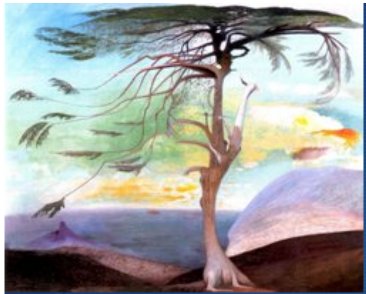

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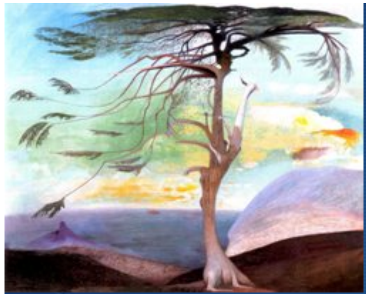
Università di Catania-INFN-LNS

outlines

1) **Introduction**
2) **Particle-particle correlation functions**
3) **Correlation functions in Xe + Au collisions at 50 MeV/nucleon with LASSA correlator**
4) **The FARCOS project**
5) **Conclusions**



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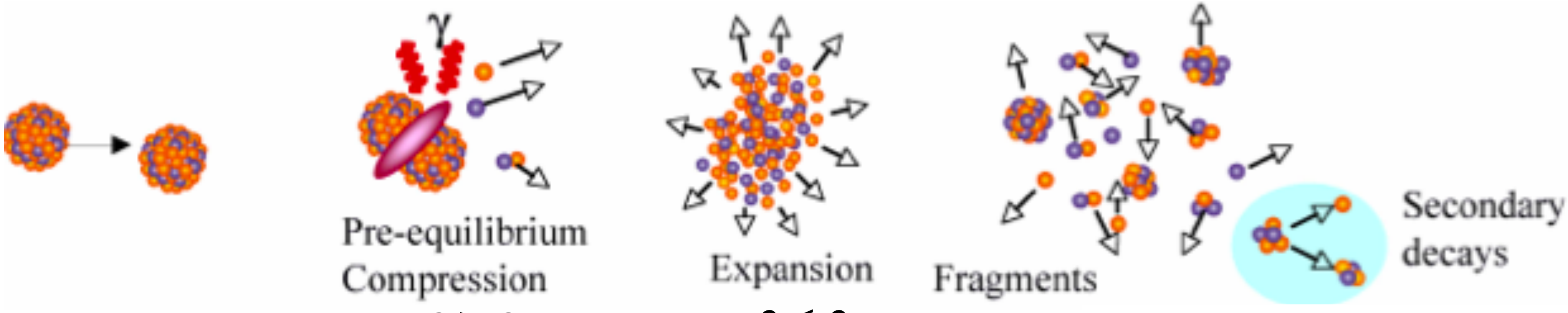
Introduction

The study of nuclear reactions in heavy ions is a very active area in nuclear physics

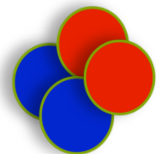
$\rho_0 \approx 0.17\ \mathrm{fm}^{-3}$

Fermi Energy

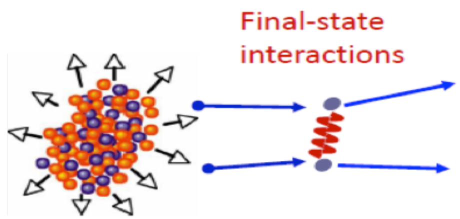
Quasi-central collisions in Xe+Au E/A=50MeV/nucleon

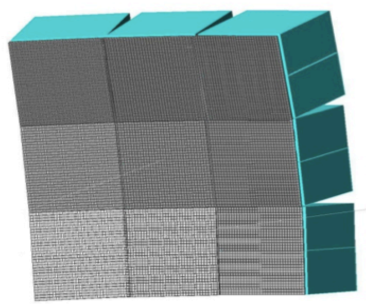


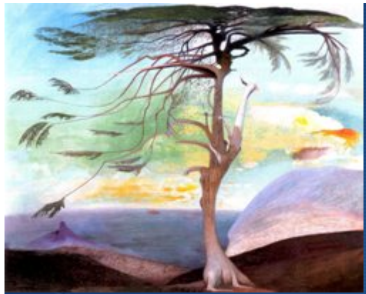
$\rho > \rho_0$ $\rho < \rho_0$



Space-time property of the emitting source: Correlation Functions







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Particle-particle correlation functions

$P_{tot}=p_1+p_2$ $\qquad q=\mu\,(p_1/m_1-p_2/m_2)$

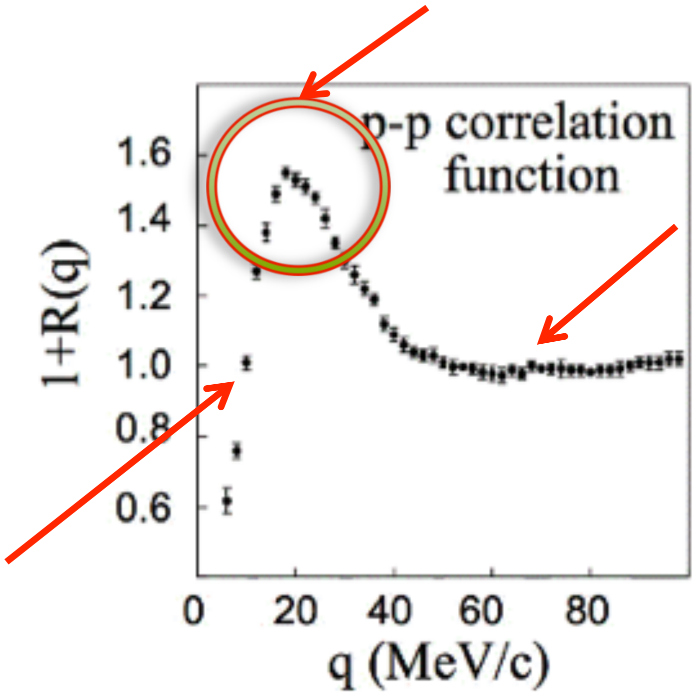
$$\sum Y_{12}(\vec{p_1},\vec{p_2}) = C_{12}\cdot[1+R(\vec{q},\vec{P})]\cdot\sum Y_1(\vec{p_1})\cdot Y_2(\vec{p_2}). \quad (2.1)$$

- **Y_{12} coincidence yield of the two particles 1 and 2**
- **Y_1 e Y_2 single particel yields of the two particles 1 and 2**
- **C_{12} constant determined by imposing $R(q,P_{Tot})=0$ (≈80-120 MeV/c in p-p)**
- **$\theta_{qP}=\arccos(q*P_{tot}/qP_{Tot})$ angle between P_{Tot} e q**

a) Directional correlation functions
b) angle-averaged correlation functions.

- P_{tot} Cut
- $Y_1*Y_2= Y_{12}^{Unc}$ *event-mixing*

$$1+R(q) = C_{12}\cdot Y_{12}/Y_{12}^{Unco}$$



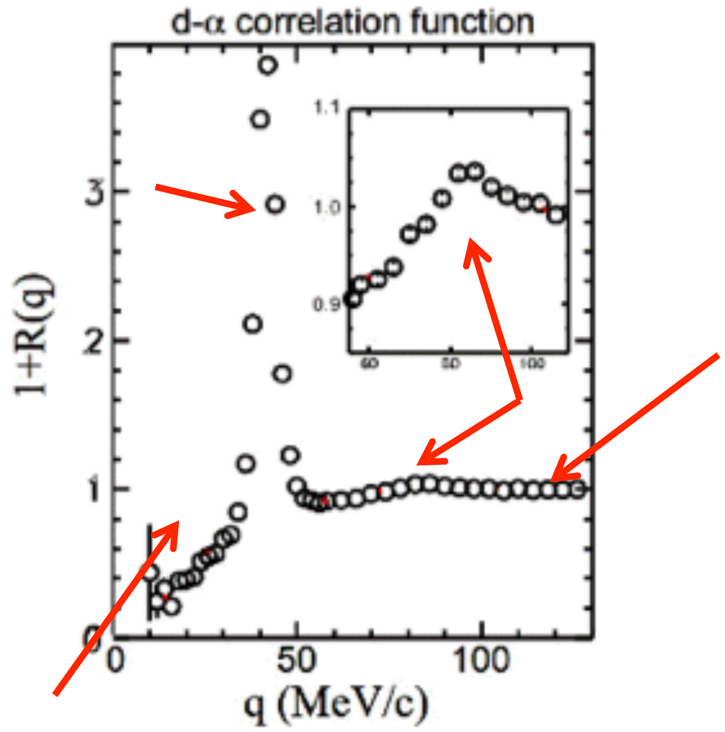
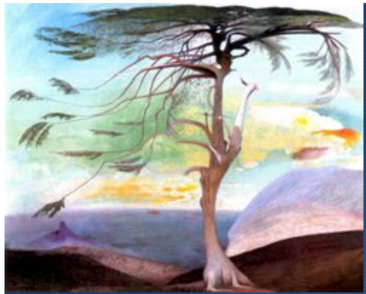


Figura 2.1: *Sinistra: Funzione di correlazione p-p misurata in reazioni $^{14}N+^{197}Au$ ad E/A=75 MeV/nucleon.*

Destra: Funzione correlazione deuterio-alfa misurata in reazioni $^{112}Sn+^{124}Sn$ ad E/A=50 MeV/nucleon.

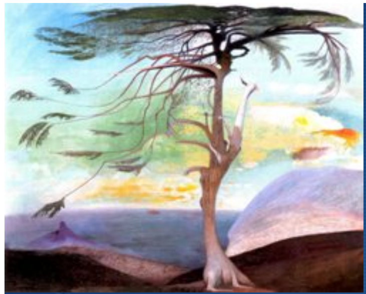


- **Proton-Proton Correlation Function**
  - **Physical**
  - **Experimental**

Theoretically the p-p correlation function is calculated by the Koonin-Pratt Integral Equation:

$$1 + R(\boldsymbol{q}) = 1 + \int d\boldsymbol{r}\, S(\boldsymbol{r}) \cdot K(\boldsymbol{r}, \boldsymbol{q}).$$

- $\tau = 0$ S(r) ➔ Spatial distribution of the emitting source
  - $\tau \neq 0$ S(r) ➔ Space-Time ambiguity



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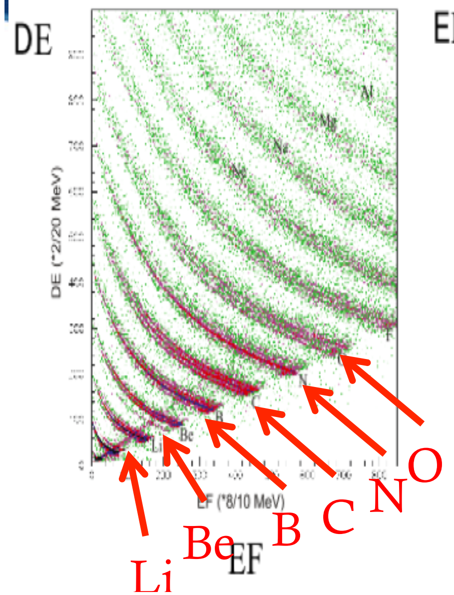
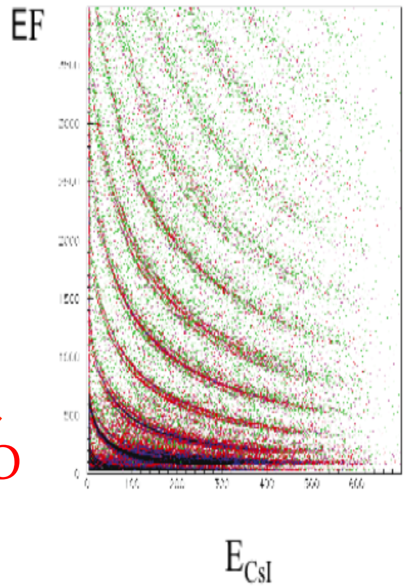
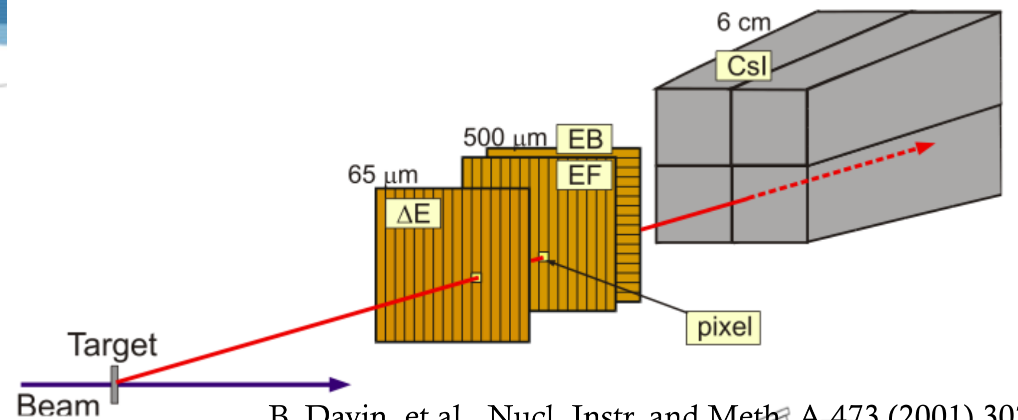
Correlation functions in Xe + Au collisions at 50 MeV/nucleon with LASSA correlator

