Analysis of the target

A. S.

How everything started..

- FIRST graphite target density was measured to be very high $\varrho_{tgt} = 4.2$ g/cm^3 while the typical graphite density is $\varrho_{tgt} = 2.6$ g/cm^3 .
- This evidence triggered further studies on the target composition:
  - two samples, with thickness of 5mm and 8mm respectively, of the material used for FIRST experiment were sent to two analysis labs in Turin/Rome. Both of them showed the anomalous density. The 8mm sample is the one we actually used for the measurements, while the 5mm one was obtained from the same material batch and used as a Xchk for material examination in Sapienza.
- XPS analyses were done by both labs:
  - A surface analysis was performed using electrons of a proper energy to excite external levels of different atoms. The produced photon spectra was registered (a "picture" is taken) and the different energy components were used to define the elements and their relative abundance.
  - Xray were also used to validate the assumption of a $CrLaO_3$ compound and verify the assembly of the atoms…

8 mm target

8mm target

- Target used for the experiment.
  - density measurements performed at SBAI and LNF revealed anomalous density.
  - Before finalizing the paper for the publication the target was sent to Torino for "further checks"
- Target analyzed @ Turin [DISAT, Politecnico Torino]
  - XPS analysis was performed along the z axis (beam) at several "depths" after having cut the target.
  - XRF measurements performed on TGT surface at the "center" along z
  - FESEM analysis performed on several surfaces along z

FESEM - XRF results

- FESEM
  - analysis done at several depths along z (beam axis):
    - z (-4) beam entrance window: Carbon + O + CrLaO3
    - z 0 tgt center: small amount of C + CrLaO3
    - z (4) beam exit window: no C, only CrLaO3
    - z (-1) : no C, some O + CrLaO3.
  - XRF
    - done only on the surface at the TGT center (along z axis): No C nor C-oxide amount was detected but XRF is not indicated for light elements, which are masked by the heavier ones
- From F. Iazzi report: "After these measurements, the situation was quite confused: LaCrO3 is everywhere present, somewhere there is C and somewhere also O, perhaps in C oxides."

Tried XPS

- Scan along z (Punto 0 close to beam exit window, Punto 11 close to beam entrance window, Punto 6 at TGT center)

	CAMPIONE XPR19FEB											
ZONA	Punto0 (at.%)	Punto1 (at.%)	Punto2 (at.%)	Punto3 (at.%)	Punto4 (at.%)	Punto5 (at.%)	Punto6 (at.%)	Punto7 (at.%)	Punto8 (at.%)	Punto9 (at.%)	Punto10 (at.%)	Punto11 (at.%)
O	44.2	45.3	45.7	46.1	48.4	46.2	45.1	45.7	45.4	48.8	50.3	49.3
C	40.6	37.9	34.7	33.3	35	31.8	36.7	32.3	35.5	31.7	30.3	29.7
Cr	8.2	7.5	8.1	8.1	7.6	11.1	7.9	7.4	7.9	8.7	8.3	7.4
La	6.2	6.4	7.1	6.7	7.2	6.3	6.4	6.4	6.2	8.6	9.4	10
Ca	0.7	1.5	1	1.4	0.7	1.3	1.3	1.6	2.1	1.6	1.8	1.2
P	0.1	1.4	3.4	4.5	1.2	3.2	2.6	6.6	2.8	0.6	<0.1	2.4

Measurements here are not reliable

In order to perform a TGT simulation these data have been used to compute and average composition of the TGT… the mean values have been used in FLUKA (see next slides for results)

