The BTF "papers"

A GEM-based Optically Readout Time Projection Chamber for charged particle tracking

R. Baracchini¹, G. Caroto^{2,3}, E. Di Marce³, M. Marafini^{3,4} G. Mazzitelli⁵, D. Finci³, F. Renga³ and S. Tomassini⁵

Abstract—The Time Projection Chamber (IPC) is an ideal condition to truck particles in a wide range of energies. IPCs of large volumes can be readest with a suitable number of chamber of the rectangular property of the particle structure, the retreased energy attenting the particle intensitients in Moneyce, the reteased revery attenting the parties intentionate. Moreover, No. based TPC are very promising to sonly for merge lens, opening the problettir for directional search of Purk Matter (EM) and study of Solar Notations (SN) on the other hand, in soler to reach a let' onergy therebold a large number of channels is required to obtain a high granularity, that could be exposeive and hort to source.

and hard to manage.
A small prescype (named LEVORs) to test and validate. A small prototype (annot LANOUS to see a sun valuation the resolvant technique bound an Misso Patiens Gas Detector (MFGD) amplification of the ionization and on the visible liggs ediscition with a sub-sufficator position modellors or SMOS (edistrible CMOS) onesers is described here. This type of tradeut is conjunction with a last light describes a fallow a 3D recommendation of the tractor, a sensitivity to the mark electrical and a new parameter solution and the confirmation of the contributions. and a cry premaing parties identification againstly useful to distinguish DV marina receils from a principal background.

Index Natur-MPGD, GEM, Dark Matter, Optical Residual

I. INTRODUCTOR

TEE use of large Time Projection Chamber CPO in High Peorgy Physics (HEP) have various application and fintuse. Although with very small efficiency, those detectors offer among the best energy resolution and particle identification capability (PD), as well as a very good tracking and spacial scitation. This is pushing an international community, called CTGNUS, to study the application of such technology to the search of directional Dule Metter (DM) and the detection of neutrinos owning form the Sun (SN).

In Early the National Institute for Nuclear Physics (INPN) is promoting the Phase-O for the construction at 1 m² demonstrator based on Micro Gu: Pattern Detector (MCPD), namely a triple large Cas Electron Multiplier (GEV), optically send by means of a rCMCS low retise and high primularity sensor.

During the Paused many protrypes, based on triple GPM. optical readout, have been tacted showing promising results to occur the Phase-I that will start in 2000 with the occstruction of the 1 m³ demonstrator to be hosted in the National Laboratory at Gran Sason (LNGS). A Phone 2 is

- Stan Sarar-Science Bestinis L'Appile, 1-97104, Baly
- Dipartimento di Pisica Sepisatro l'Astronità di Roma, 1-00114, Italy Indicate Musicando di Fisica Nucleure Sepisate di Roma, 1-00115, Enly
- Name Street arts From a Castro State & Souther Franco Servi-cas not Venimb 1, South 1903th, July 1995. Laborate Maciental & Brownii, Processi (ISE, Indy-concept. Laborate Maciental & Brownii, Processi (ISE, Indy-concept. Laborate at 110 ft.er., 1979). 17

pressure (He based) equipped with high ganularity and sensiirity MCPD optilal real wat

- MGPO ontical resident can relay chapping the noradience
- optical sensors offer higher granularity with respect to
- electron sensitive devices: optical coupling allows to keep sensor out of the sensitive volume reducing the interference with high voltage
- operation and lowering the gas contamination; the use of suitable less allow to acquire large surfaces with small sersors:

Moreover, in last years, optical sensors had a large develop-ment and are side to provide larger granularity along with very lew make level and high sensitivity.

Recently, as part of the Phase-C, meany test has been

done with different prototype (NITEC [1], CRANGE [2], [3], [7], [5], LEMOn [6], [12], [13]) at electron beam test facility, neutron beam and with various sufforcing sources. in the following we report the results obtained with LEMOs prototype at the Prescut: Beam Test Facility.

II. LEMON PROTOTYPE DESIGN

The LEMOn prototype structure (Fig. 1) was made of ASA, Acrylonicile Styrene Acrylate, at the 3D printing Pacifity of the National Laboratory of Practacl (INFN)². This has offered the opportunity to easily design and to quickly develop detectors and also to test the 3D prixing system for the gas detector applications.

The LEMOn's heart consists of a 7 liter eative shift volume corrounded by an elliptical field cage (200x 200x 200 more) made of 1 mm Cu4Ag wires insorted in ninoteen 3D-granted rings. Ten mm for from the last field eage ring is located a LHCl-tike (E)(200-240 mm² rectangular triple GEM (70 mm diameter below with 1400 year plicit) structure (Fig. 7), with res-2 men high transfer field gaze among them. From the last Gidd National Laboratory at Gran Sasan (LNGS) a Phase F is side a 203 × 254 × 1 mm² transported window and a teaching then foresten to realize a 20-100 m² detector, as a batch of bellow allow to collect the light by using an GBCA-Flash 4.0 camera²² located at 52 cm. from the fast perm plane. The latter device is board on a CMOS sensor with a high granularity CO48 × 2048 possist, very low noise (around two photons per pixel), high sensitivity (70% of QE @ 600 mm) and linearity.

Pargote) InCode in No princing dealing half Pargoteurs become transport (SEE INT). Meet

- energy calibration
- energy resolution
- "diffusion" behaviour and Z estimator
- FC effect
- two proceeding published: 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC), 2017 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)

Introduction

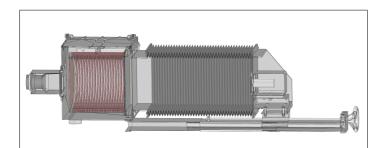


Fig. 1. LEMOn 3D printing design: left PMT holder, semi-transparent cathode, field cage rings, triple GEM stack and large transparent windows, optic bellow and ORCA Flash camera holder.

This camera is instrumented with a Schneider lens (f/0.95-25 mm) and each pixel was looking at an effective area of $125{\times}125~\mu m^2.$



Fig. 2. Triple GEM system and the 3D-printed field cage equipped with a semi-transparency cathode

On the other side, LEMOn has been equipped with a $50\times50~\text{mm}^2$ HZC Photonics XP3392 photomultiplier³ detecting light through a transparent $50\times50\times4~\text{mm}^3$ fused silica window

This system allowed to study - mainly for timing purpose the primary light scintillation in the drift volume and the secondary light produced by the first GEM layer 200 mm far away. A $\simeq 70\%$ transparent cathode has been realized using an ATLAS MicroMegas mesh, glued on the last ring of the field cage and ensuring an adequate light transmission. The box $370\times270\times280$ mm³ and 2.5 mm thick has been equipped with two $180~\mu m$ thin 200×200 mm² windows made of TEDLAR in order to guarantee the gas containment and to reduce as much as possible the multiple scattering of the impiring electrons.

3http://www.hzcphotonics.com/products/XP3392.pdf

III. DETECTOR OPERATION

Data reported in the following have been collected at the Frascati Beam Test Facility (BTF) [14] optimized to deliver electrons with an energy of 450 MeV, a typical beam spot size $\sigma_{x,y} \simeq 2$ mm, a divergence $\sigma_{x,y} \simeq 2$ mrad, and an energy spread of $\simeq 1\%$. Moreover, for some measurements the beam multiplicity has been tuned from the single particle up to hundred electrons per spill (I0 no bunch length). The beam was monitor in multiplicity and spot size by means of a front detector, namely a flipix and a calorimeter [16] accommodated in the back of LEMOn and acquired with the camera image and the TCP PMT signal.

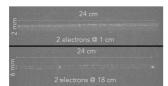


Fig. 3. Example of two tracks collected at the Frascati BTF with electrons retraversing the major axis (240 mm) of the field cage close to the GEM (up), and 180 mm far away (down).

The prototype was operated with 60:40 HeCF₄ gas mixture at atmospheric pressure and at very high gain $(>5 \times 10^5)$ in order to reach a good light production. With this mixture, a photons yield of 0.07 photons/electron has been measured [4], [9], [11]. Moreover, by means of a Garfield simulation a typical energy loss of 0.23 keV/mm for a $\simeq 400$ MeV electron and about 7 primary e $^{\prime}$ /mm are expected.

The field cage was powered by a CAEN N1570⁴, actually limiting the maximum field at 0.6 kV/cm. A drift velocity

4N1570: http://www.caen.it/csite/CaenProd.jsp?parent=21&idmod=894.

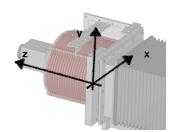
- Was aimed to fully report the designi and contraction methodology underling also that was fully realised in 3D printing
- but:
 - Davide have exploit large text and figure in Fe paper
 - We discover that the design and choices were wrong

Data

of 4.36 cm/us for a drift field of 0.6 kV/cm was evaluated lower field in order to understand the field cage performances The triple GEM system was powered with a HV GEM power supply [8] ensuring stability and accurate monitoring of the

The ORCA Camera I/O has been configured in order to get a pre-trigger, that must occur 80 μs before the shutter, and to synchronize the PMT signal waveform acquired with a oscilloscope LeCroy 610Zi. Optics and exposure time were optimized to ensure the largest light collection and to avoid events due to the natural radioactivity. Between 100 and 300 mages were typically acquired per run. Fig. 3 shows two examples of track images acquired with LEMOn.

The 450 MeV of the BTF were delivered by accelerato along the X (see Fig.4) direction whit a repetition rate of one second and the The prototype was accommodated over the notely controlled table of the BTF in order to scan Y, Z

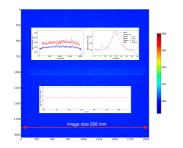


IV. TEST BEAM RESULTS

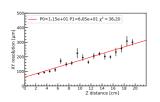
In the following the we report the most interesting results

prototype, the most probable track has been identified in any image by means of a Hough transform [17]. Each track appropriately rotated, is sub-divided in 36 segments of 48 pixels each, a sub sample of 18tn segment around the center is then selected in order to avoid field distortion and inefficiency [18]. In each segment the light profile transverse to the track direction is fitted with a Gaussian and the mean value is used to identify the segment position and uncertainty, as shown in Fig. 5.

In Fig. 5 (bottom) examples of longitudinal and transverse light profiles are shown



Then, a linear fit of the traversal light main position along each segment is performed and the residual distribution is used to evaluate the detector X, Y resolution, providing an ir esolution in both plane of about 60 μ m.