LASSA (Large-Area Silicon-Strip-CsI(Tl) Array)

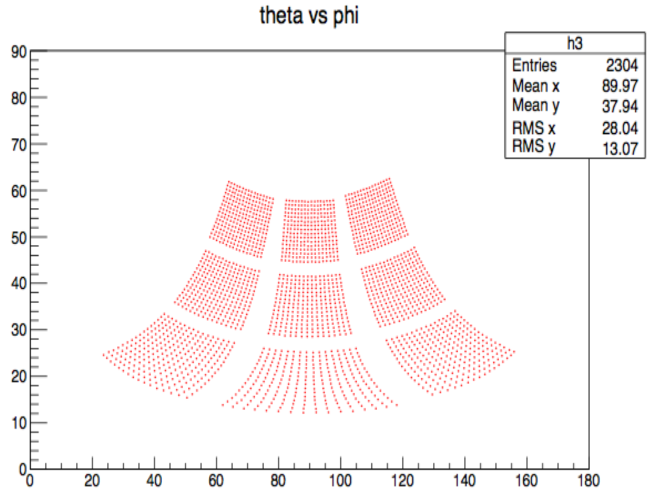
9 telescopi







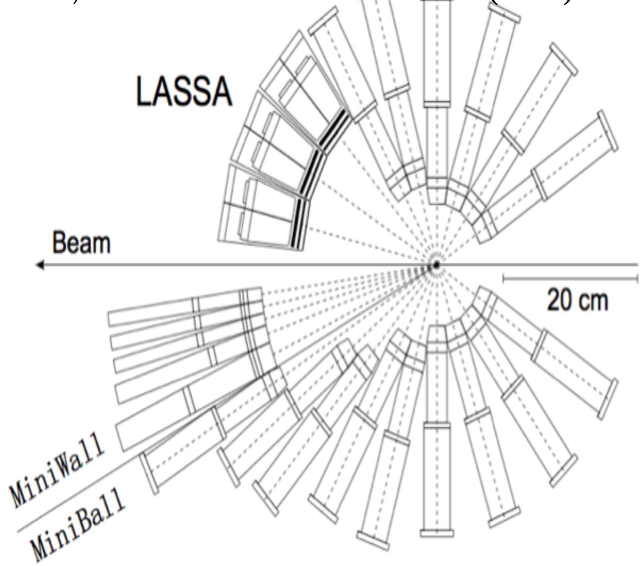
B. Davin, et al., Nucl. Instr. and Meth. A 473 (2001) 302.



The Xe+Au experiment was performed at NSCL-MSU

MiniBall/miniWall

LASSA : $12° \leq \theta \leq 62°$
e
$24° \leq \phi \leq 156°$



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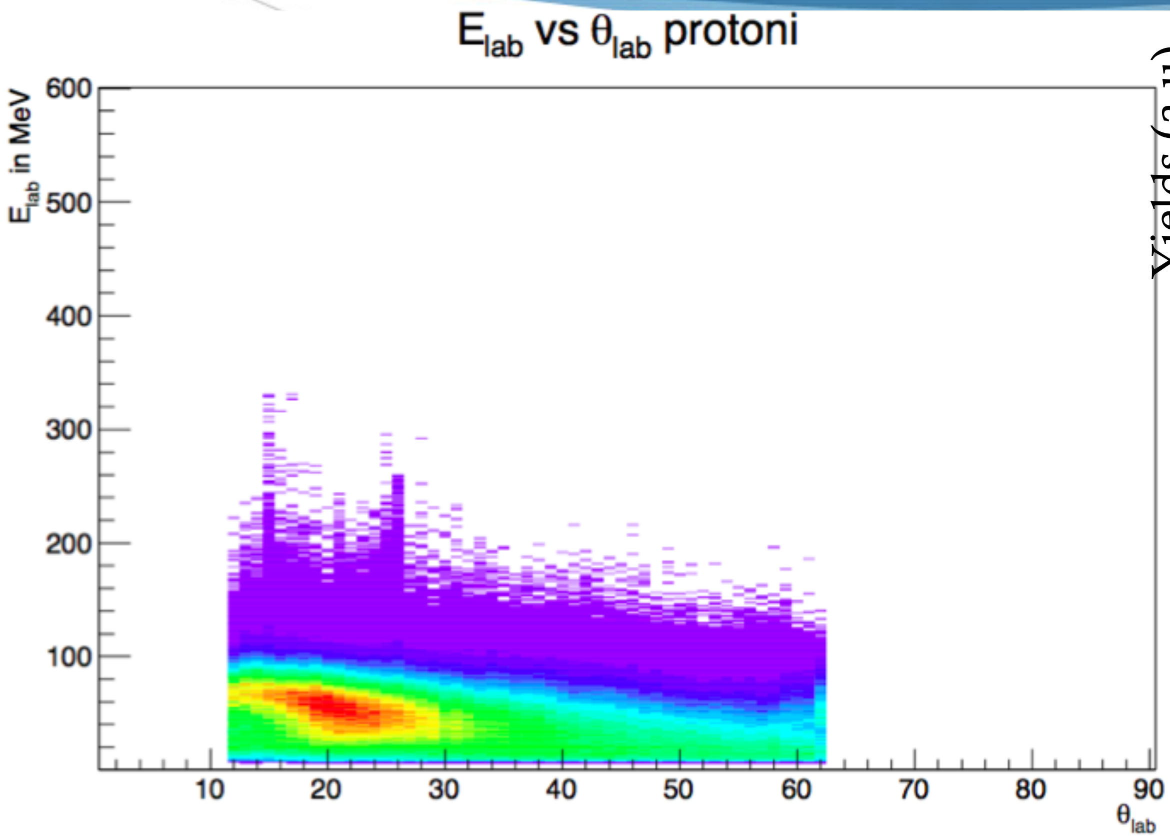
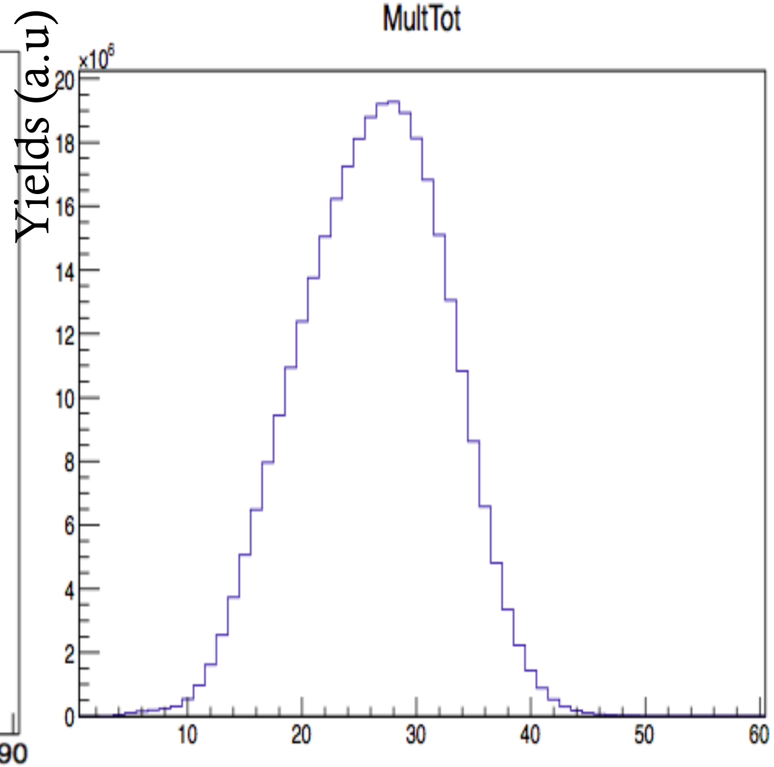
- $Mult_{Tot}$ (LASSA+MiniBall/MiniWall)
  - $Mult_{Tot} > 25$





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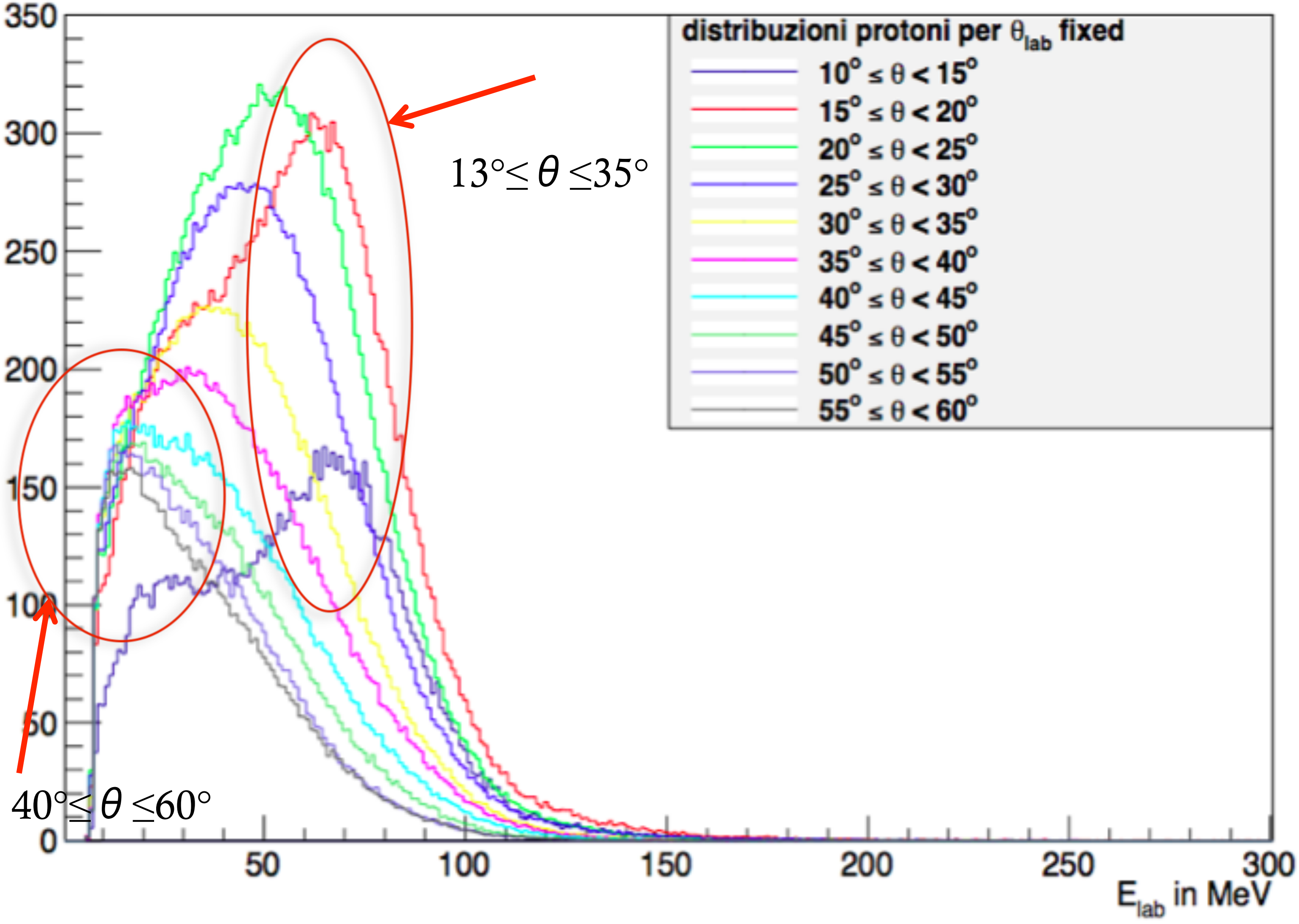
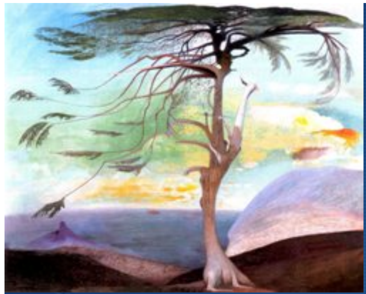
Higher energy contributions at small angles between 13° and 35° (bump between 60 and 90 MeV), fast sources of the quasi-projectile.