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*      O       C          Cr         La       Ca      P
* 46.7083+34.125+8.18333+7.2292+1.35+2.40417
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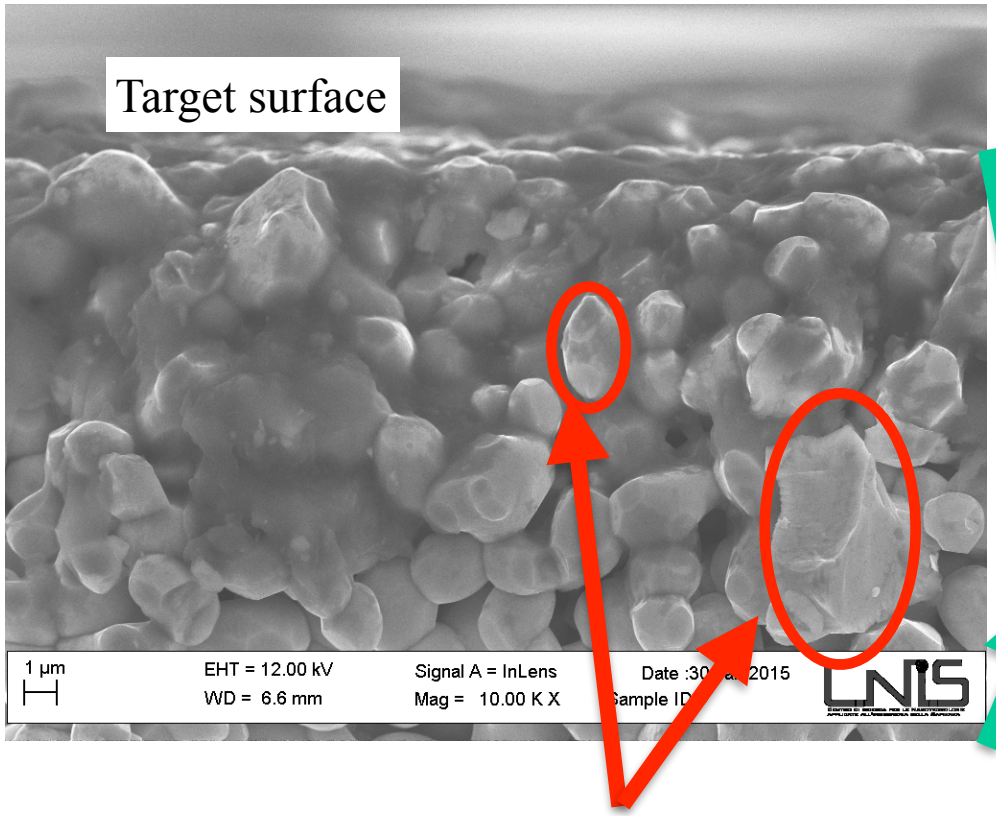
5 mm target

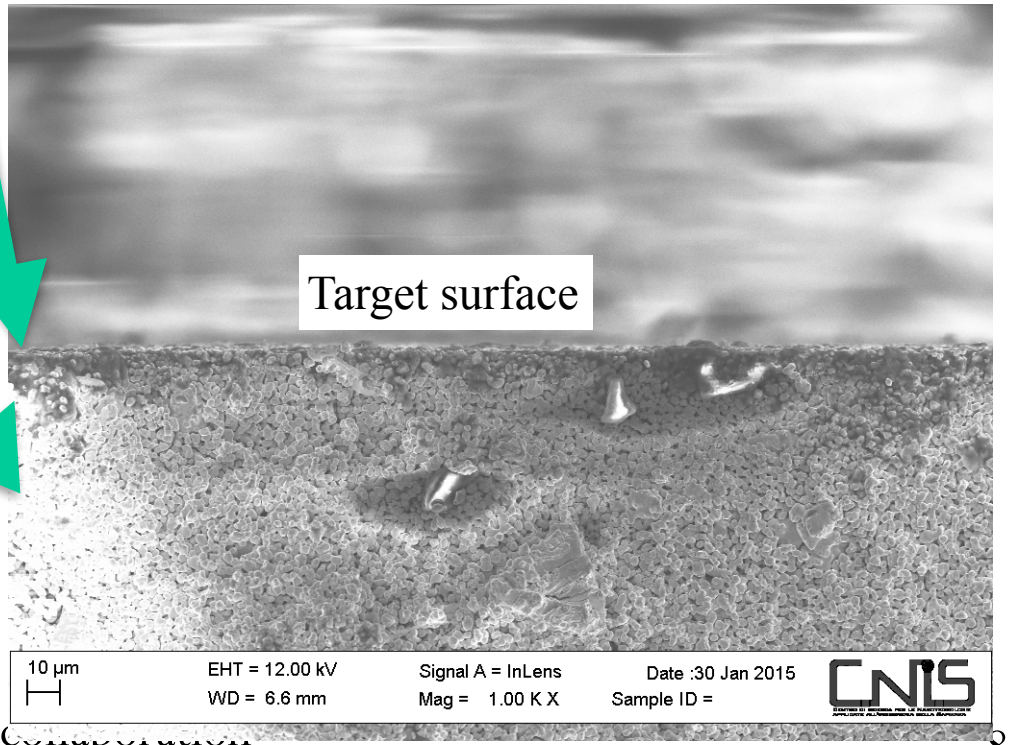
The 5mm target

- CNIS Lab (Sapienza - Roma) results obtained on the 5mm sample
- Visual inspection revealed a graphite coating of a NON graphite material

Images reveals that grains of $CrLaO_3$ are covered with graphite on the surface, while C impurities at ~100μm from the surface are almost negligible (<1%)…. Analysis in following slides.