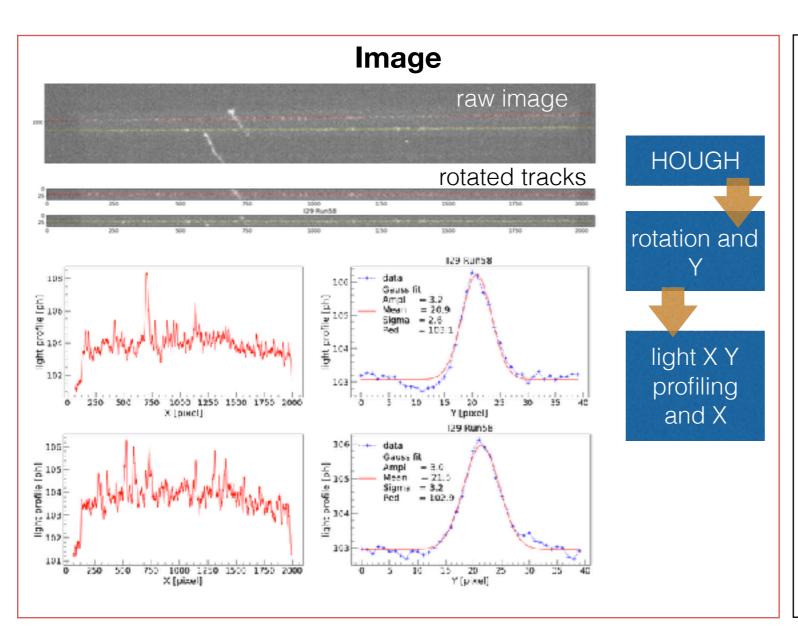


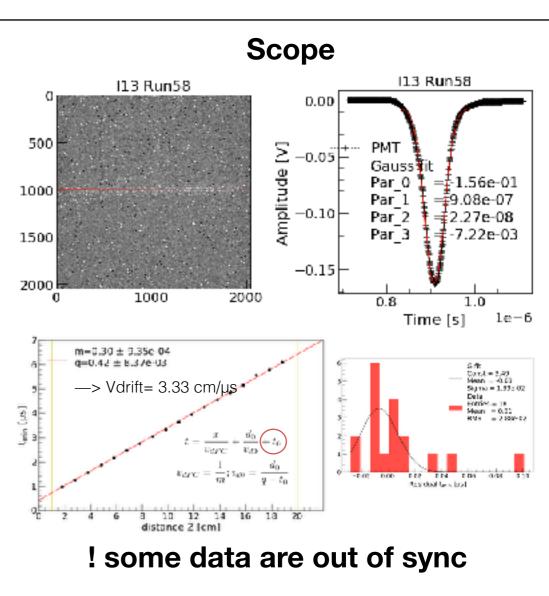
The degraded resolution of 10µm/cm (Fig. 6) is strongly determined by the drift field and is limited in LEMOn by High Voltage connectors and the power supply. The new proof Frascati will be able to provide 1 kV/cm over 50 cm of drift length. LIME will be also equipped with a 33×33 cm In order to evaluate the tracking performance of LEMOn GEM amplification stage constituting one of the 18 modules

is well in agreement with the expected value obtained with Garfield simulation from where is also expected a better behaviour ad higher drift field up to 2kV/cm. The intercept at zero of 400µm is typical for a triple GEM stack and their intrinsic misalignment of the hall

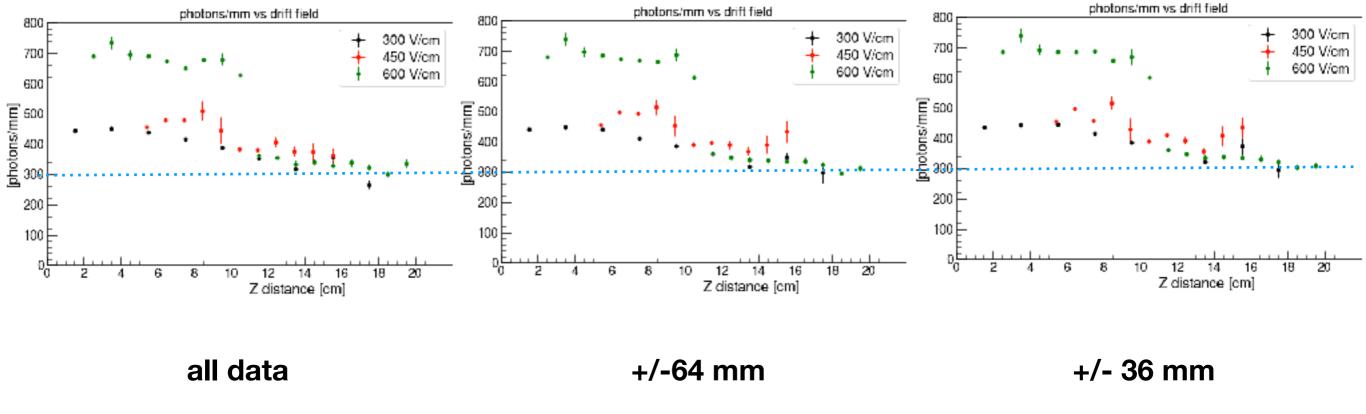
- We have 3 set of runs (0.6kV/cm, 0.45kV/cm, 0.3kVcm), almost any of that is affected by some issue that compromise the comparison
- each sets of runs consist run at different position (Z and Y)
 - in general there is a lack of statistic, 20-30 "nice" events per run -> it's difficult to assign a reasonable error
 - we discover that old 10 cm around the center have a good field
 - the field between GEM and first FC ring is often unknown
 - The runs at 0.6kV/cm have a strange behaviour not understood

Methodology

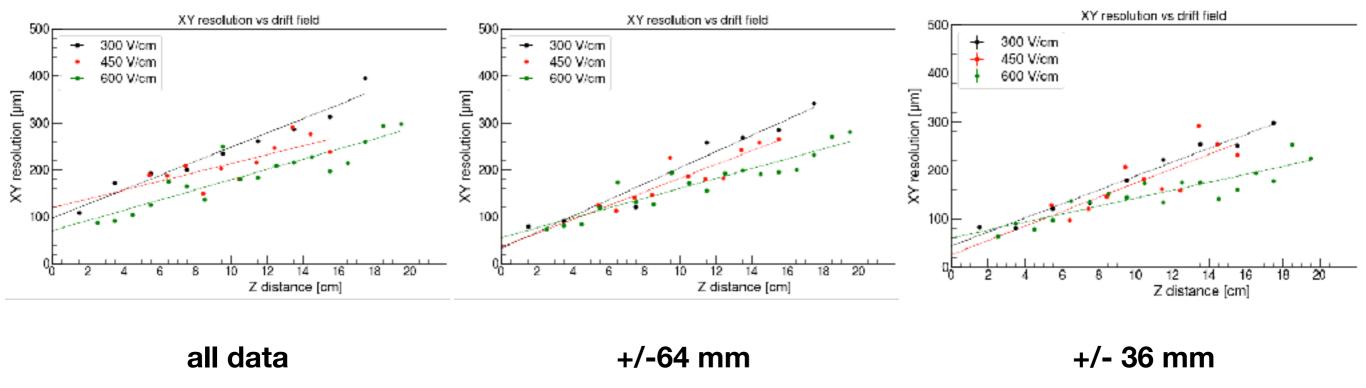




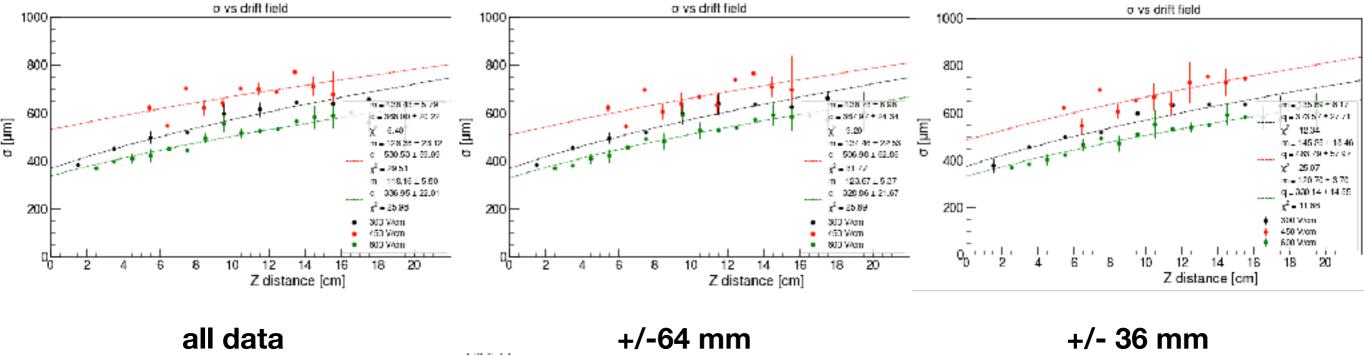
Luminosity: all data vs center FC data

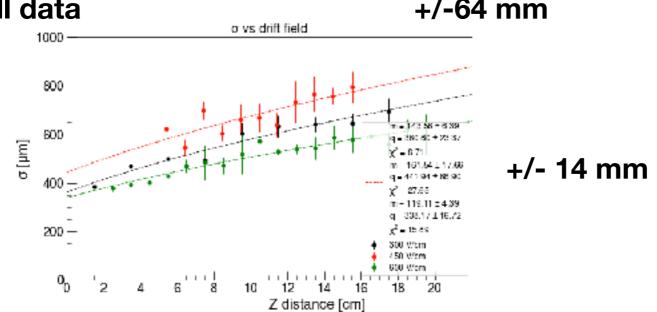


Resolution: all data vs center FC data



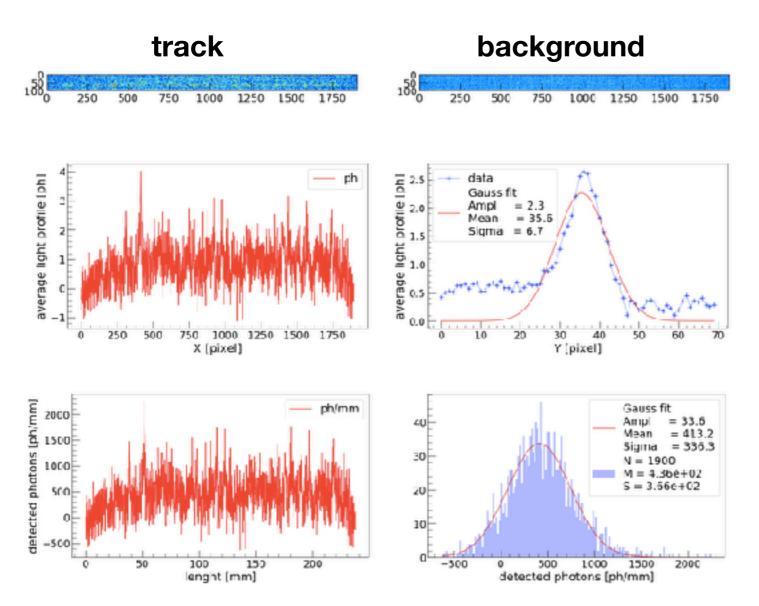
Diffusion: all data vs center FC data





G. Mazzitelli, CYGNO Weekly Internal Report

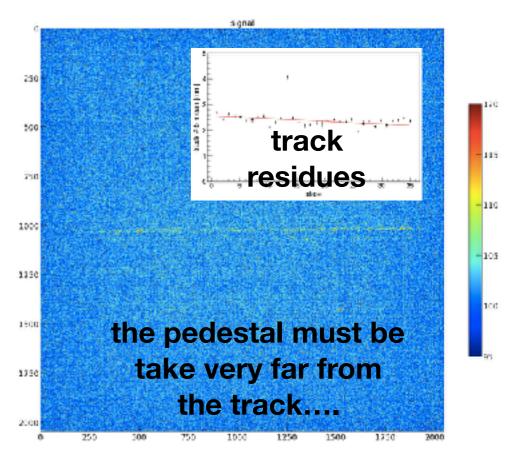
example: 450e- RUN87-5, 2/455V/0.6kV/0.01s



Pedestal mean: 101.78, sigma: 1.03, over th. (12 Sigma mean: 2.67, sigma: 2.13, over th. (50) 12