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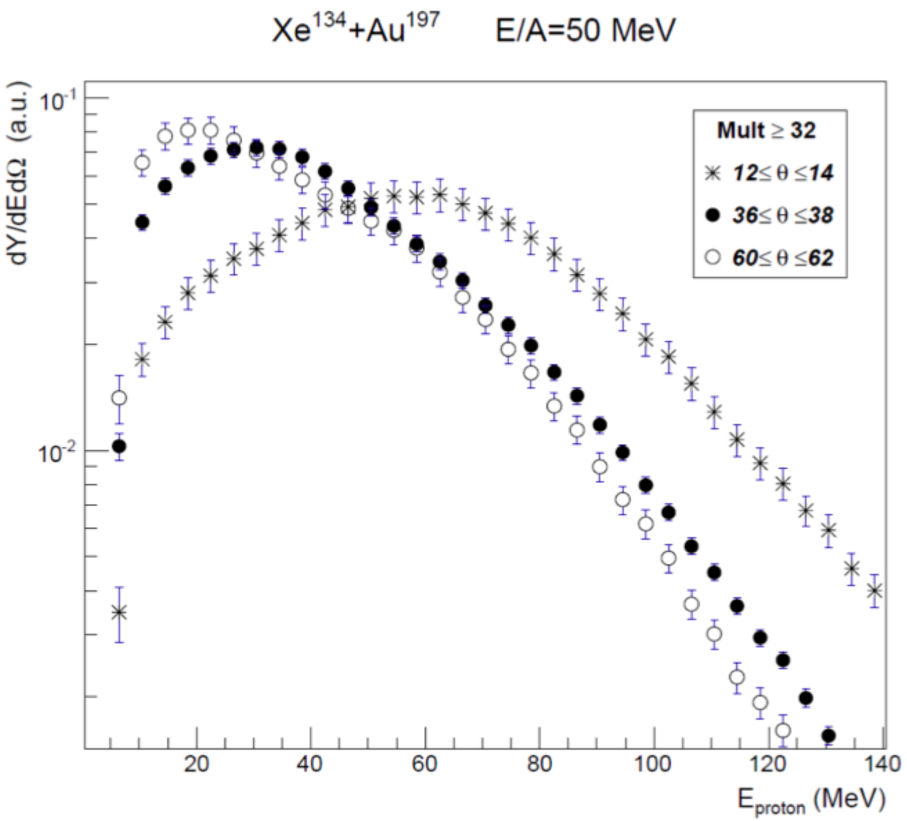
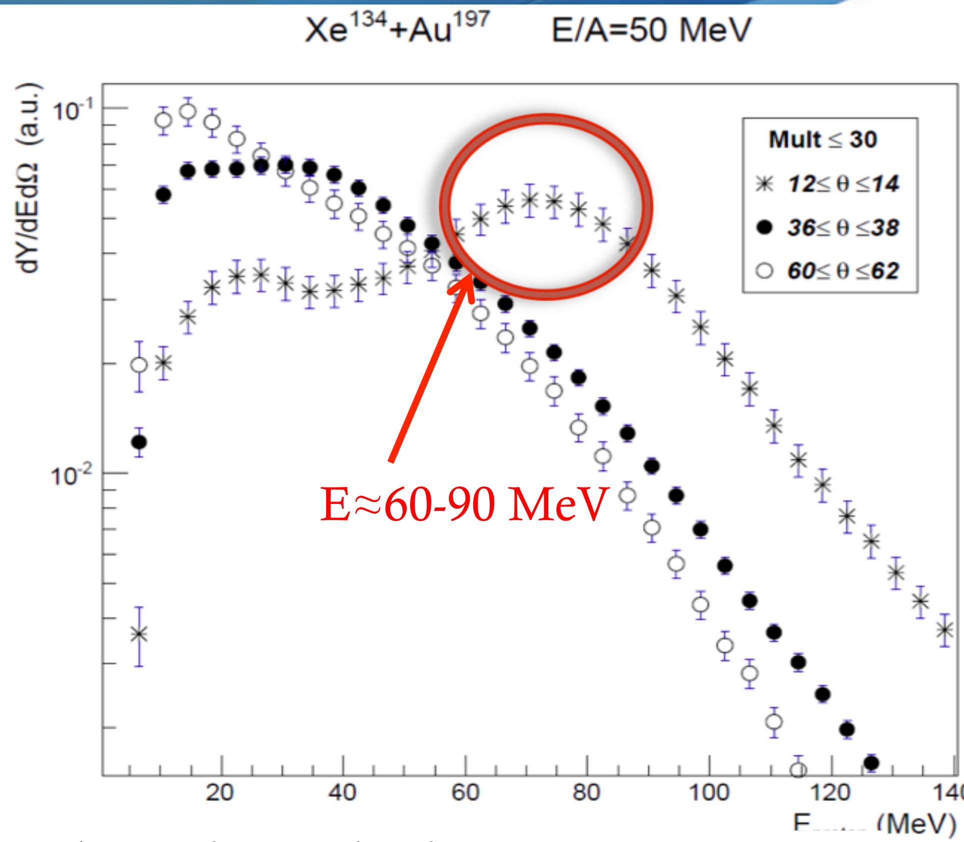
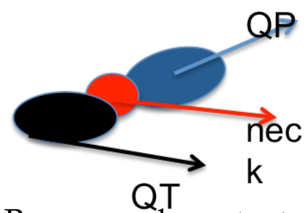
More of one sources: participant/neck and quasi-projectile

$Mult_{Tot}$ > 25 central collisions dominant + semi-periferal





$Mult_{Tot}$ Cut and in angular regions selections



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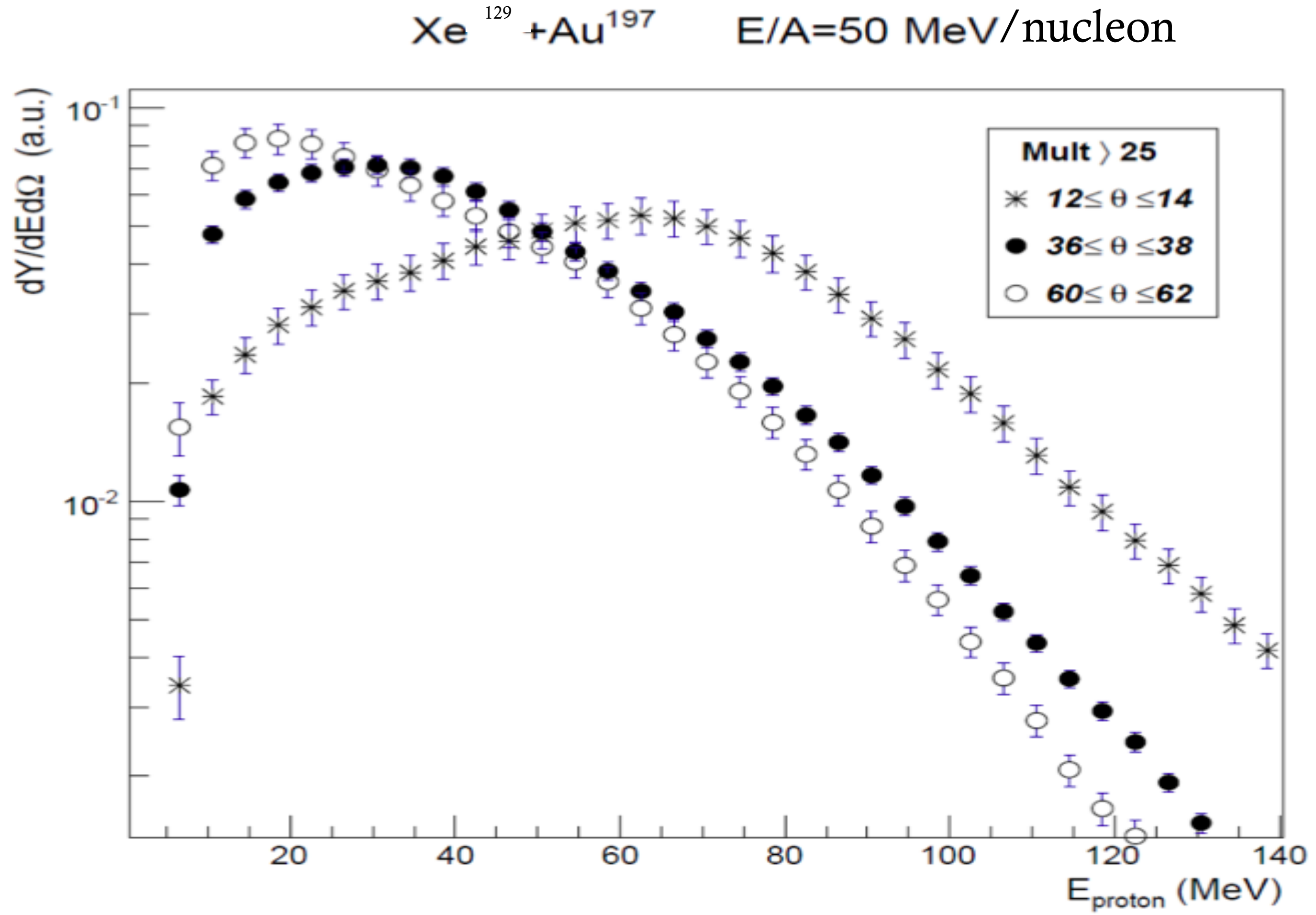

Compromise between statistical and centrality $Mult_{tot}$> 25

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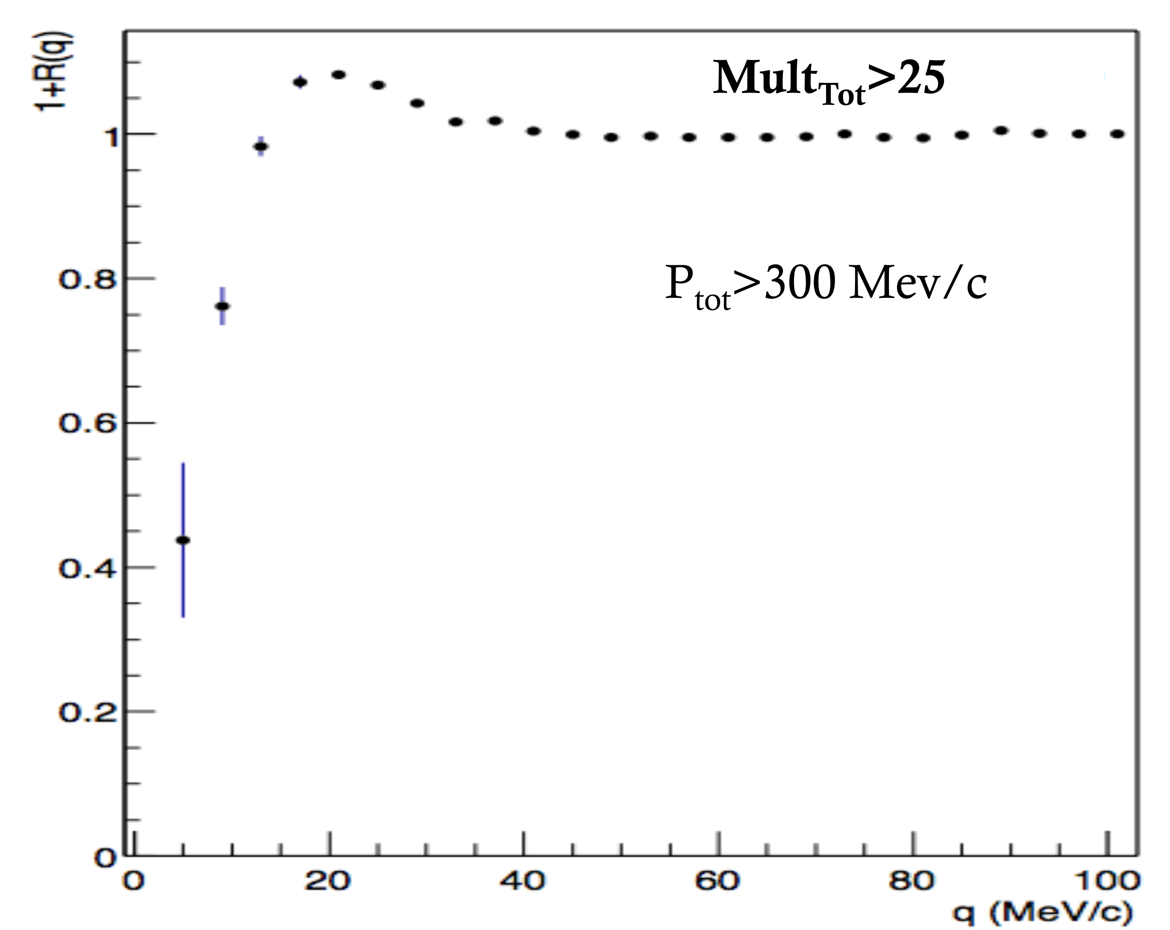

- Different Contributions (quasi-projectile) e (quasi-target)
  - More of one emitting sources
- Fast e slow processes (IMF, evaporazione da quasi-proiettile)