$CrLaO_3$ grains



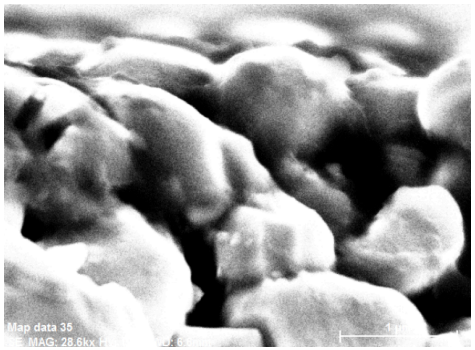
Surface analysis

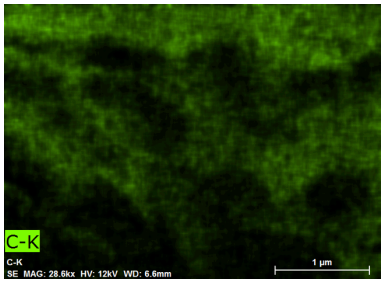
- Analysis of the surface
  - Selected a sample (few μm wide): this is a "punctual" analysis… really dependent on the exact point under analysis
  - Spectral analysis performed on the sample revealed a graphite coating of $CrLaO_3$ grains (see pictures on right)

Spectrum: grafite_ 1

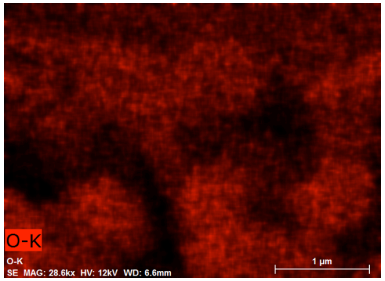
Element	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (2 Sigma) [wt.%]
Oxygen	8	K-series	24.33	26.56	41.64	6.01
Carbon	6	K-series	18.86	20.59	42.99	4.83
Chromium	24	K-series	15.46	16.87	8.14	1.10
Lanthanum	57	L-series	31.42	34.30	6.19	2.08
Calcium	20	K-series	1.53	1.67	1.05	0.17
		Total:	91.60	100.00	100.00	