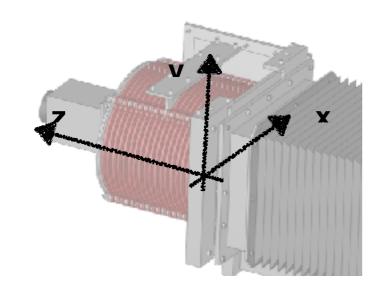
Th mean = 104.34, sigma = 2.15

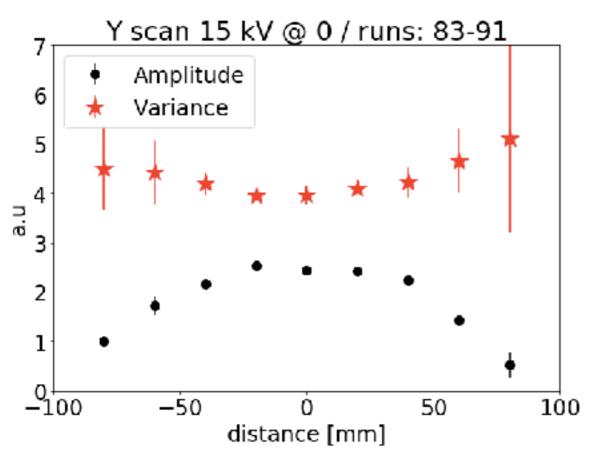
Signal: 127185

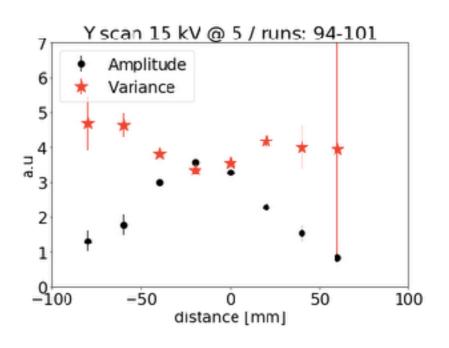


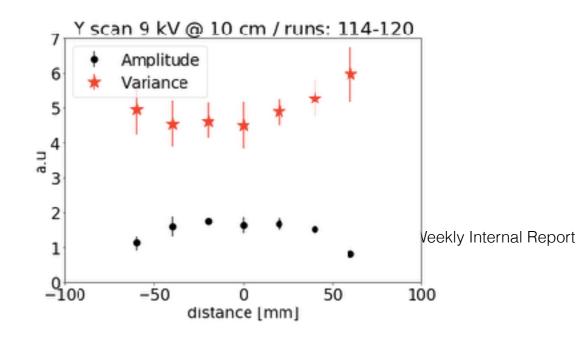
G. Mazzitelli, CYGNO Weekly Internal Report

450 e- @ BTF FC goodness



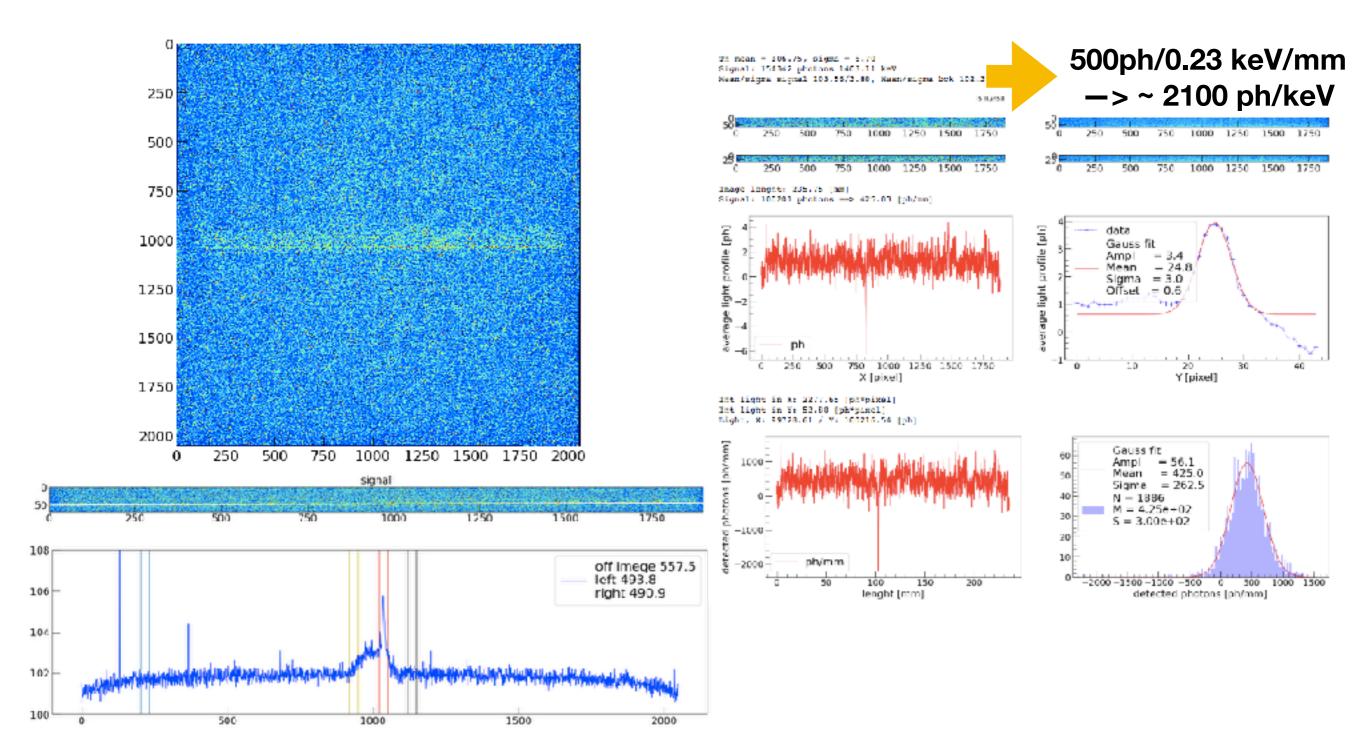




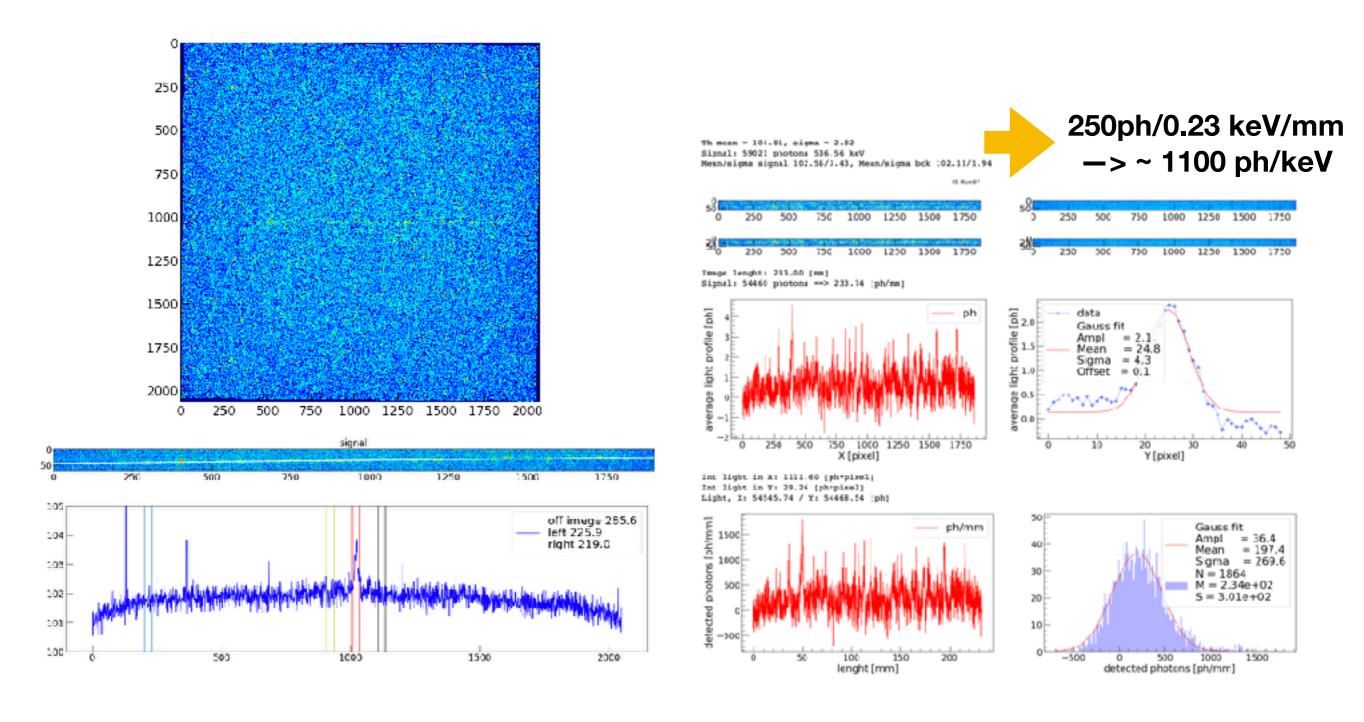


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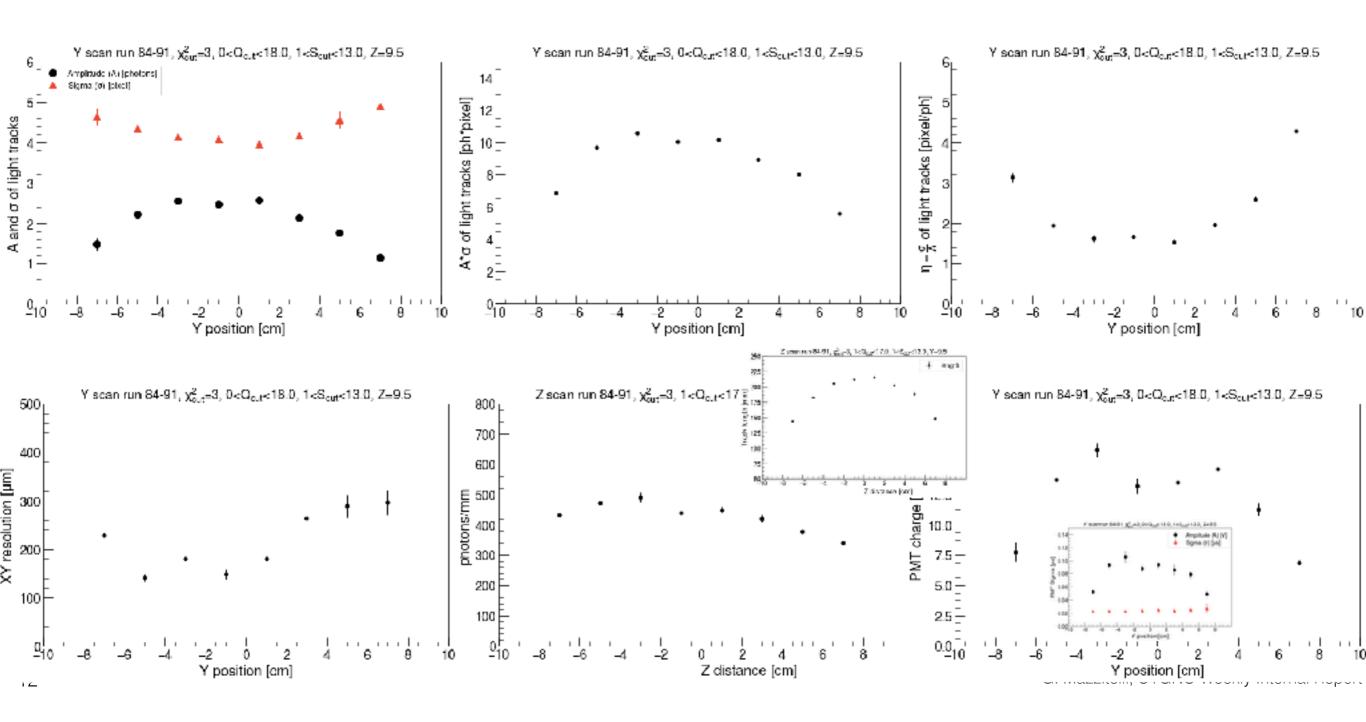
Photons reviewed