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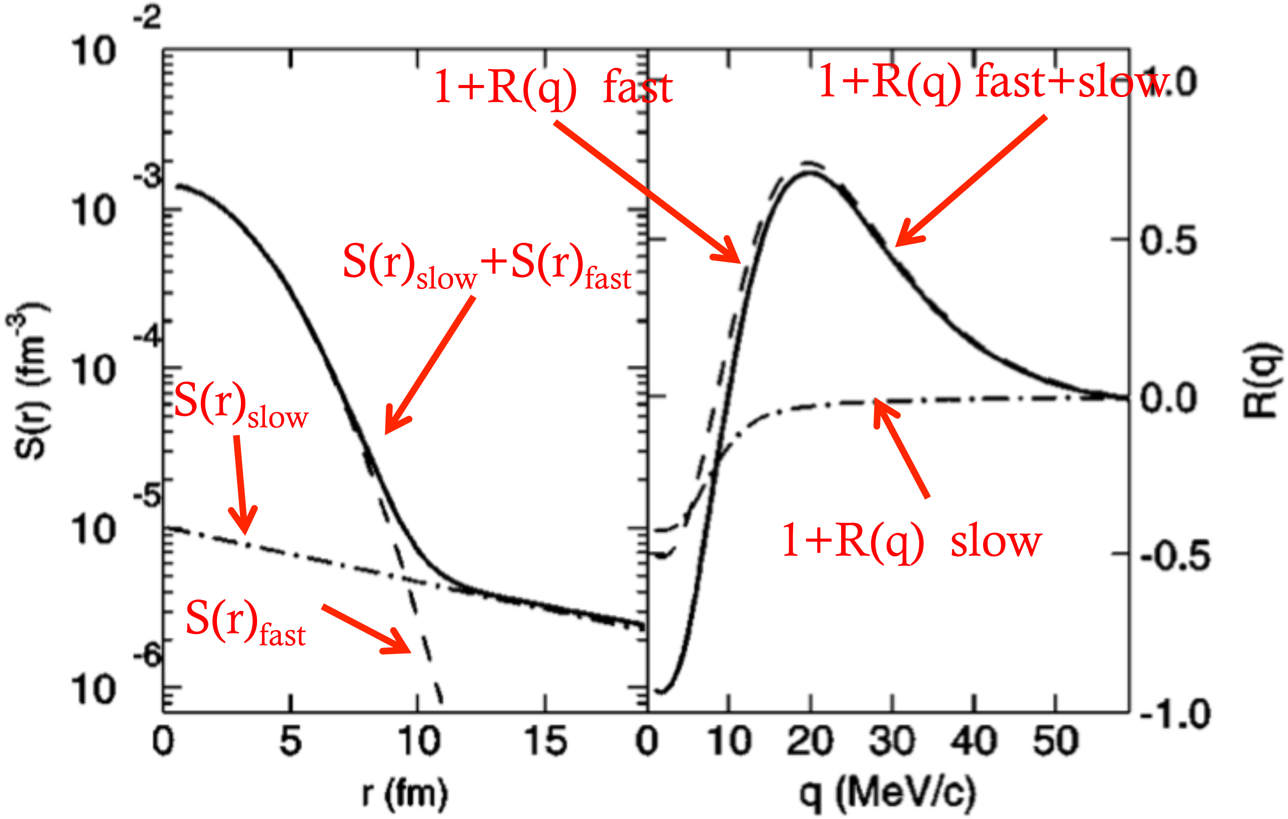
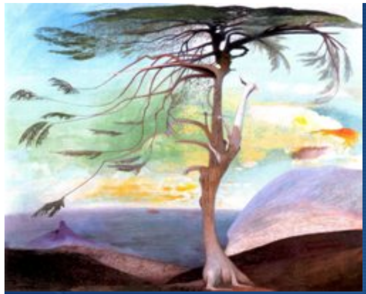


S(r) will be the sum between $S(r)_{fast}$ and $S(r)_{slow}$.



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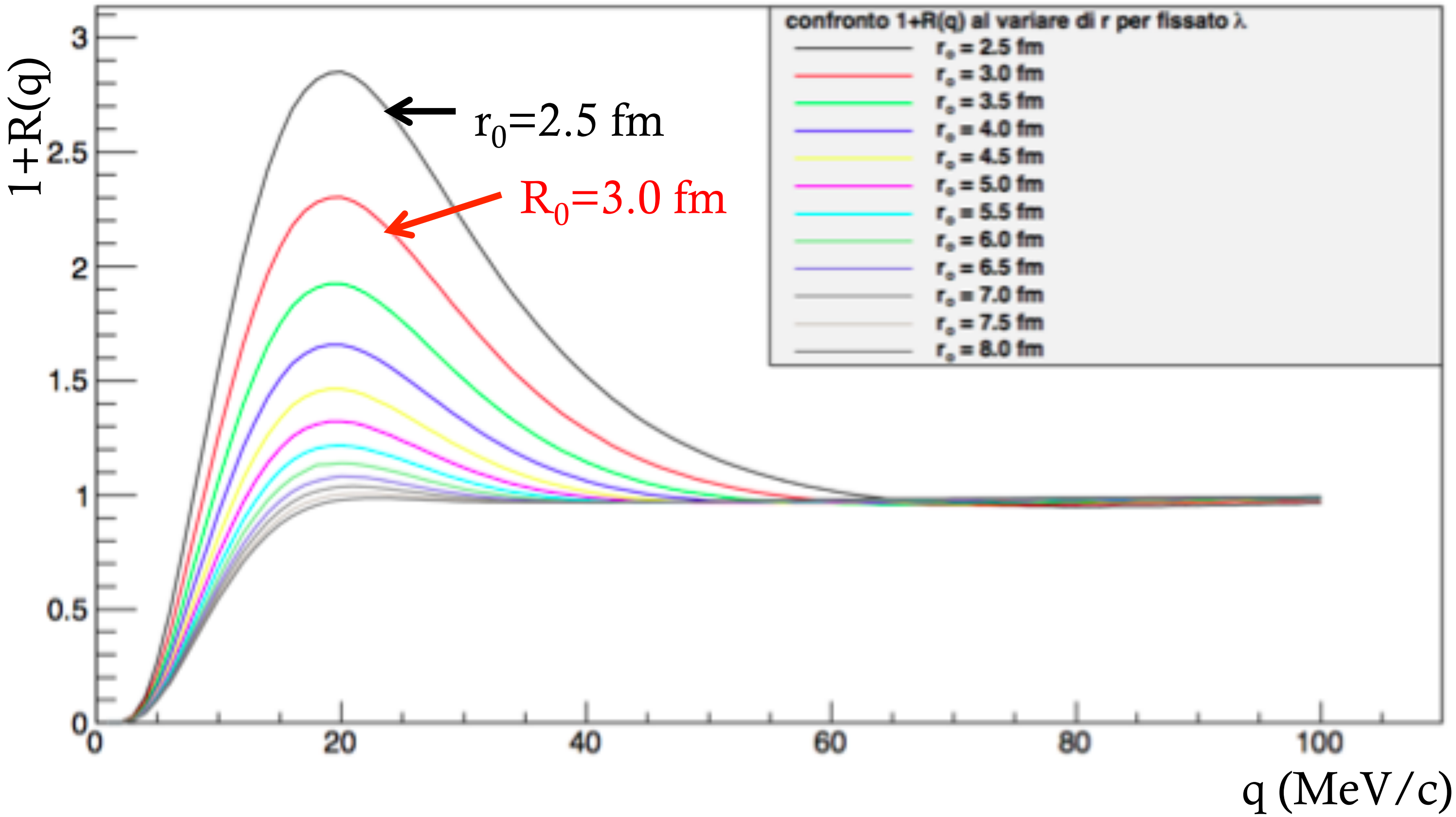
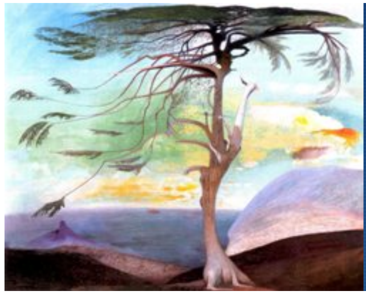
$$S(r) = \frac{\lambda}{(2\pi)^{3/2} r_0^3} exp\left(-\frac{r^2}{2r_0^2}\right)$$

confronto 1+R(q) al variare di r per λ=1





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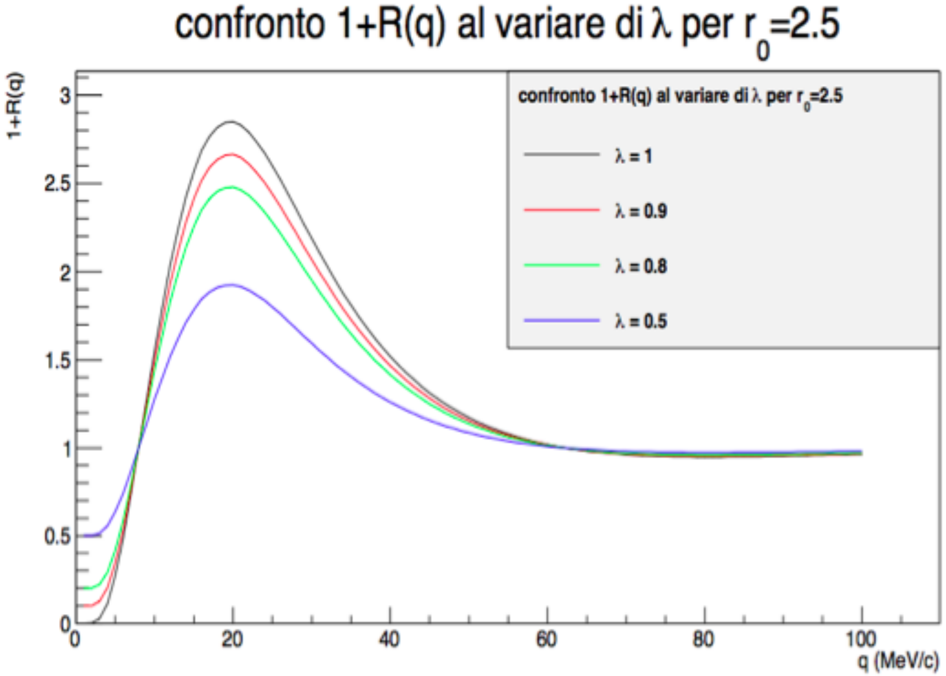
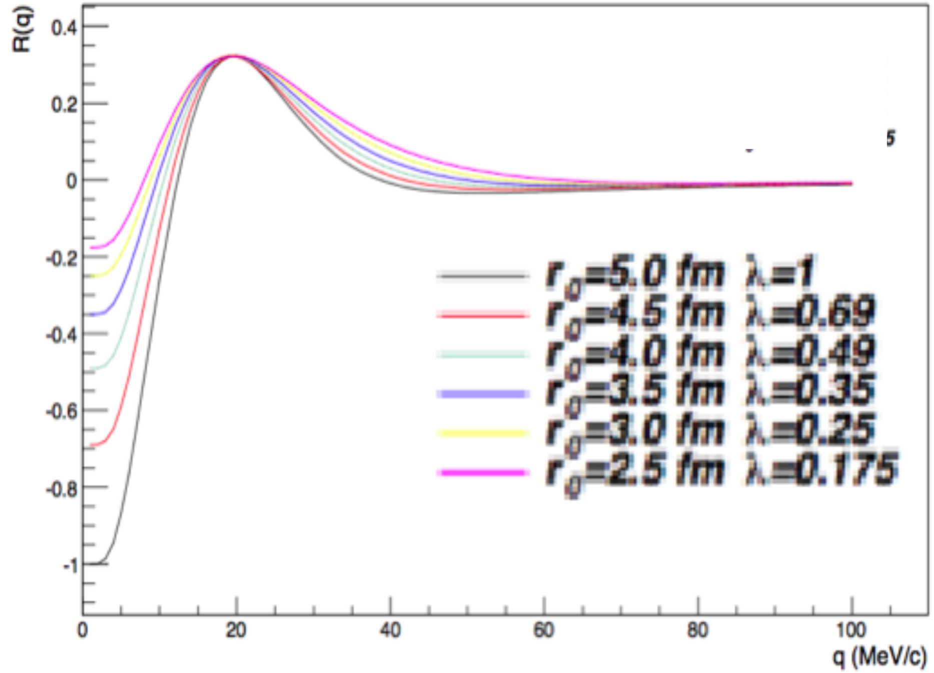
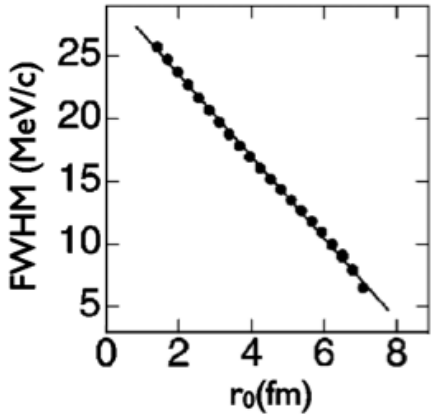




The height of the peak is not uniquely related to the size
Less extensive sources give rise to wider widths