Surface Sample

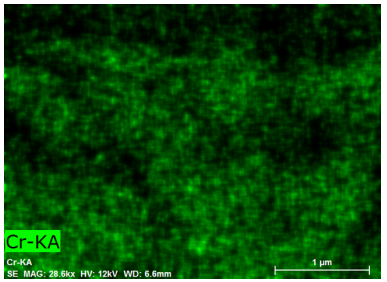




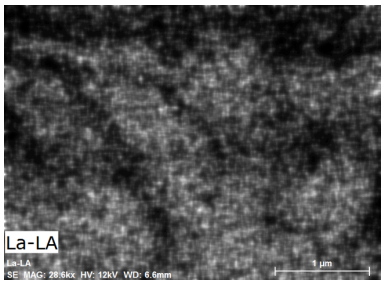
Graphite



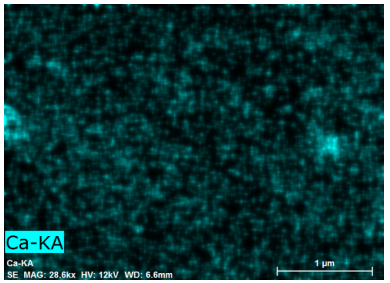
Oxygen



Cr



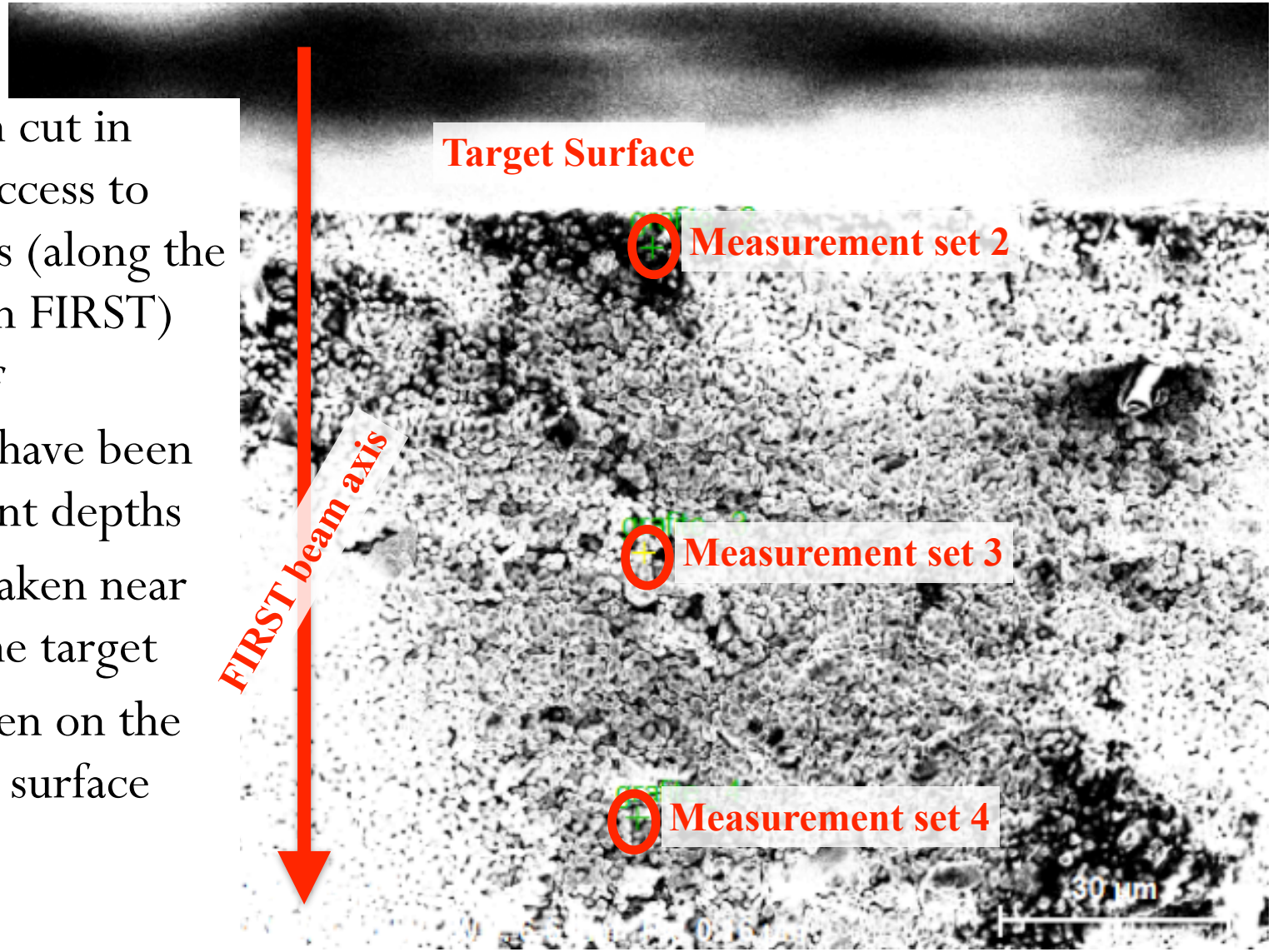
La



Ca

Measurements

- Target has been cut in order to have access to different depths (along the z / beam axis in FIRST)
- Different set of measurements have been taken at different depths
- Sets 6,7 were taken near the center of the target
- Sample 8 is taken on the opposite target surface



Results

- Sample 8 contains also a non negligible contamination with Aluminum (20%), not shown in the table.. Flagged as **local tgt surface impurity**
- Shows the concentration of atoms

Fluctuations of the size shown in the table among samples 3,4,6,7 are expected due to the nature of the measurement (local!)

	C	Cr	La	O	Ca
Sample 2	54,3	5,5	4,4	34,6	1,1
Sample 3	5,6	36,3	21,7	32,7	3,7
Sample 4	4,7	42,7	24,6	25,1	3
Sample 6	4,5	35,1	22,1	35,8	2,4
Sample 7	0	57,7	27,8	11,3	3,2
Sample 8	45,5	18,4	9	5,7	1,4