Photons reviewed



Y scan detail at Z=10 (center)



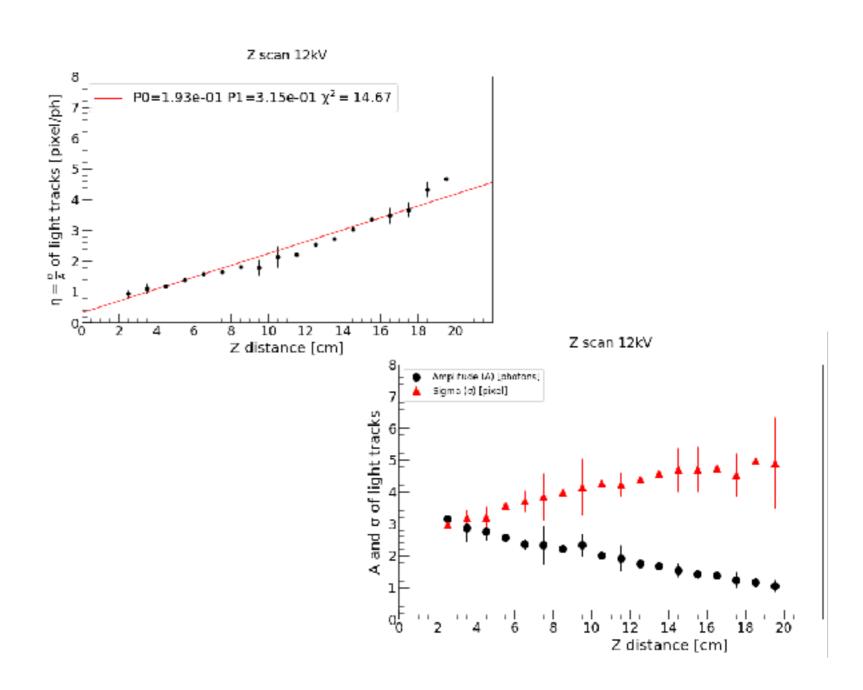
Physic Model

3. Physics model

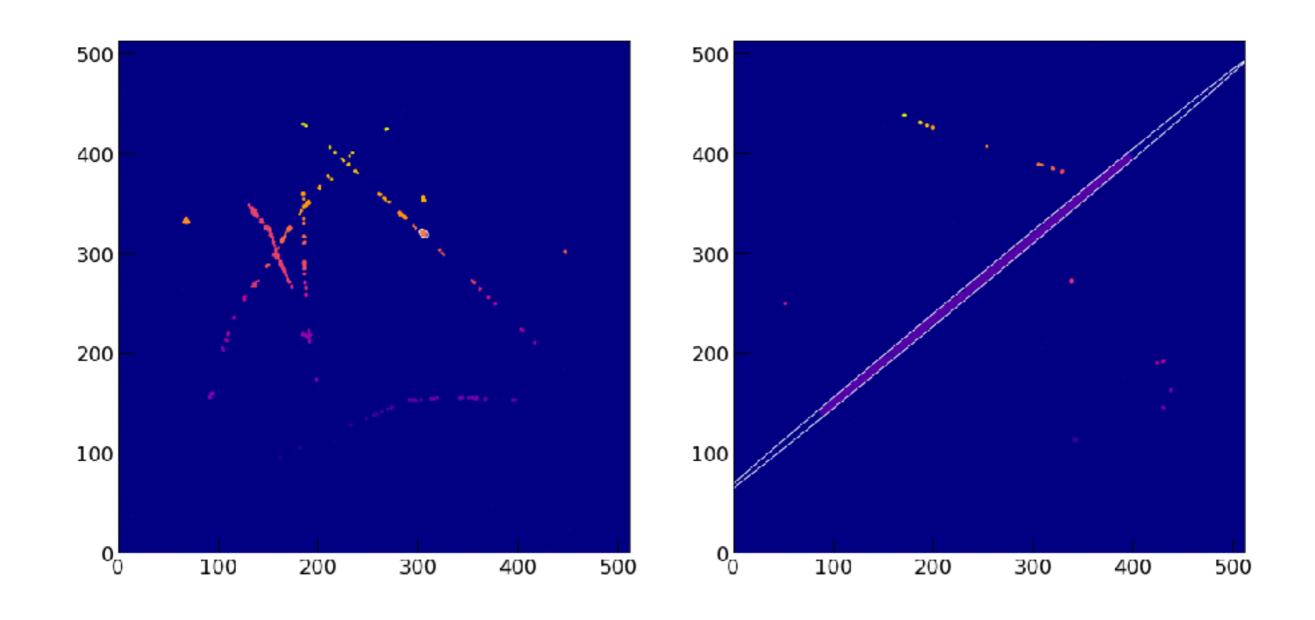
We use a simplified model of charge cloud dynamics to derive the expected variation of track topology with z. Specifically, we consider a line of ionization charge with an initial delta-function charge cross-section. The constituent charges diffuse in space in a 3-D random walk over time, giving a charge profile which is Gaussian in cross-section with a constant integral and a width that is proportional to the square root of time, $\sigma_z(t) \propto \sqrt{t}$. In the presence of a linear potential, the charge line drifts to the detector plane at a constant velocity, implying that the width of the charge distribution is also proportional to the square root of absolute z, or $\sigma_z(z) = B\sqrt{z}$. There is a fixed z-independent width A associated with the resolution of the readout plane, leading to an expected relationship between the width of the charge distribution and absolute z given by the quadrature sum of both terms [5]:

$$\sigma(z) = \sqrt{A^2 + B^2 z}.$$
 (2)

Our model does not include two minor effects: first, reabsorption of drift electrons with gas impurities such as oxygen, which results in a linear decrease in the total charge of the track over drift distance. Second, based on the track position along the Bragg curve, we expect small changes in the initial ionization density along the track (dE/dx), a z-independent effect. We confirm that neither effect impacts our measurement of absolute z