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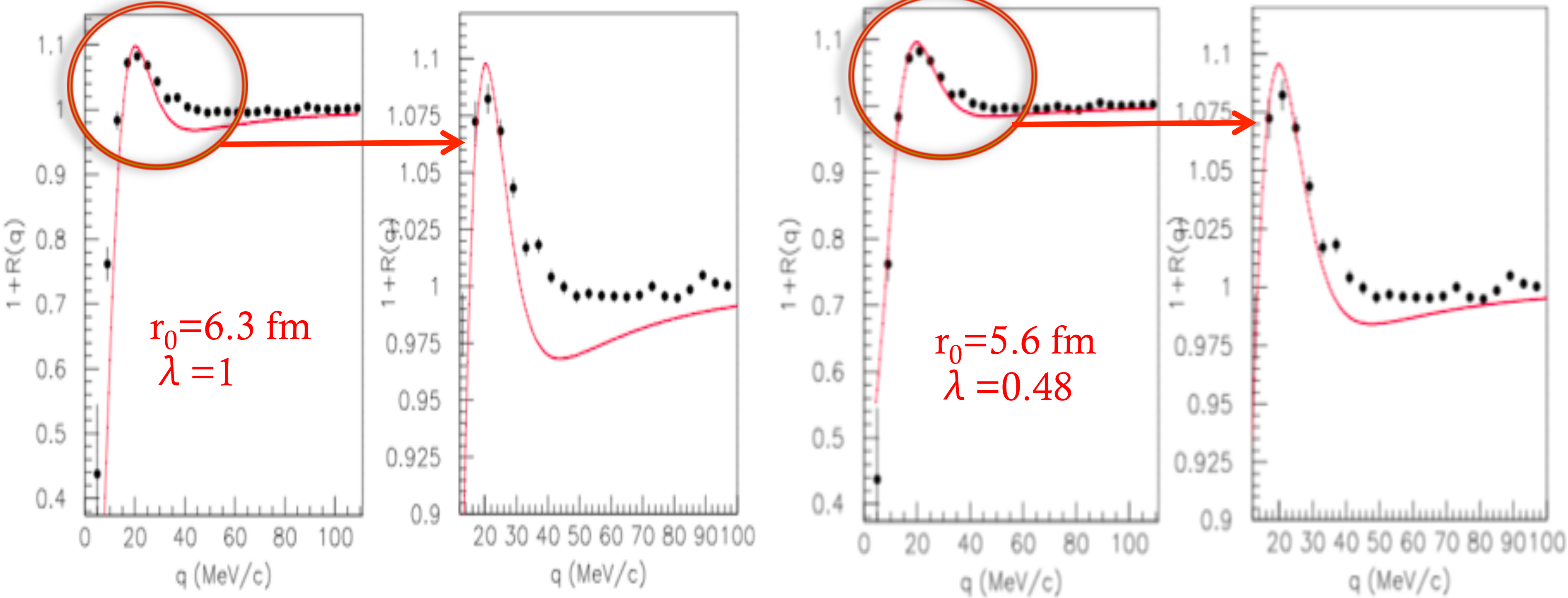

$\chi^2=7.45$

$\chi^2=0.96$

The emitting source is therefore a little bit smaller and it is a fast source emitting approximately 50% of proton-proton pairs of the system.

$$S(r)=\frac{\lambda}{(2\pi)^{3/2}r_0^3}\,exp\left(-\frac{r^2}{2r_0^2}\right)$$

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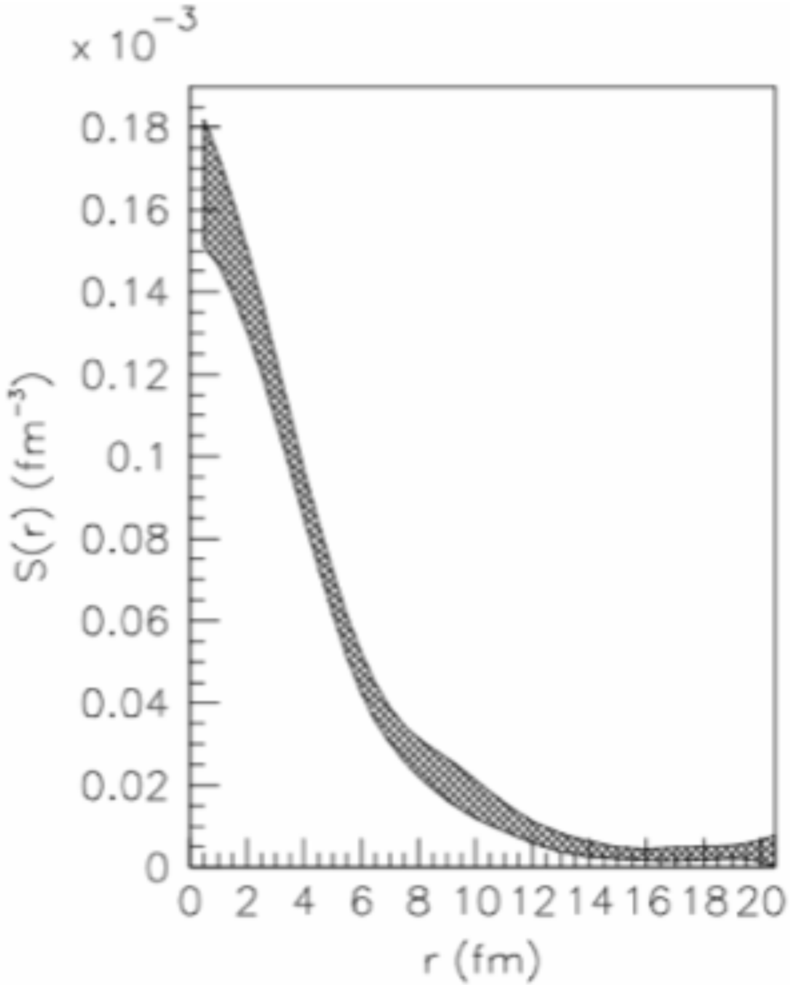
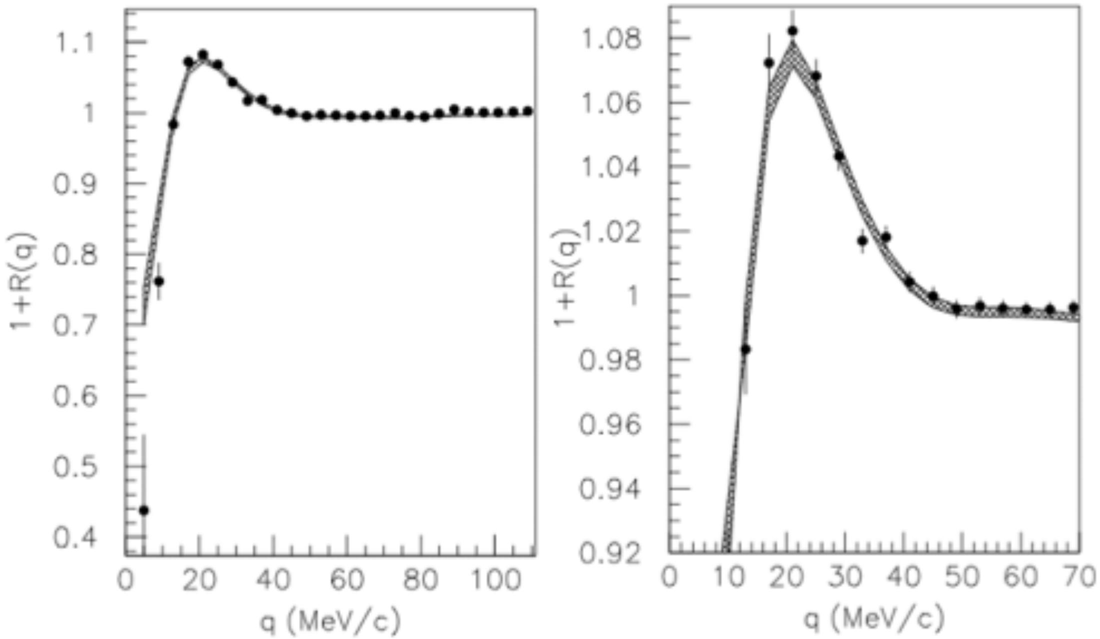
Analisi di Imaging

G. Verde et al., Phys. Rev. C 65, 054609 (2002)

D.A. Brown, P. Danielewicz, Phys. Lett. C 64 014902 (2001)

$$1 + R(\boldsymbol{q}) = 1 + \int d\boldsymbol{r}\, S(\boldsymbol{r}) \cdot K(\boldsymbol{r}, \boldsymbol{q}).$$





- $R_{1/2}$=FWHM della S(r)
- $R_{1/2}$ = 4.4(±0.3)fm
- λ_{fast}=0.18

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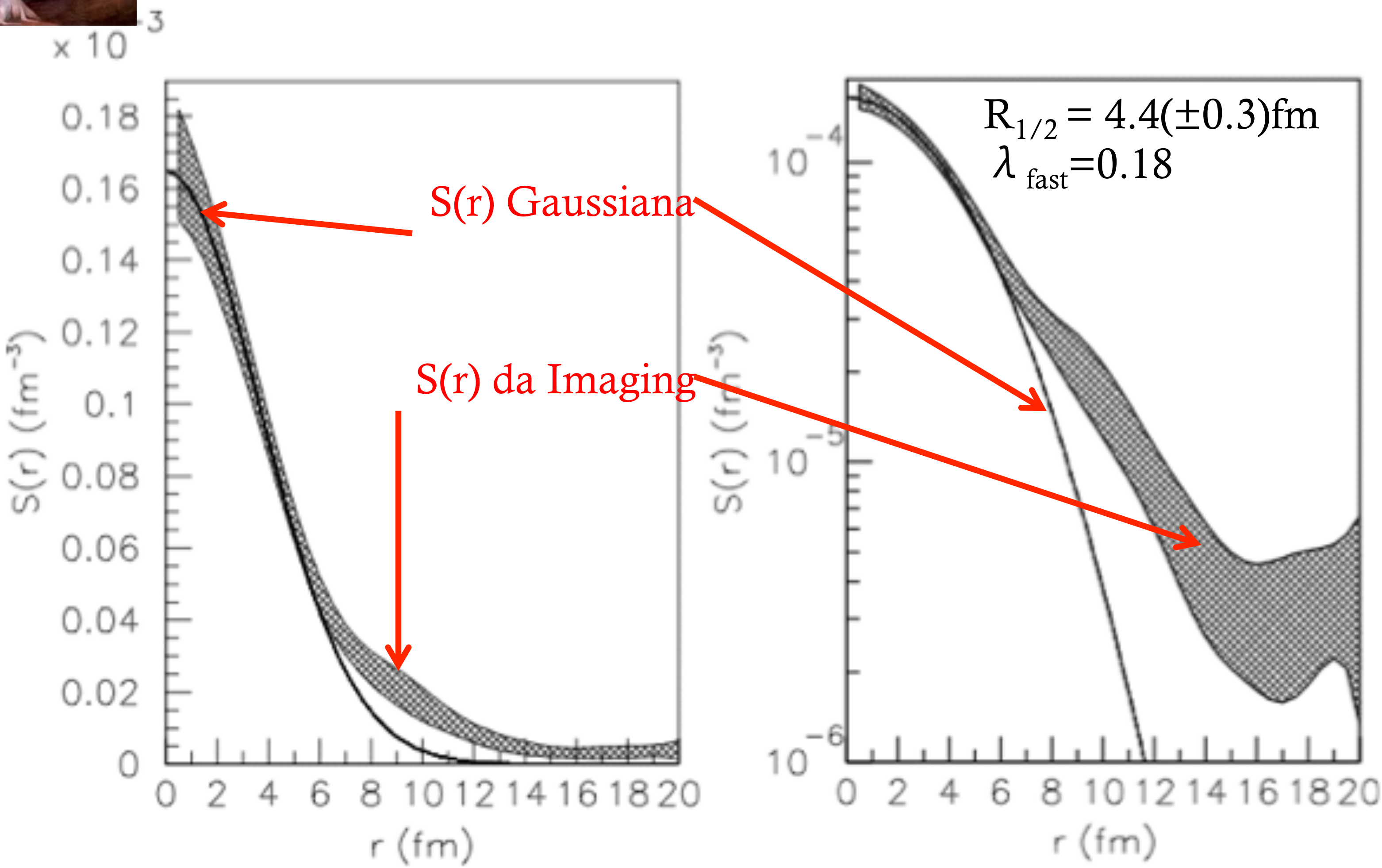

Imaging reveals strong evidence of long-lived decay (slow, confirmed by the shape of the energy spectra)

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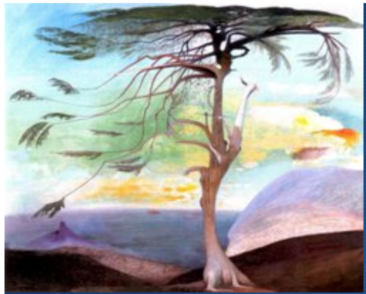