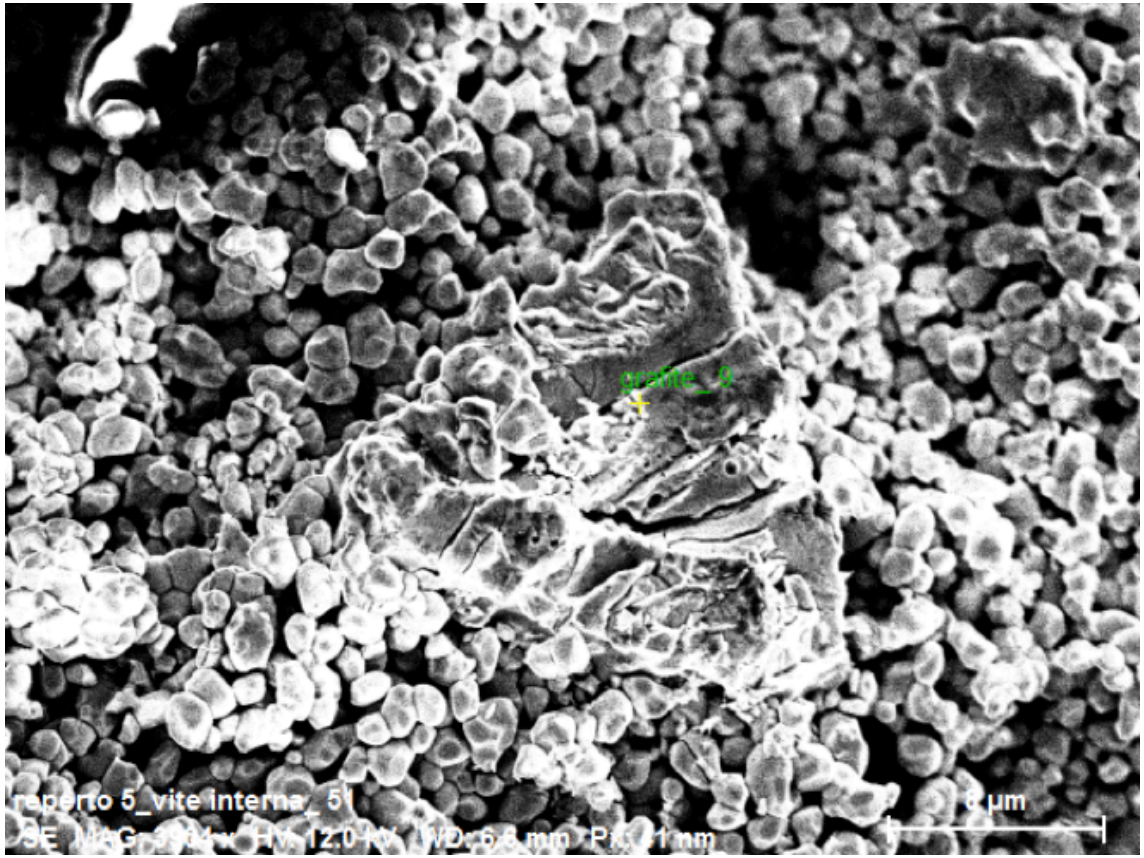
Close to surface

@ target center

Close to other surface

Non granular structures

- Analysis was also performed on non granular structures: $CrLaO_3$ hypothesis confirmed
- It seems that the $CrLaO_3$ has been smashed in little grains, but few larger pieces are still present



Spectrum: grafite_ 9

Element	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (2 Sigma) [wt.%]
Oxygen	8	K-series	26.65	28.76	63.72	6.74
Chromium	24	K-series	20.95	22.61	15.42	1.50
Lanthanum	57	L-series	40.77	43.99	11.23	2.71
Carbon	6	K-series	2.48	2.68	7.91	1.05
Calcium	20	K-series	1.81	1.95	1.73	0.20
		Total:	92.66	100.00	100.00	

Current analysis status

To understand the target…

- … we can try to use the beam itself!
- What can we expect about the beam spread? Before we assumed that the TGT was made out of Hyper dense graphite.
  - x: 0.8 cm ; X_0 C: 42.70 g/cm^2 18.8 cm ➞ Hyperdense C ~11 cm.
  - $\sqrt{x/X_0}$ C = 0.27
  - β,cp,z = 0.7, 12 GeV, 6