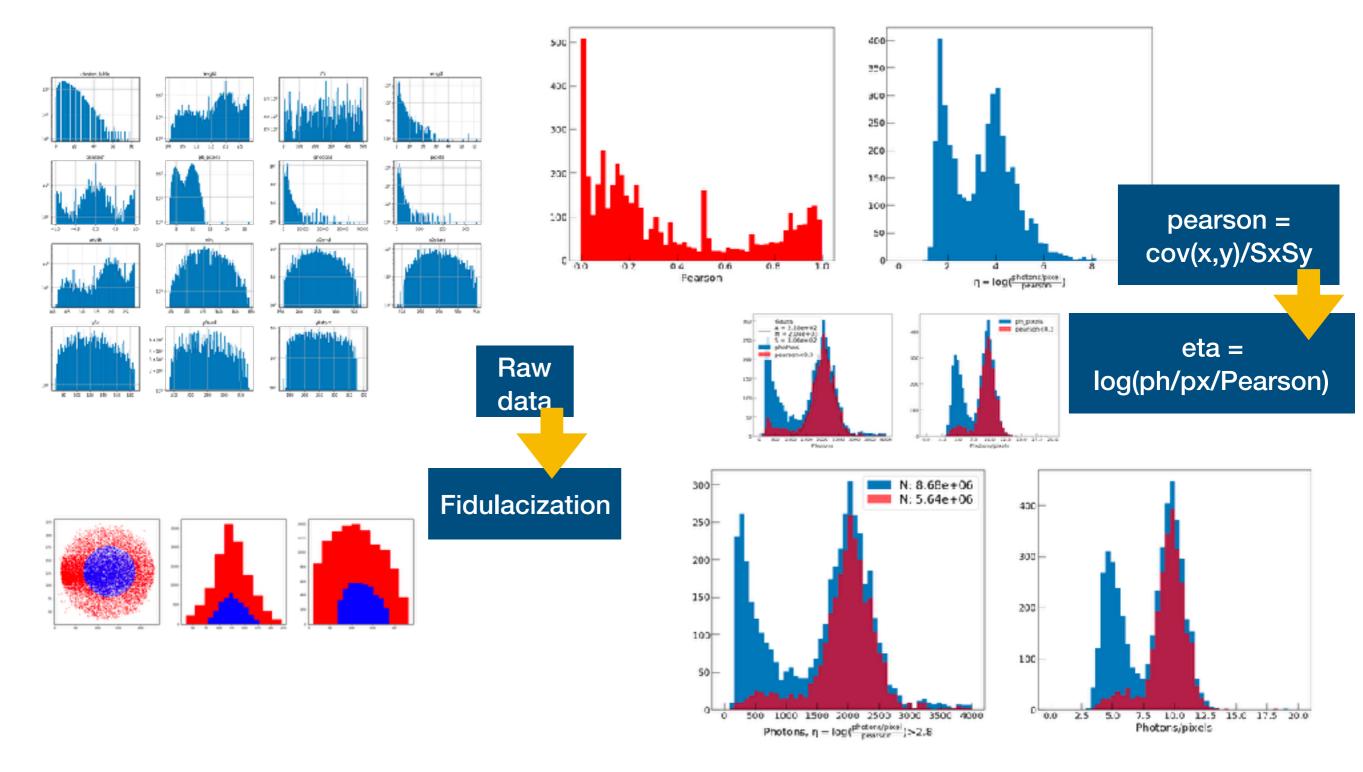


fast and dirty output

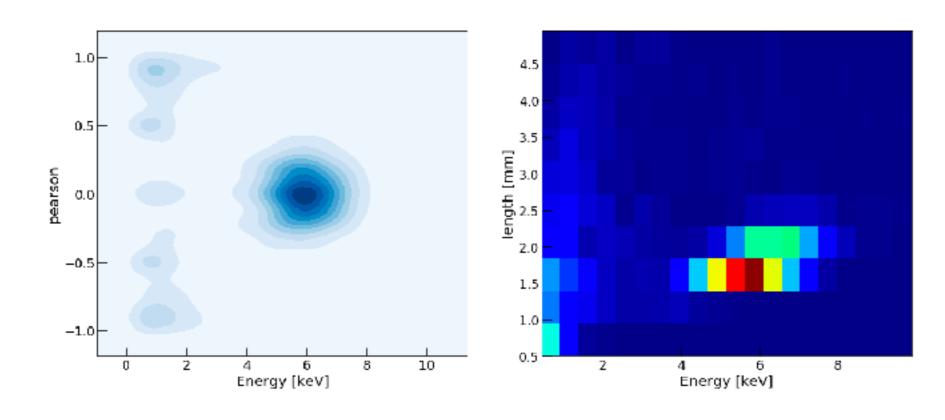


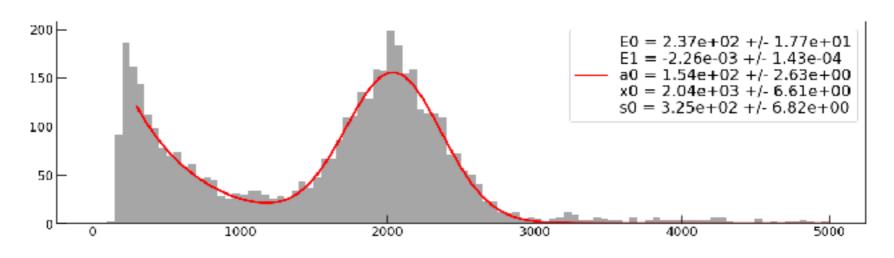
Fe

fast and dirty output



fast and dirty output

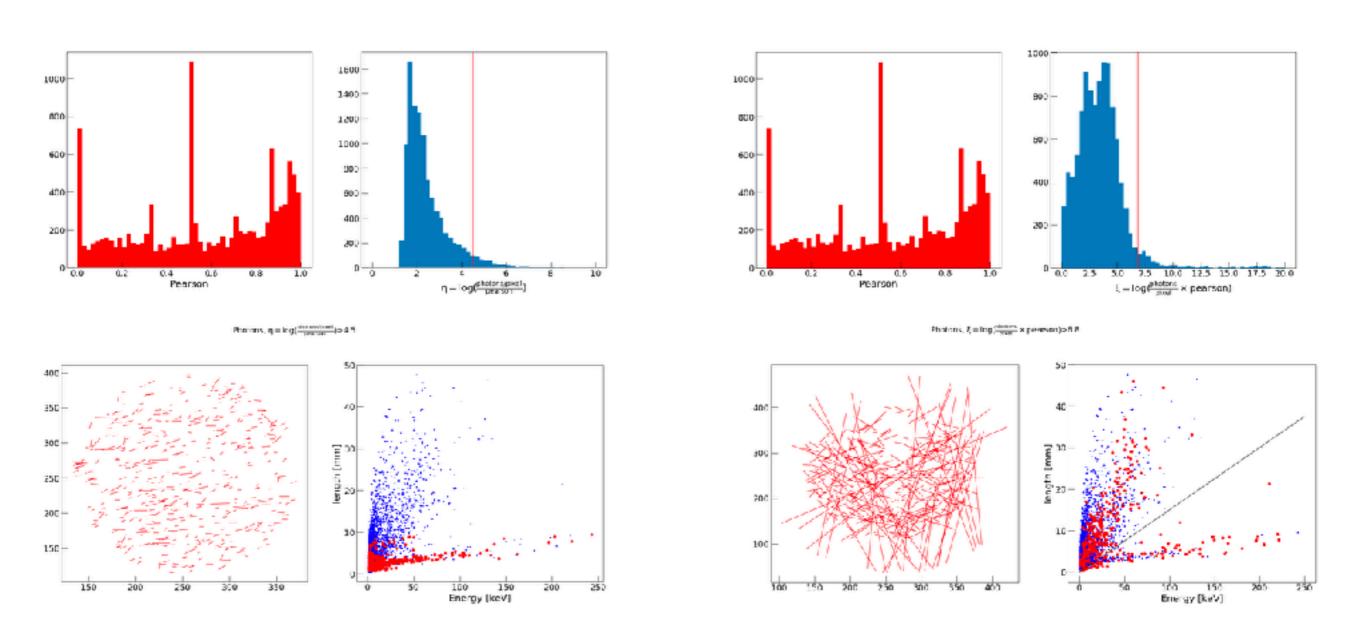




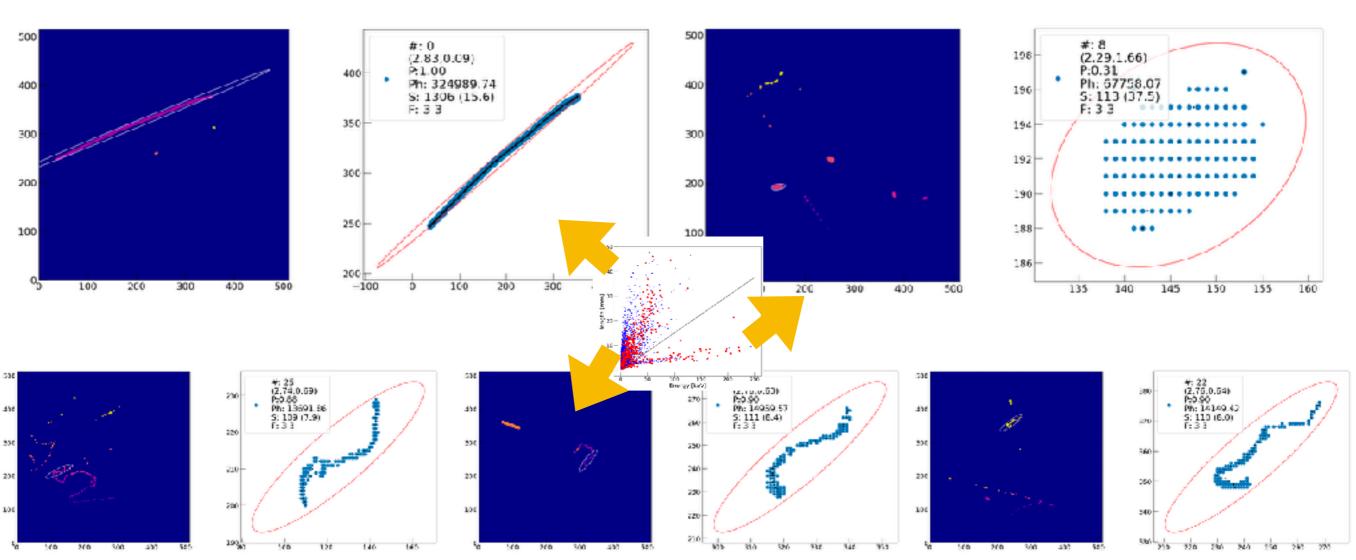
350 ph/keV

AmBe

fast and dirty output

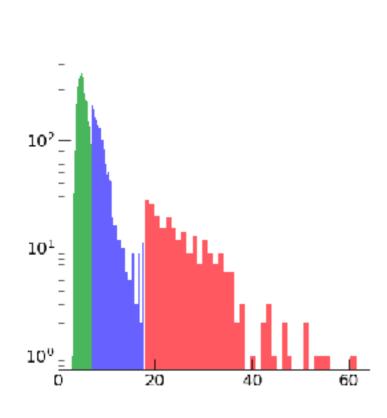


fast and dirty output

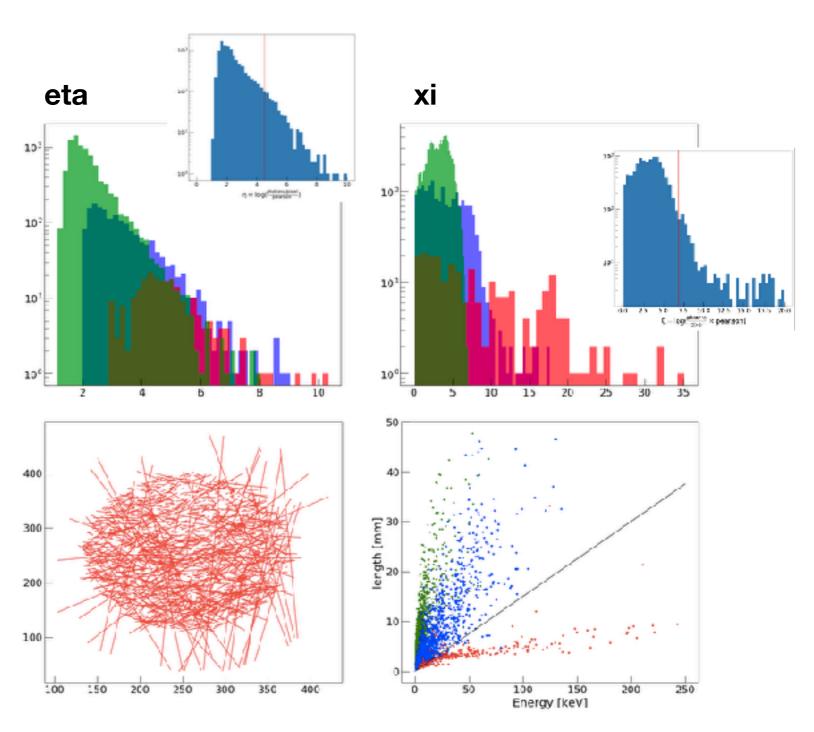


10-20% contamination some and look not 100% efficien

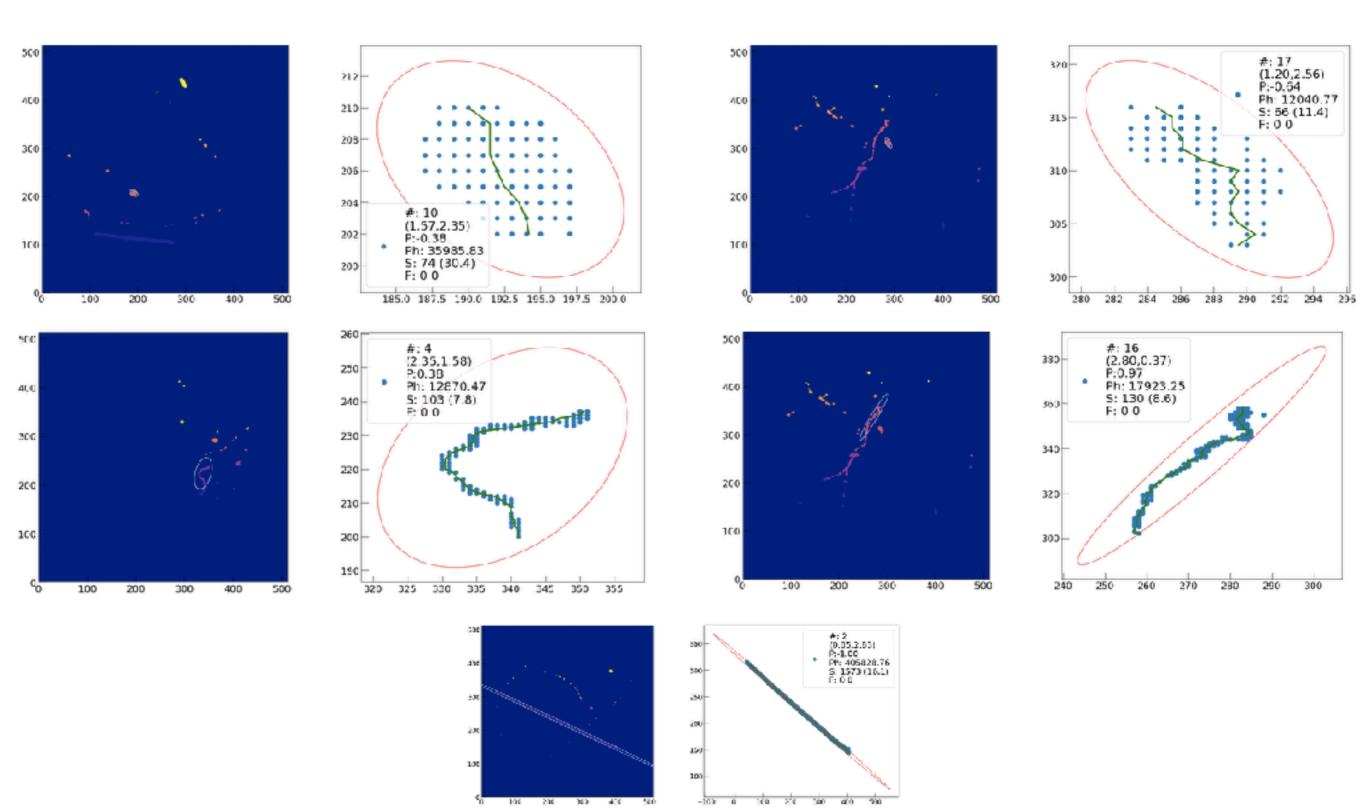
Clustering KMeans (ph/px & pearson)



selection: 2100!
All but to many auto low energy
Look very efficient



working around length



Safety & host @ LNF

DOCUMENTO DI VALUTAZIONE DEI RISCHI PER L'ESPERIMENTO CYGNO @ LNF Versione 0.1 del 9 Dicembre 2019