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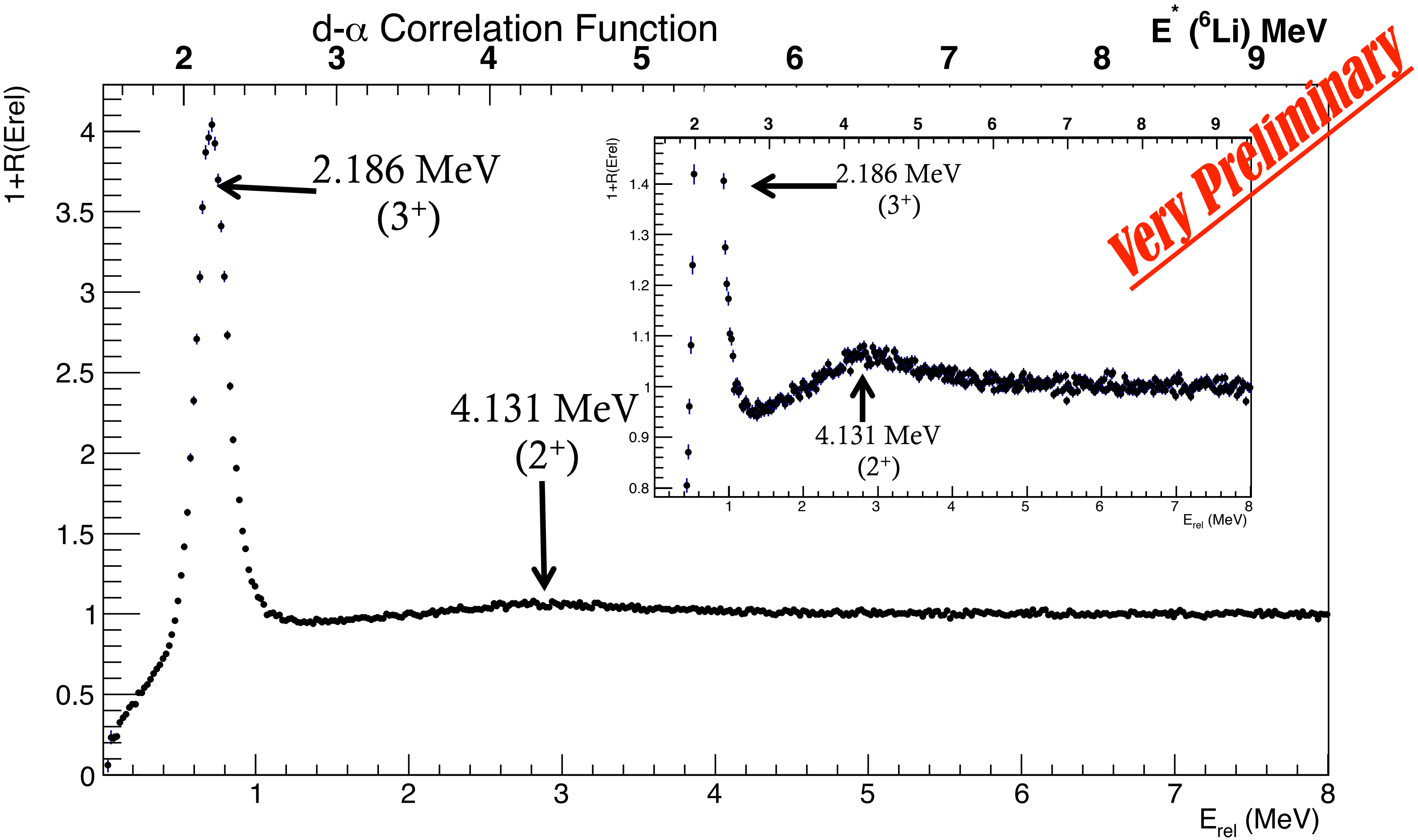
$^{6}Li \rightarrow d + \alpha$



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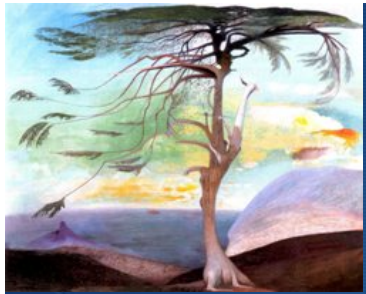
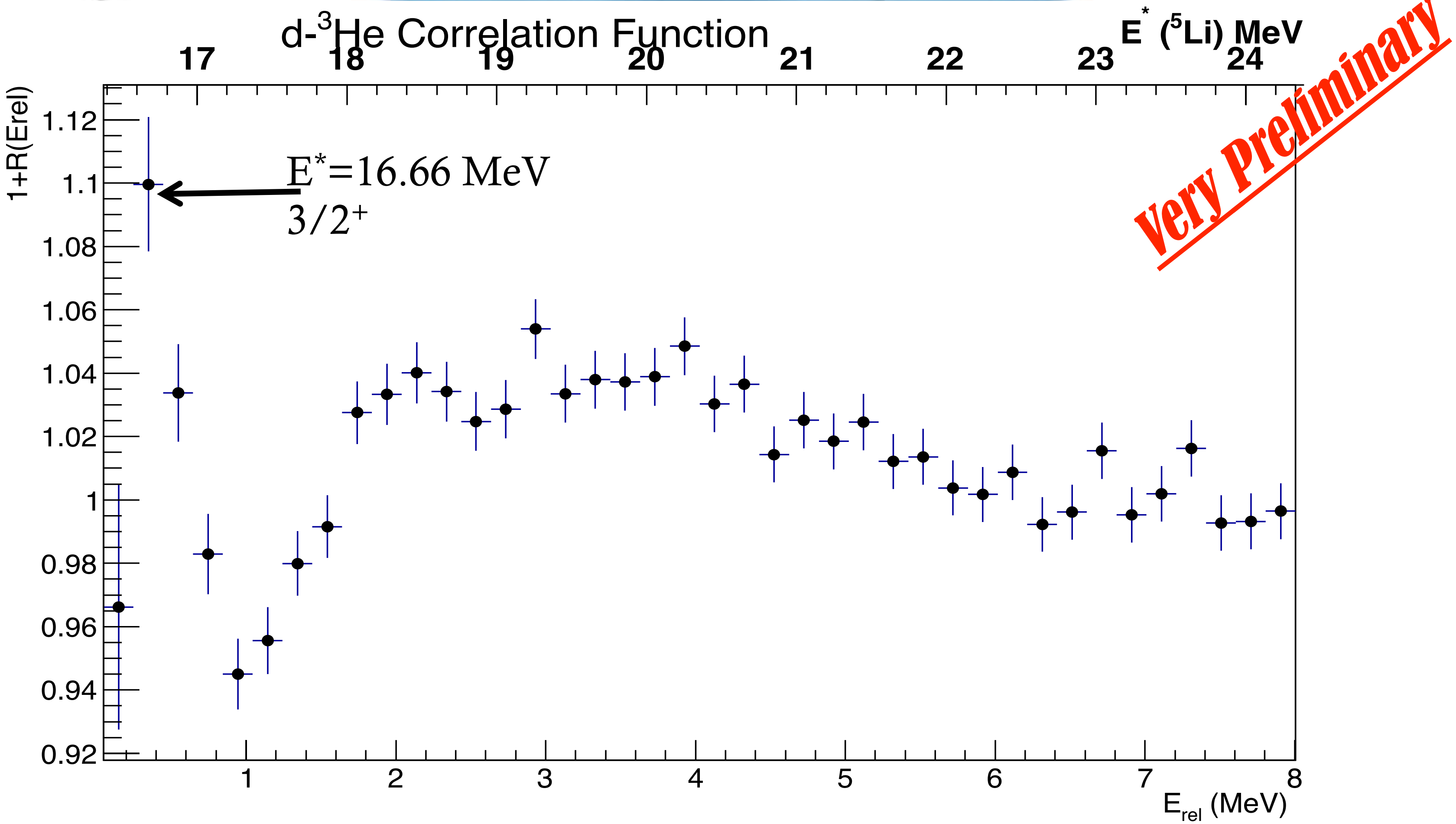
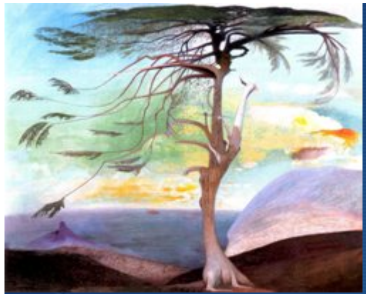


$^{5}Li \rightarrow d + {}^{3}He$





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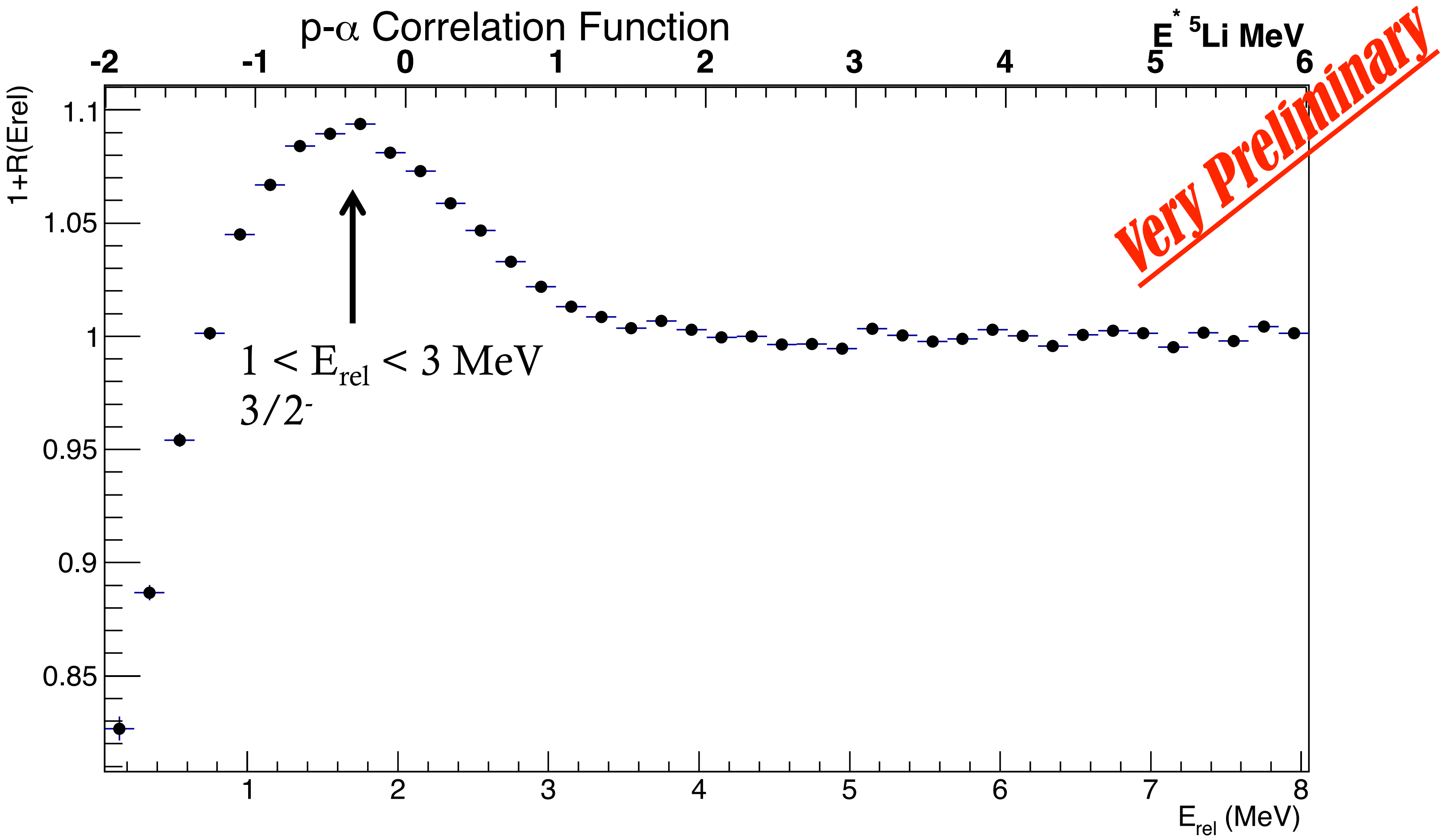
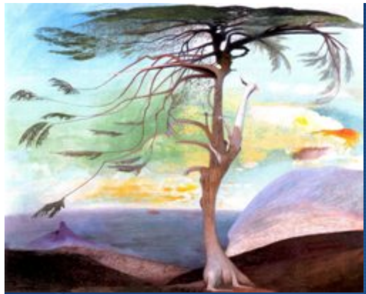
$^{5}Li \rightarrow p + \alpha$