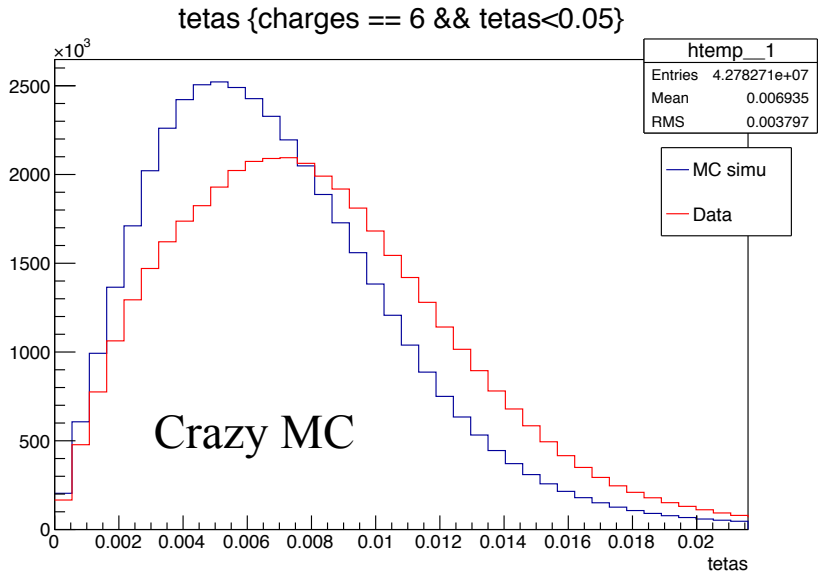
$$\theta_0 = \frac{13.6\ \text{MeV}}{\beta cp}\, z\, \sqrt{x/X_0}\left[1 + 0.038 \ln(x/X_0)\right]$$

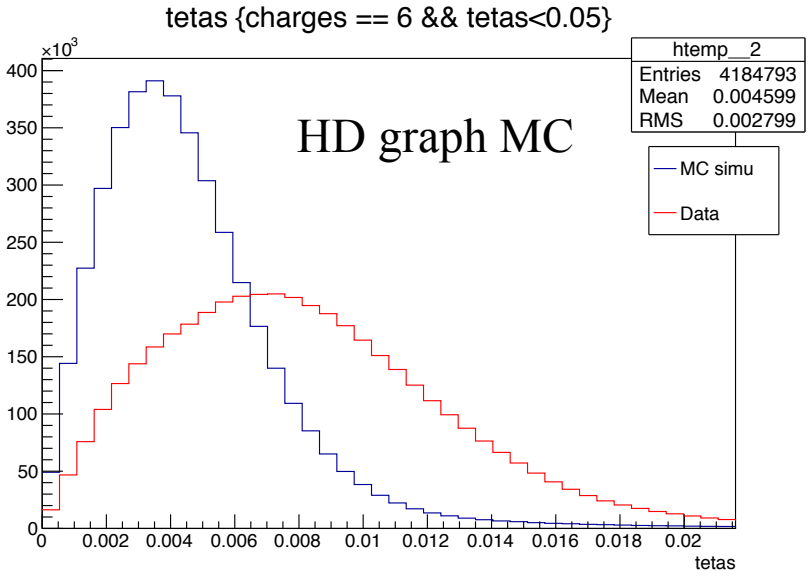
- Expected Beam Spread:
  - Carbon = 2.6 mrad

- At some point we will need also to recompute everything for the *Crazy TGT* as well. For now we trust the MC results for this….

Simulation

- Checking MS against simulation:
  - The MC sample behaves as expected and is NOT able to reproduce the data! [now we know why]





  - The "crazy" MC sample behaves shows a better agreement but is NOT able to reproduce the data!

Hint that the target composition from Torino scan is not yet correct? It seems that we need to add more "heavy" stuff to our sample to "enrlarge" the MS….

To publish the "crazy" data

- TGT composition has to be understood BEYOND the atomic relative abundance. We need to understand HOW we can have so much C and O mixed with CrLaO3 inside a solid tgt!
- We need to evaluate carefully the impact of publishing the data without any MC **OR** we need to evaluate the impact of trying to convince Fluka to allow us to publish:
  - From Fluka license [http://www.fluka.org/fluka.php?id=license&mm2=3]: "Publication of any results of comparisons of specific internal physics models extracted from FLUKA with permission under section 6 with data or with other codes or models is subject to prior written permission."
  - http://www.fluka.org/fluka.php?id=FLUKASingle-UserLicenseAgreementFAQ&mm2=3 specifies explicitly **what is not allowed**:
    - Comparison of FLUKA results with particle production data from thin target experiments
    - Comparison of FLUKA results with data on ion beam fragmentation in thin or thick targets
- From the analysis point of view
  - MC has to be checked, Eloss correction has to be re-tuned.
  - Unfolding has to be redone with new MC as well as the efficiency calculation