Scopo e Descrizione Tecnica dell'esperimente CYGNO

Nell'ambito del progetto CYGNO è prevista l'istallazione di un apparato sperimentale (rivelatore gas basato sulla tecrica della Time Projection Chamber) all'interno dei laboratori sotterranei dei Laboratori Nazionali del Gran Sasso, situati alla progressiva 3,6 km del fornice di sinistra del tunnel autostradale del Gran Sasso.

Il rivelatose è costituito da un recipiente di un metro cubo contenente una miscela di HeCF4 (60:40) a pressione atmosferica contorrato da un campo ciettrico generato da un alimentatore di alta tenzione in grado fornire un voltaggio di 50 kV (350W). Il contenitore, realizzato in PMMA, sarà alimentato attraverso un opportuno sistema di flussaggio, purificazione, ricircolo e recupero dal quale non e' prevista alcuna perdita. Il segnale generato dall'amplificazione tramite Gas Electron Multipliers della carica rilasciata dal passaggio delle particelle nel gas, sarà letto attraverso telecamere collegate al sistema di acquisizione di front-end insieme a tutti i canali ausiliari per il monitoraggio e il settaggio dei parametri di operazione. Il rivelatore sarà collegato con una sala di controllo ai laboratori esterni dei LNGS sito ad Assergi (AQ) e/o attraverso controllo remoto, con un collegamento in fibra ottica dedicato.

L'apparato sperimentale sarà schemnato dalla radioartività ambientale residua nella galleria attraverso opportani strati di materiale inerte (acqua, rame, pivmbo) opportanamente sostenuto e progettato a regola d'arte e nel rispetto delle normative antisismiche.

Il rivelatore finale CYGNO e' in fase di propettazione e sara' costruito tra il 2020 e il 2021 presso i Laboratori Nazionali di Frascati. Attualmente sono in costruzione test alcuni prototipi ORAGE (HeCF4, 1 cm drift, 1kV HV max), MANGO (HeCF4, SF5, 5 cm drift, 8kV HV max), LEMON (HeCF4, 20 cm drift, 15kV HV max), LIME (HeCF4, 50 cm drift, 50kV HV max). Il lavoro di R&D viene svolto presso tre sedi: Ed28, Ed 27 ed Ed48 per calibrazione con sorgenti radioattive (https://www.lnf.infn.it/lrfadmin/travel/mappa_lnf.pdf).

Il detector e i suoi sottosistemi sono descritti nel documento (All. 1)

https://drive.google.com/open?id=1eG2:44Th0Yu5deZZ4V5TDvyQXYLRdoD ed e' stat
assegnata alla ditta NIER ingegneria la Valutazione Preliminare dei Rischi (PRA) presso i

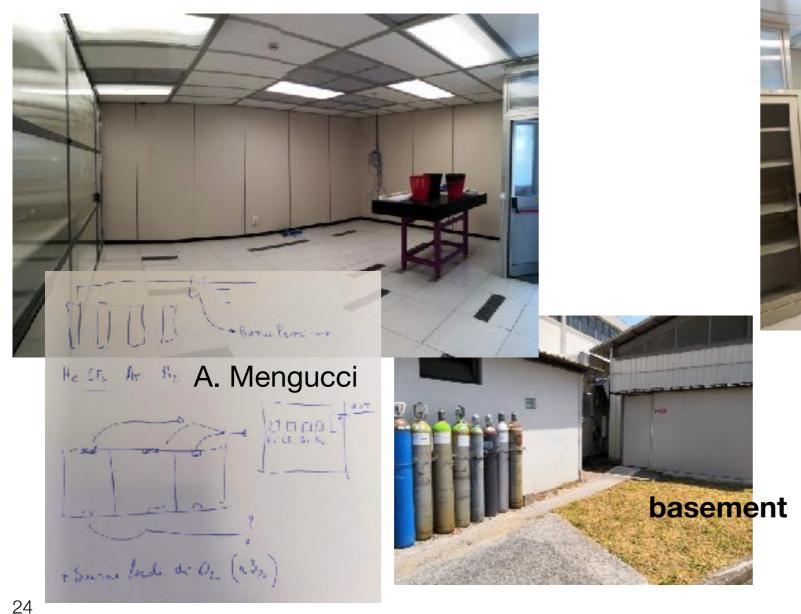
LNGS. La documentazione di gara, capitolato tecnico ecc. e' raccolta al link: (All. 2)

https://drive.google.com/open?id=1eiJ=4xnFFuIZYZaeY2SseY72hIN4a0Bq Inoltre numerosi

articoli e note tecniche sono disponibili sul sito dell'esperimento: https://web.infn.it/cygrus/.

- Content: activities and procedure
- Description of workplaces and duty
- Responsibility (organigramma)
 - —> Document of Risk Evaluation on witch are based the personal safety and radio protection risk and training
- Open issues: the LNF are using a new safety and radioprotection on line form that do not describe correctly the hosted user in the case of CYGNO —> we probably have to go back to paper...

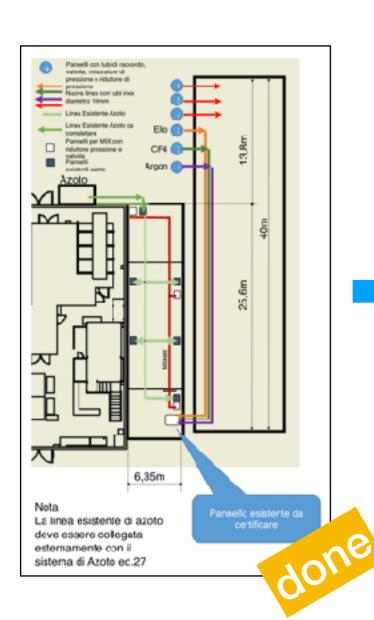
LNF infrastructure





G. Mazzitelli for CYGNO/INITIUM Collaboration

Procurement



Work will start at the begging of 2020





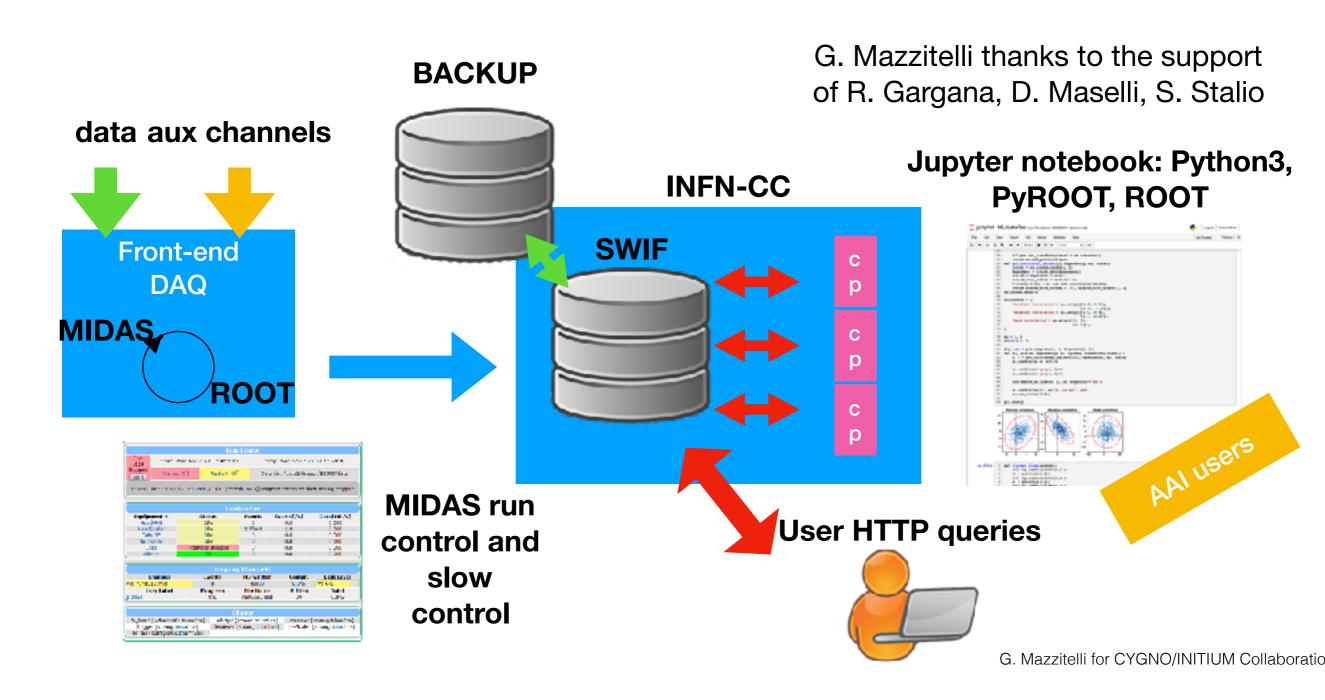
Ready to go

On going soon

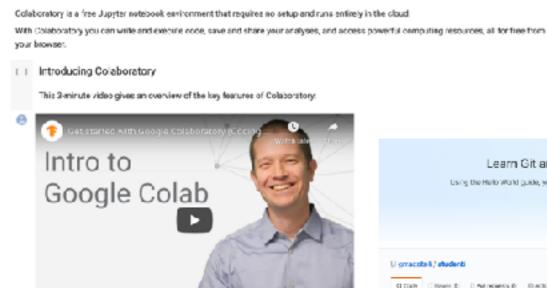
- ICARUS is going to finish the CRT for the beginning of 2020
- UTA refurbishing or substitution (Jan-Mar)
- Gas distribution system installation

Computing/DAQ-SC-DQM/network

INFN-CC @ LNGS-LNF

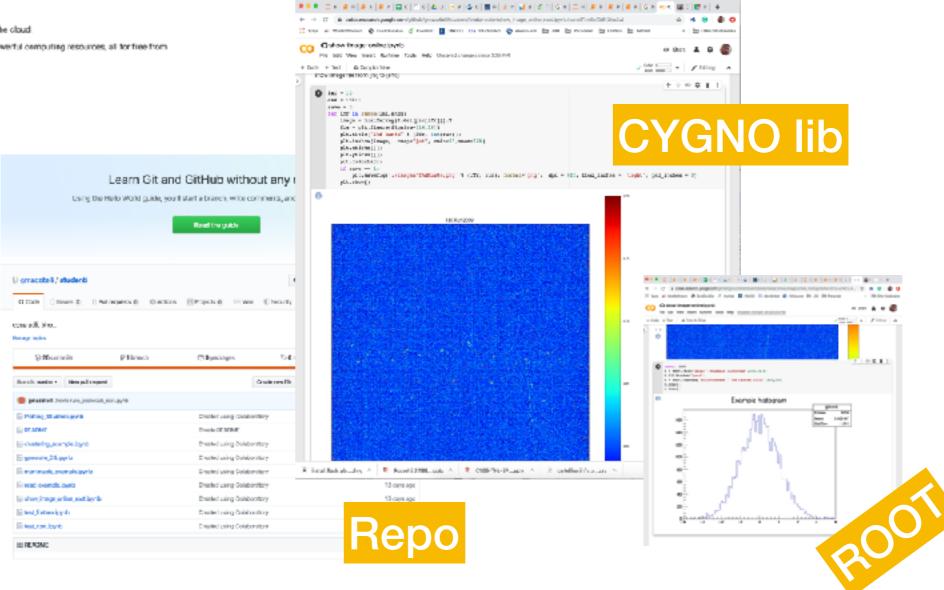


Backup



Welcome to Colaboratory!