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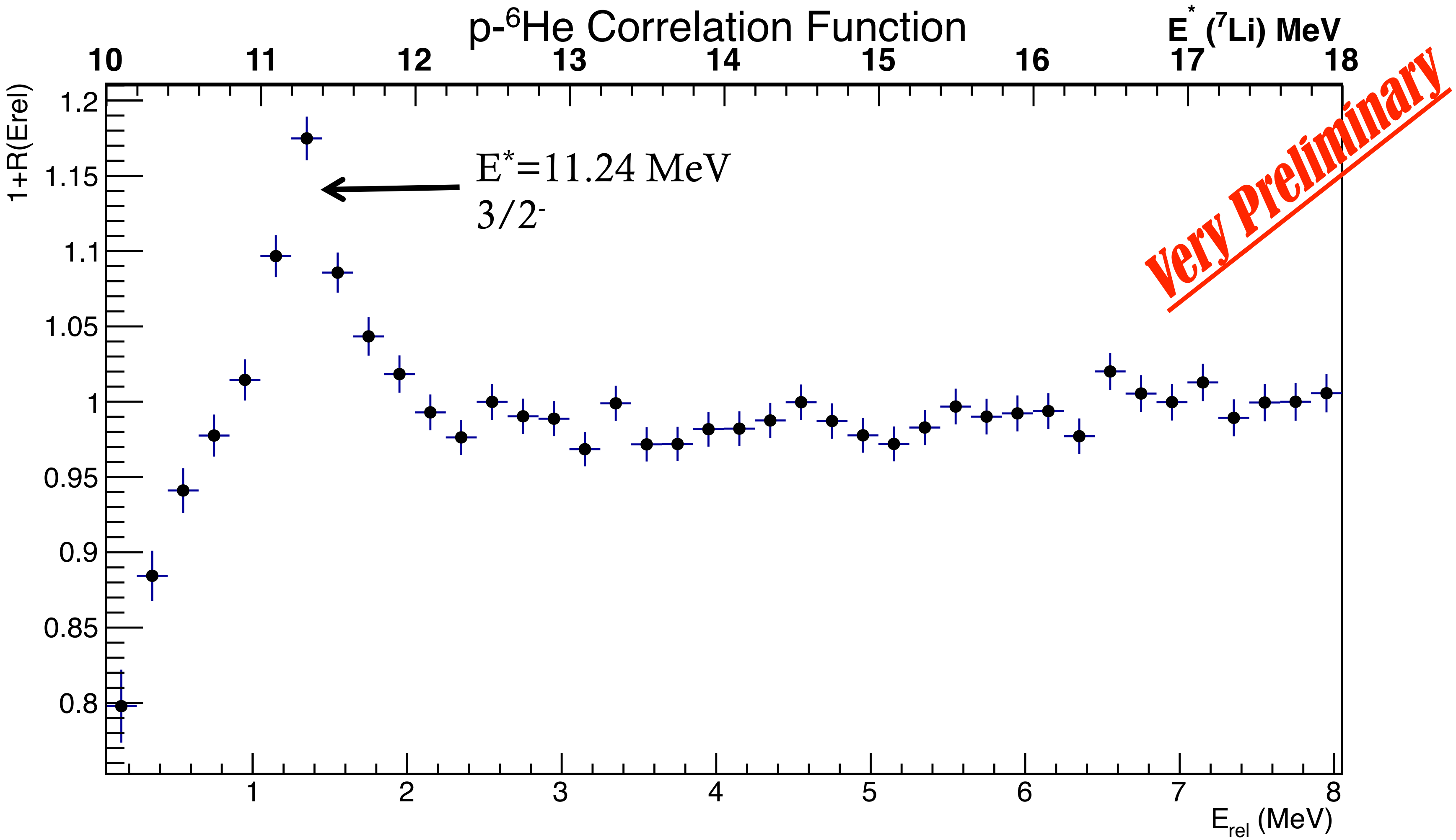
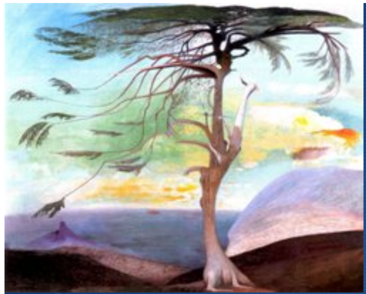
$^{7}Li \rightarrow p + {}^{6}He$





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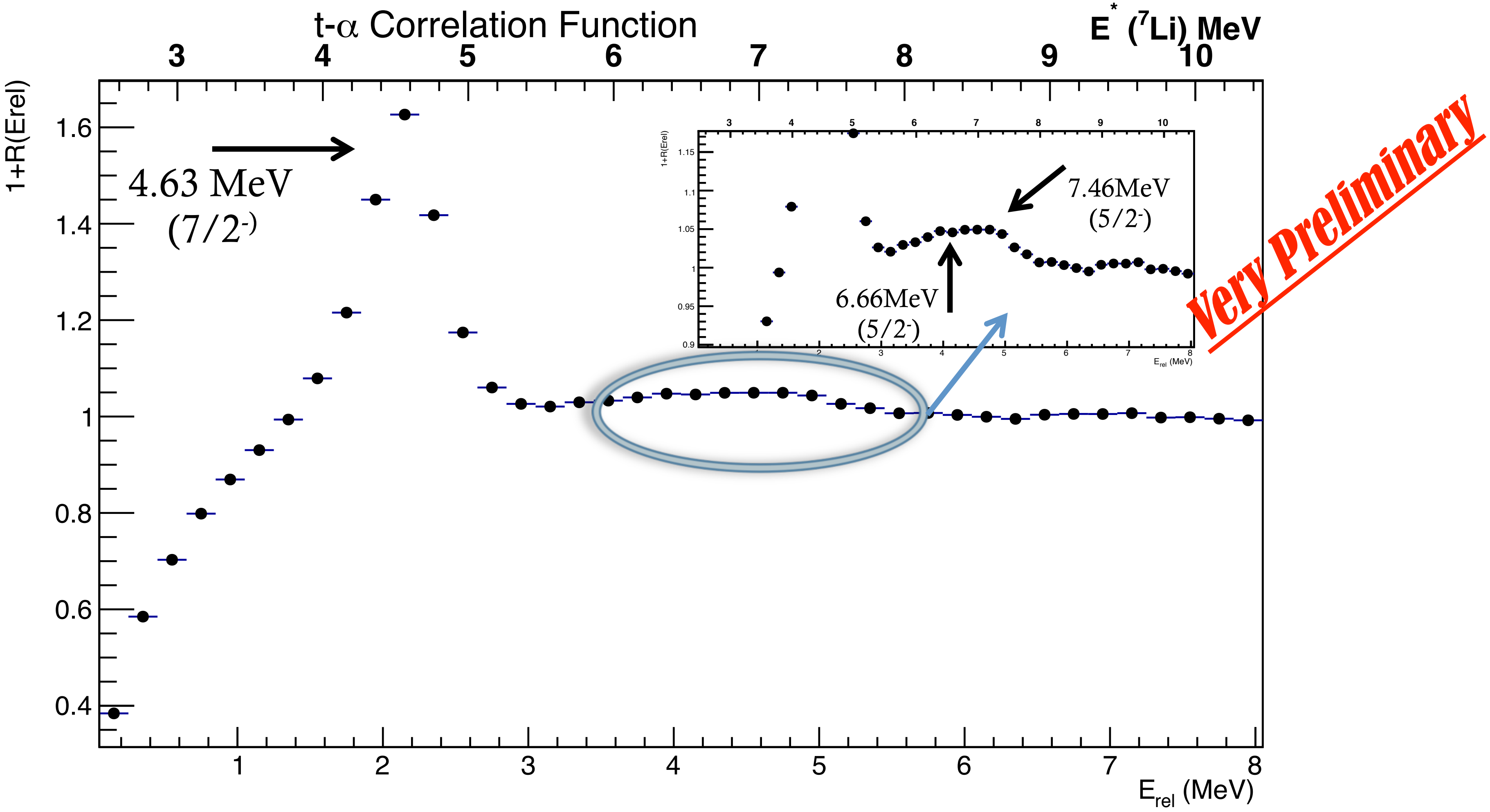
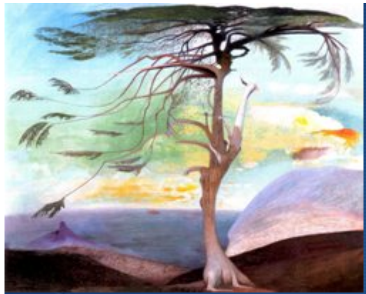
$^{7}Li \rightarrow t + \alpha$





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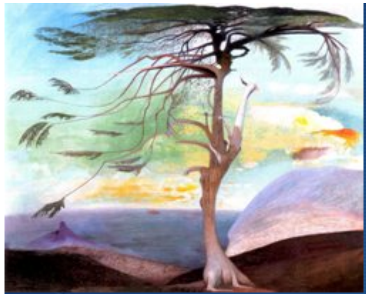
The FARCOS project

- **FARCOS (Fentoscope ARray for Correlations and Spectroscopy)**
- **Modular array of telescopes**
- **High energy and angular resolution**
- **ΔE/E discrimination, pulse shape discrimination and TOF discrimination (4pi CHIMERA)**
- **Digitization**
- **DSSSD(Double-Sided Silicon Strip Detector) each with 32 strips, both in vertical and in a horizontal and 4 crystals of CsI(Tl).**
- **Portability and modularity to be coupled to 4π detectors as CHIMERA or magnetic spectrometers**
- **Integrated and reconfigurable electronics**
- **Possibility of updating and upgrades (neutrons)**



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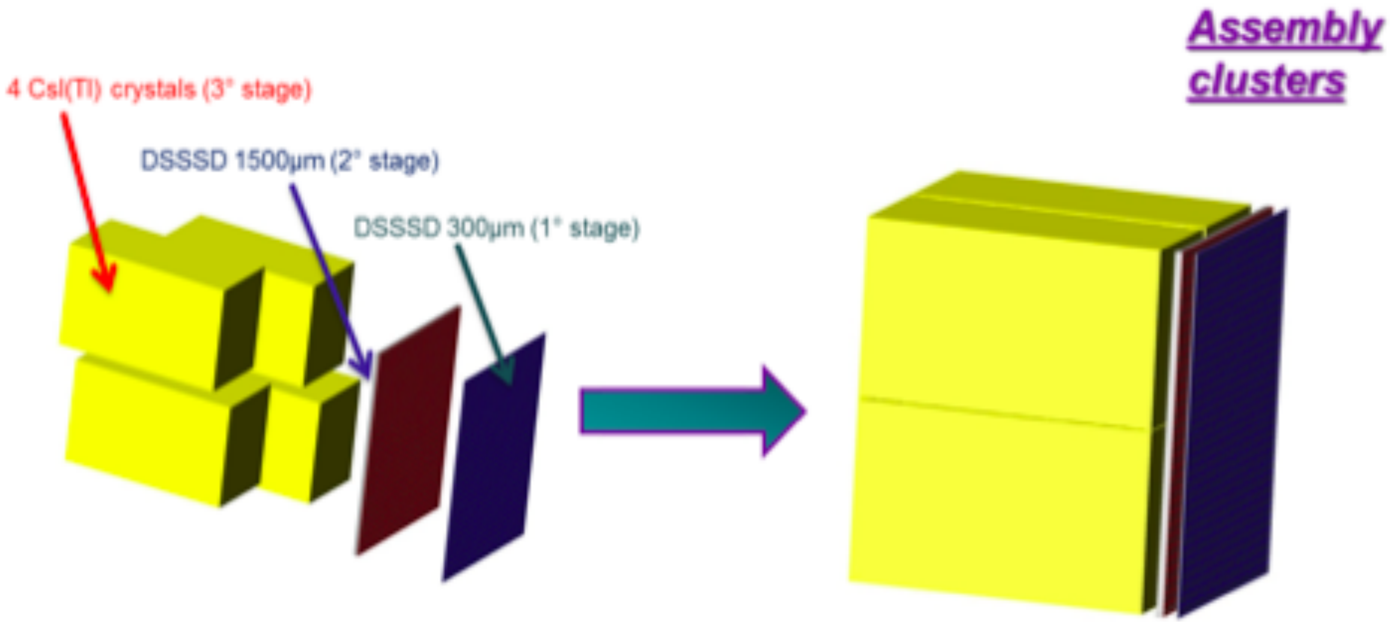
The FARCOS array composition

- Based on (62x64x64 mm^3) clusters
- 1 square (0.3x62x62 mm^3) DSSSD 32+32 strips
- 1 square (1.5x62x62 mm^3) DSSSD 32+32 strips
- 4 60x32x32 mm^3 CsI(TI) crystals (window shape)



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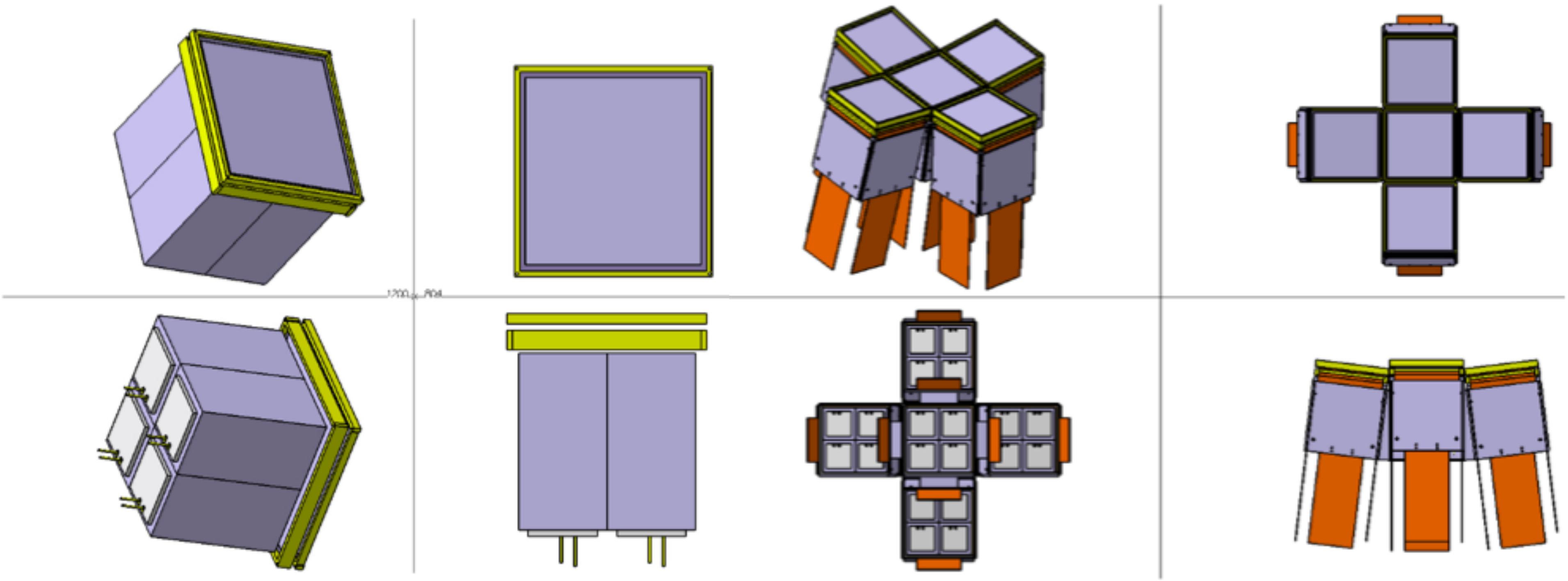

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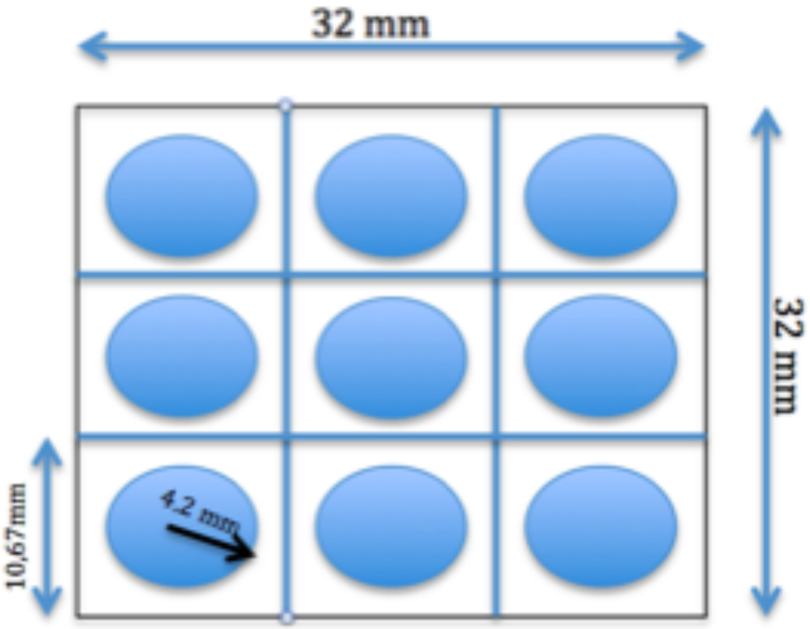
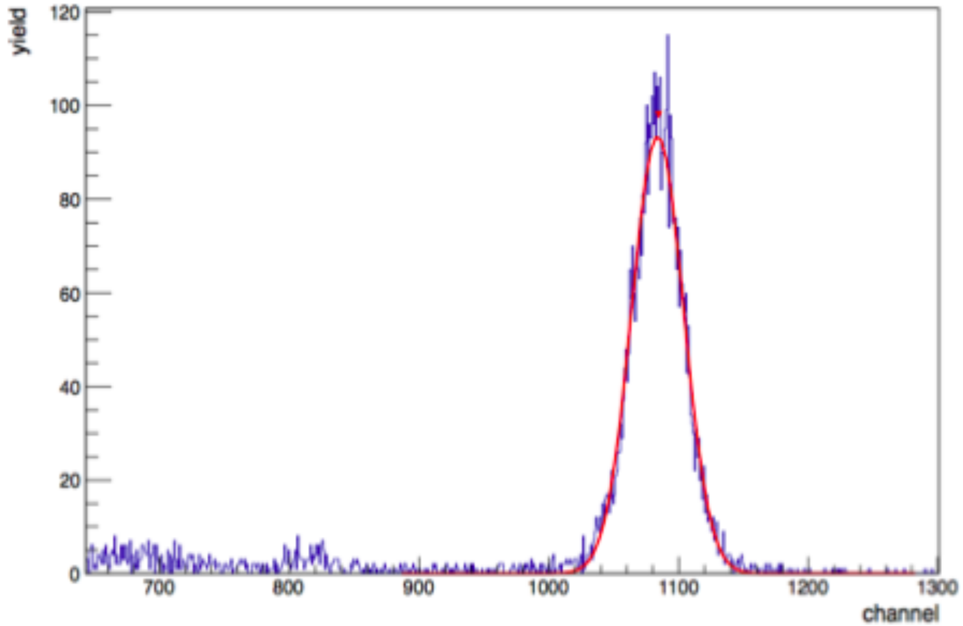
Tests and characterizations

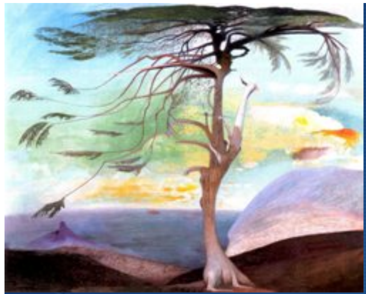
- response testing in light surface of the crystals of CsI (Tl)
  - Doping 1200 e 1500 ppm
- vacuum conditions ($\approx 10^{-2}$ *mbar*)
- ^{241}Am source of 150 nCi of intensity, $E_{\alpha} = 5.485$ MeV.





1) Peak position
2) FWHM
3) the number of counts

$$FWHM/CH_{picco} \approx 2\%.$$



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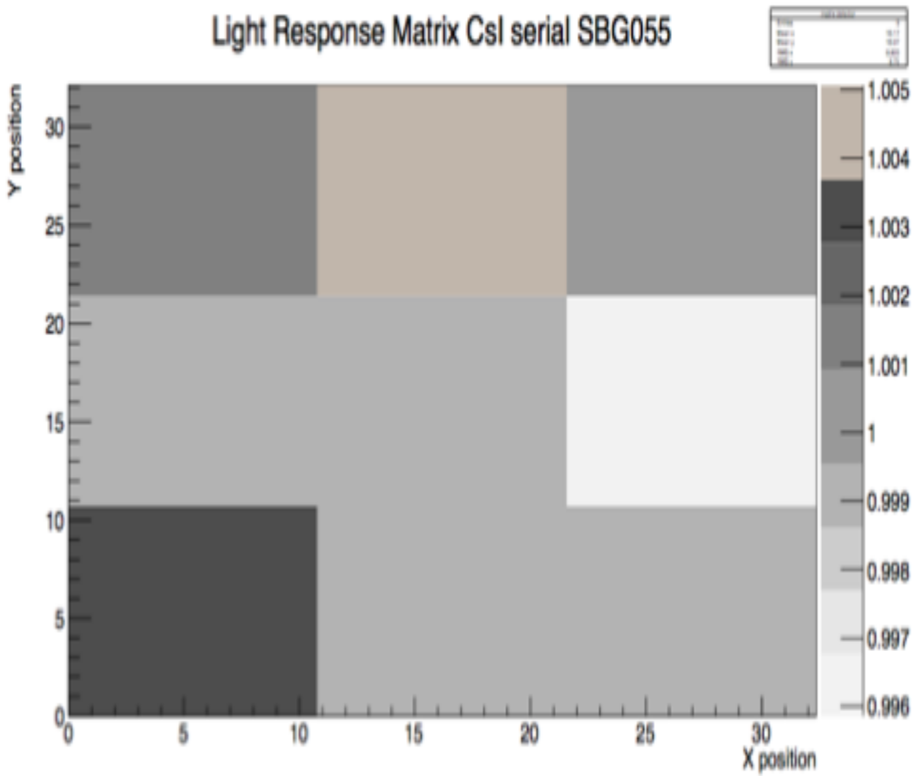
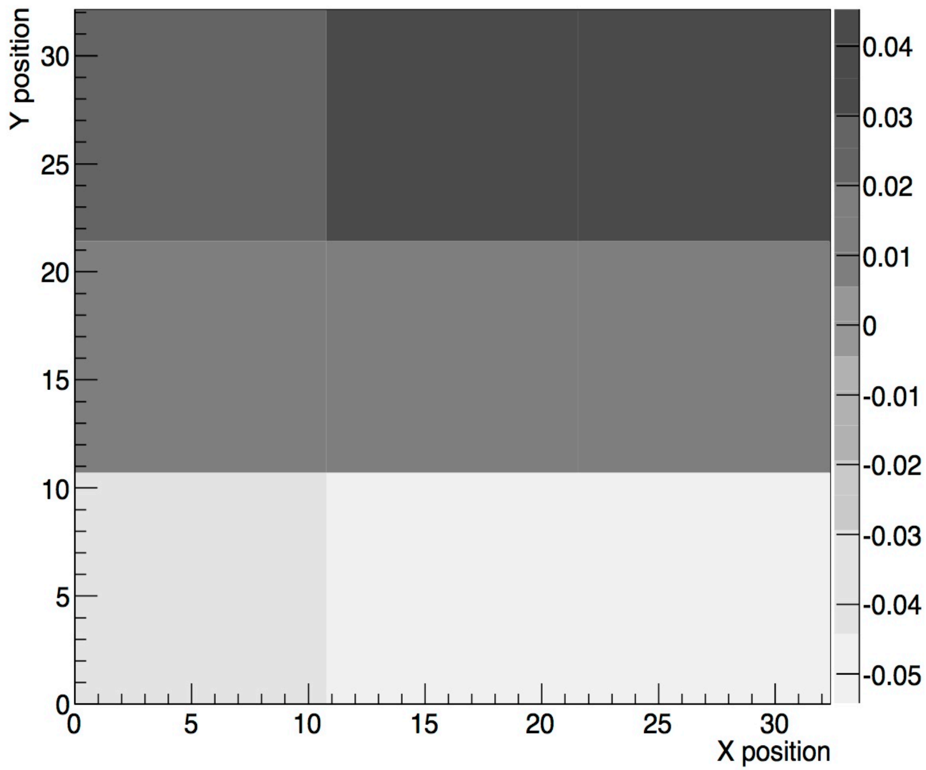
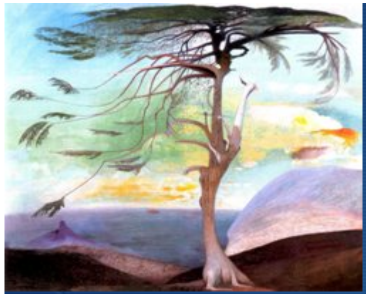




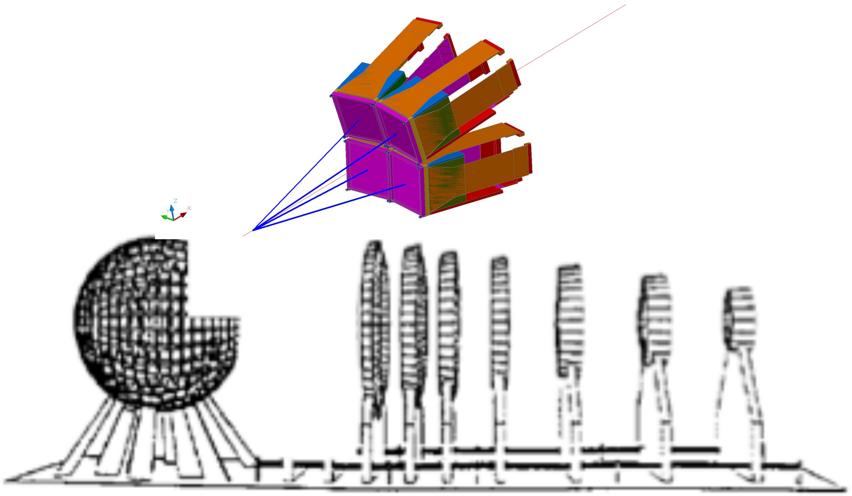


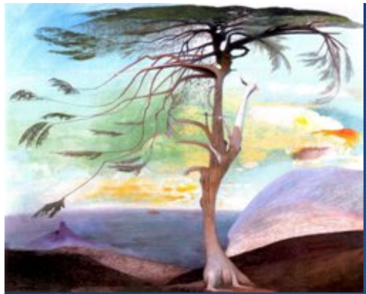
E. V. Pagano
Università di Catania-INFN-LNS

Future Perspectives

Next April 6 telescopes of FARCOS will be tested in collisions of

$^{124}Xe + ^{64}Zn$ and $^{124}Sn + ^{64}Ni$ E/A = 35 MeV/nucleon





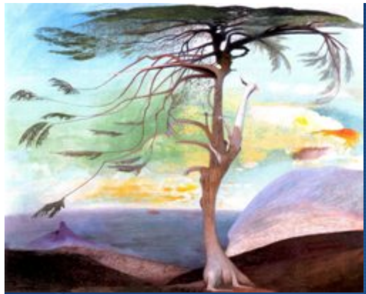
E. V. Pagano
Università di Catania-INFN-LNS

Conclusions

- **Study of proton-proton correlations in collisions of Xe+Au at E/A=50 MeV/nucleon**
- **Experimental construction of the correlation function**
- **Their use in terms of progress in the understanding of nuclear reactions**
- **Estimate of the size of the emitting sources r_0=4.4 fm**
- **Estimated fraction of proton pairs from the emissions "fast"**

Approximately 20%: <u>quantitative information on long-lived contributions</u>

- **The FARCOS Project**
- **Future Perspectives**



THE END

Thank you for your attention