Coding TensorFlow



LNGS computing meeting

Sandra Parlati Responsabile del servizio calcolo LNGS sandra parlati@Incs.infn.it

> p.c.: Stefano Stalio stefano.stalio@lncs.infn.it

p.c.: Dott.sa Elisabetta Baracchini Responsabile ERC INITIUM elisabetta baracchini@gssi.it

> p.c.: Dott. Davide Pinci Responsabile CYGNO davide.pinci@roms1.infn.it

Frascati, 13 Novembre 2019

OGGETTO: richiesta servizi di calcolo LNGS per il dimostratore CYGNO, ERC INITIUM e il PRIN Zero Radioactivity in Future Experiments

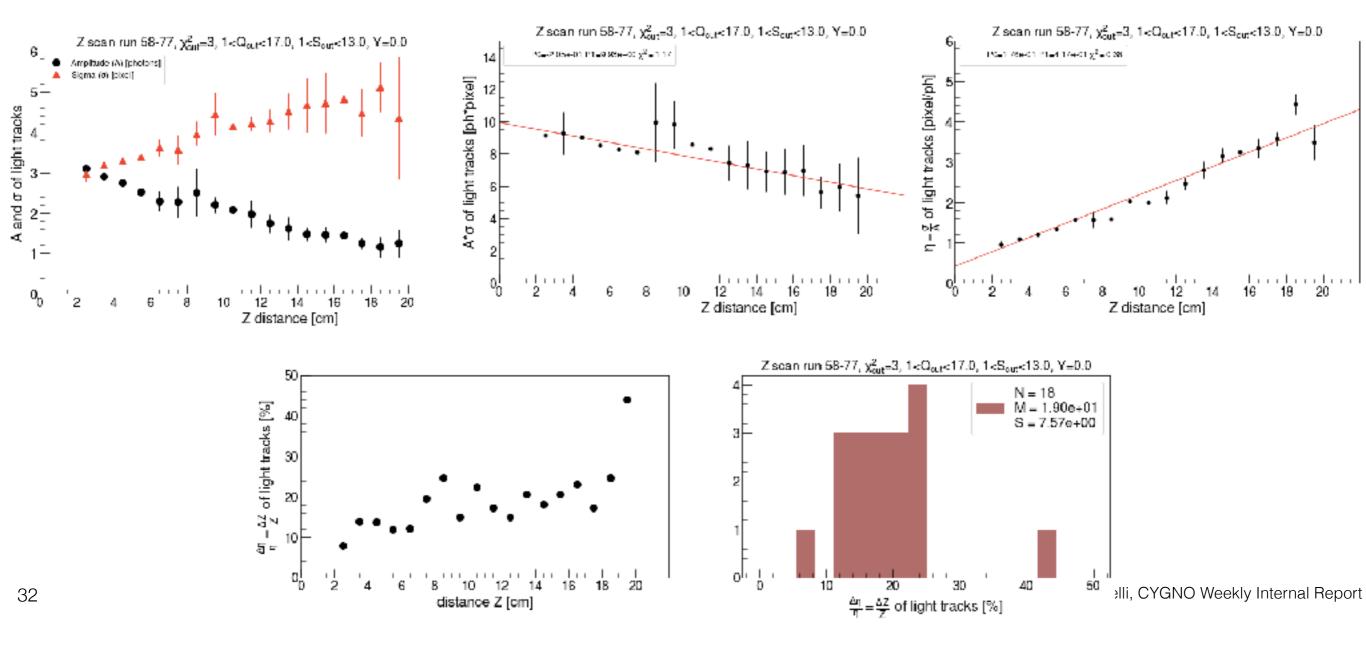
Gentilissimi,

Il dimostratore CYGNO, prototipo per la realizzazione di una grande TPC a gas per materia oscura direzionale e studio dei neutrini solari, è stato approvato dalla Commissione Nazionale II dell'INFN per prossimi 5 anni in sinergia con l'ERC INITIUM e il PRIN Zero Radioactivity in Future Experiments che ne garaniscono la validità scientifica e la sostenibilità economica. L'obiettivo del dimostratore è portare la tecnologia delle TPC a gas ad essere competitiva con i grandi esperimenti per lo studio della materia oscura di bassa massa e aprire una nuova finestra sull'astronomia solare tramite la spettroscopia del neutrini di bassa energia.

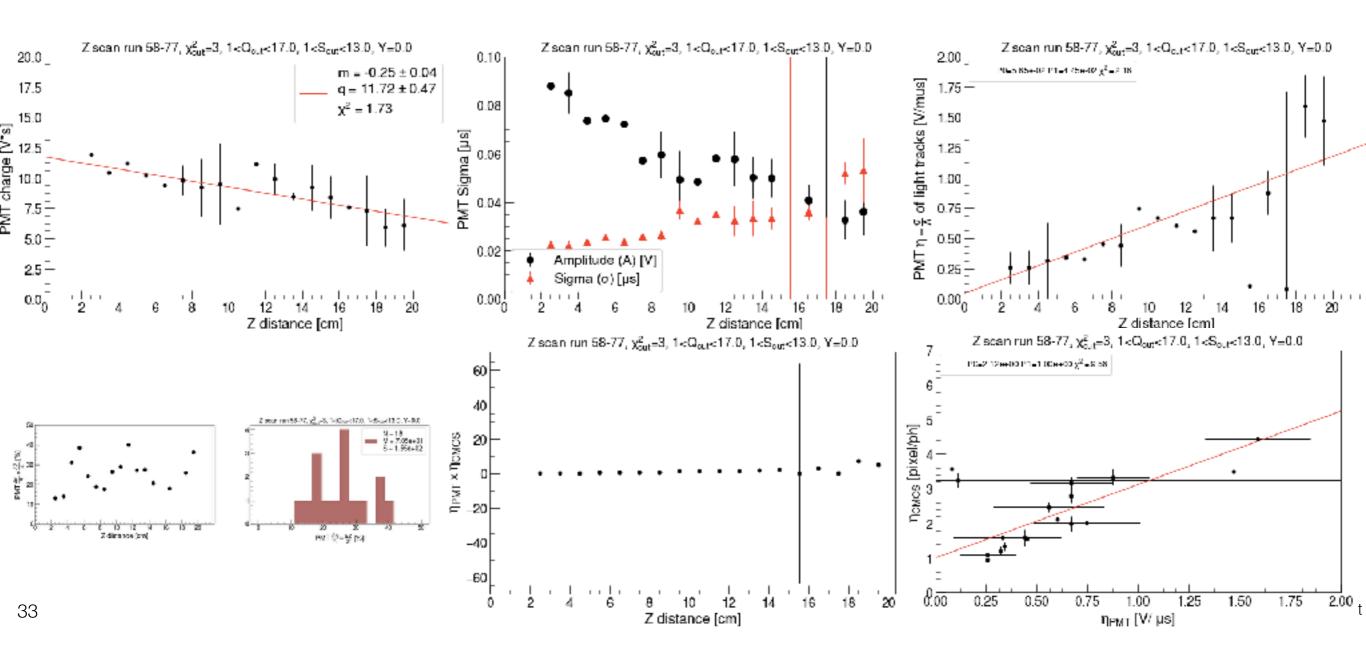
- Niece and constructive feedback
- No problem for the DAQ throughput (up to 40Gb/s easy) soon probably more available, doubling and redundancy nel be easy as soon as the new optical cables will be available
- We must be more accurate on the evaluation of the computing resource for simulation (CPU and storage)
- Contact person
- On call when running (DAQ/computing expert)
- procurements: 3 switch 40Gb/s and some support to the computing cluster.
- Next step: request to CNAF

SPARE

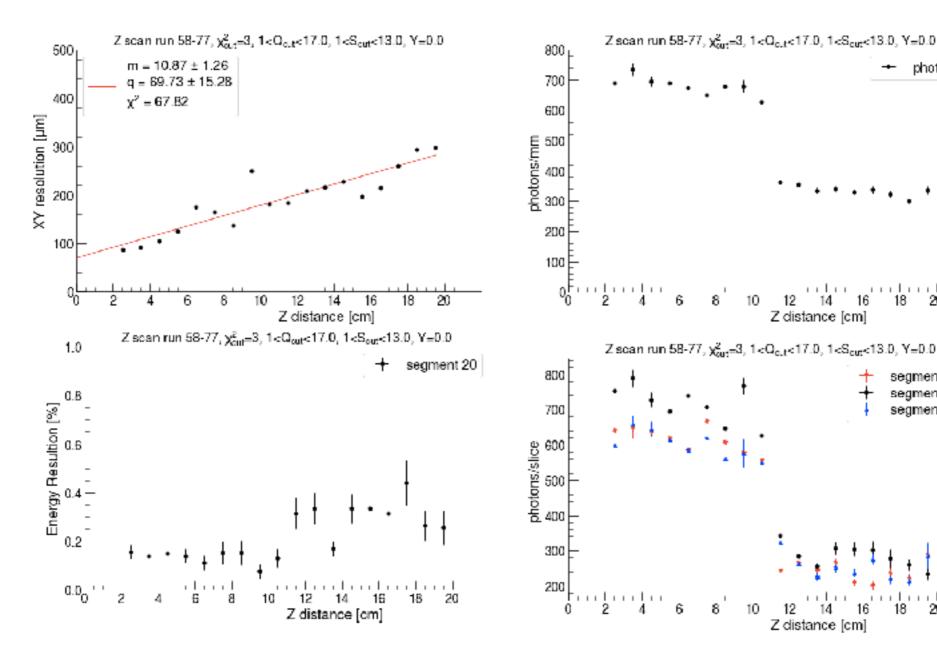
MIP 0.6kV/cm (1938 pixel)



MIP 0.6kV/cm (34 segments)



MIP 0.6kV/cm (34 segments)

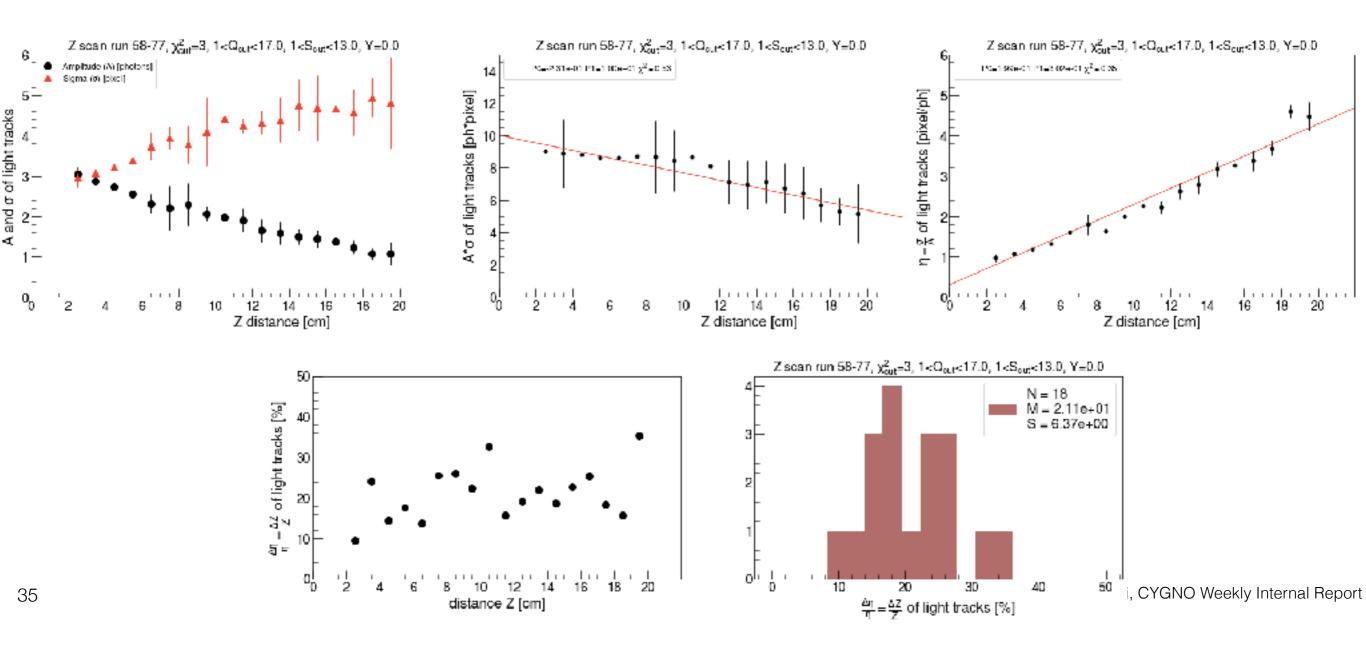


photons

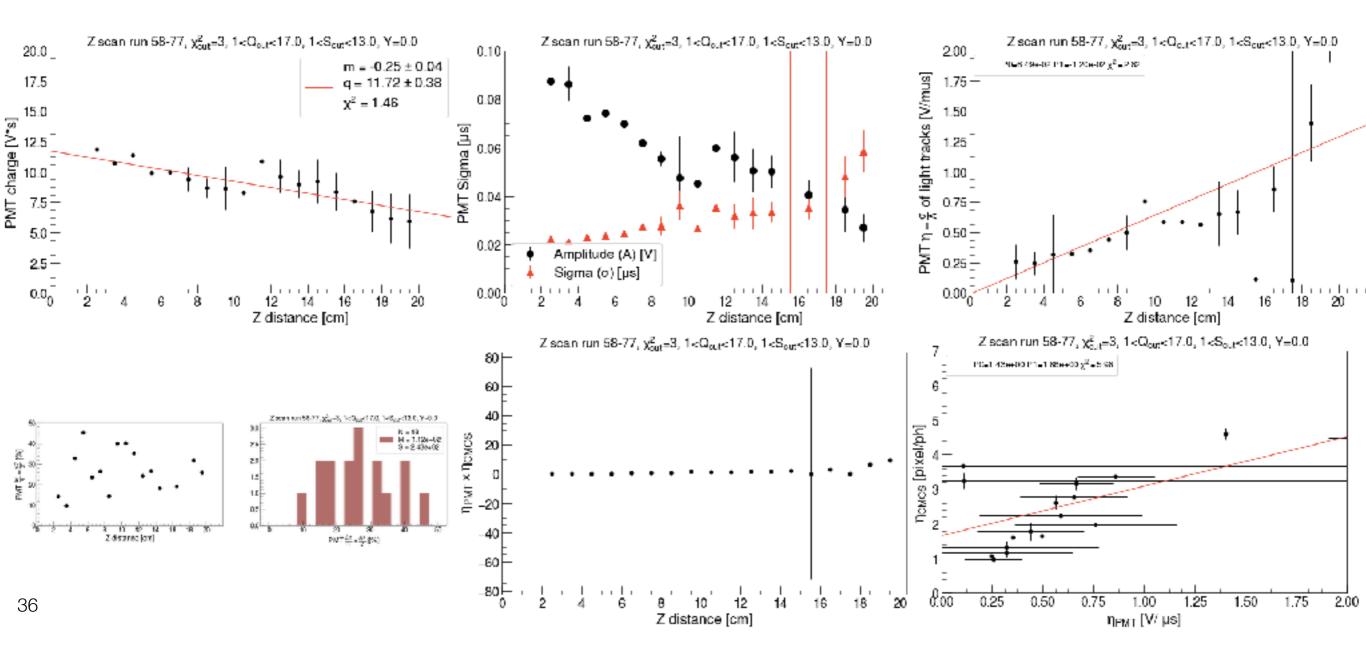
segment 10 segment 20

segment 30

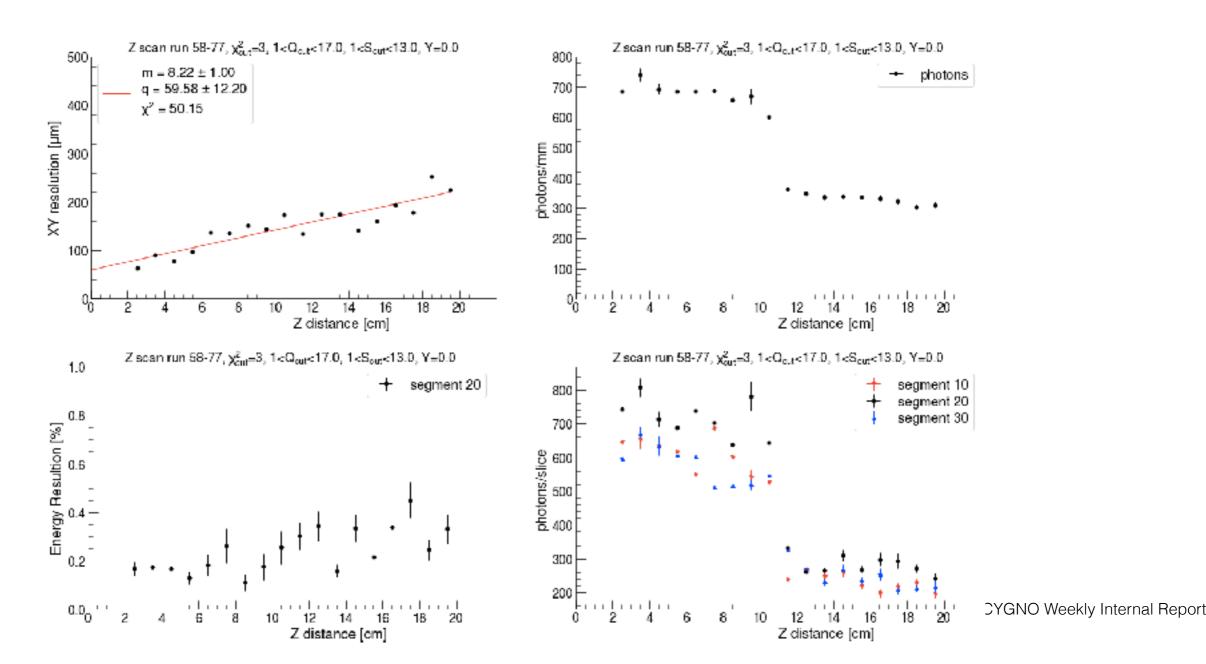
MIP 0.6kV/cm (568 pixel)



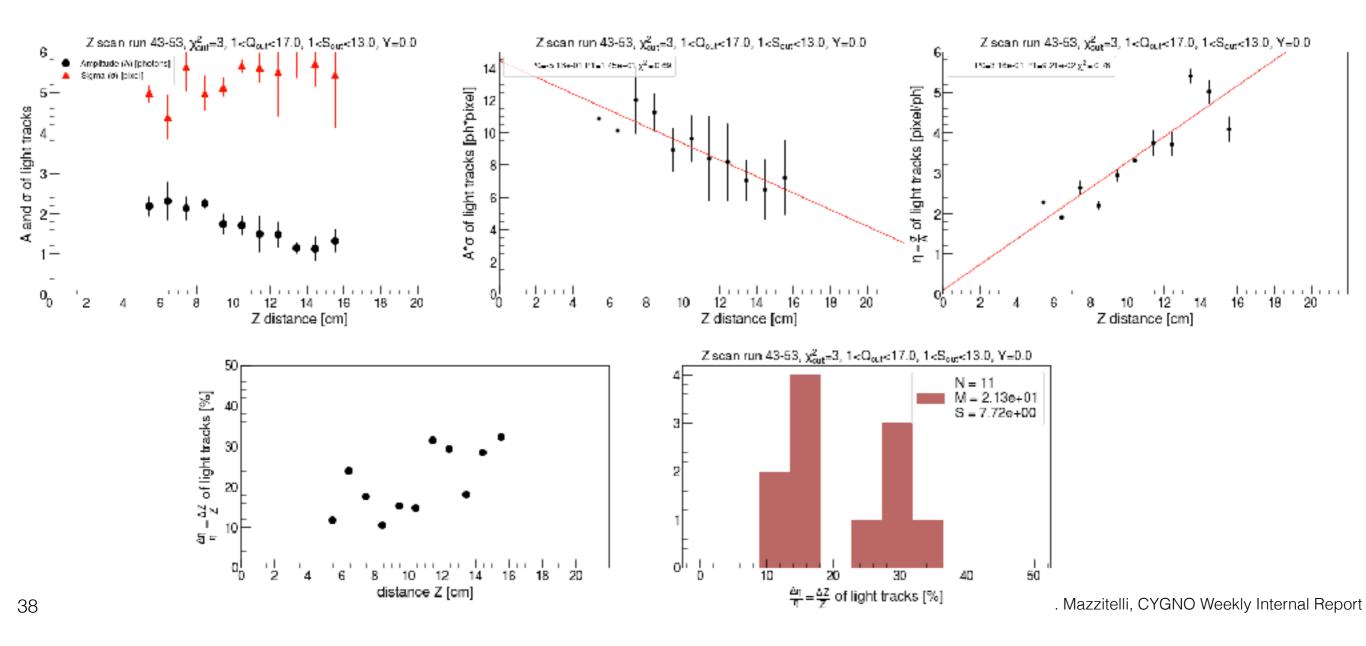
MIP 0.6kV/cm (10 segments)



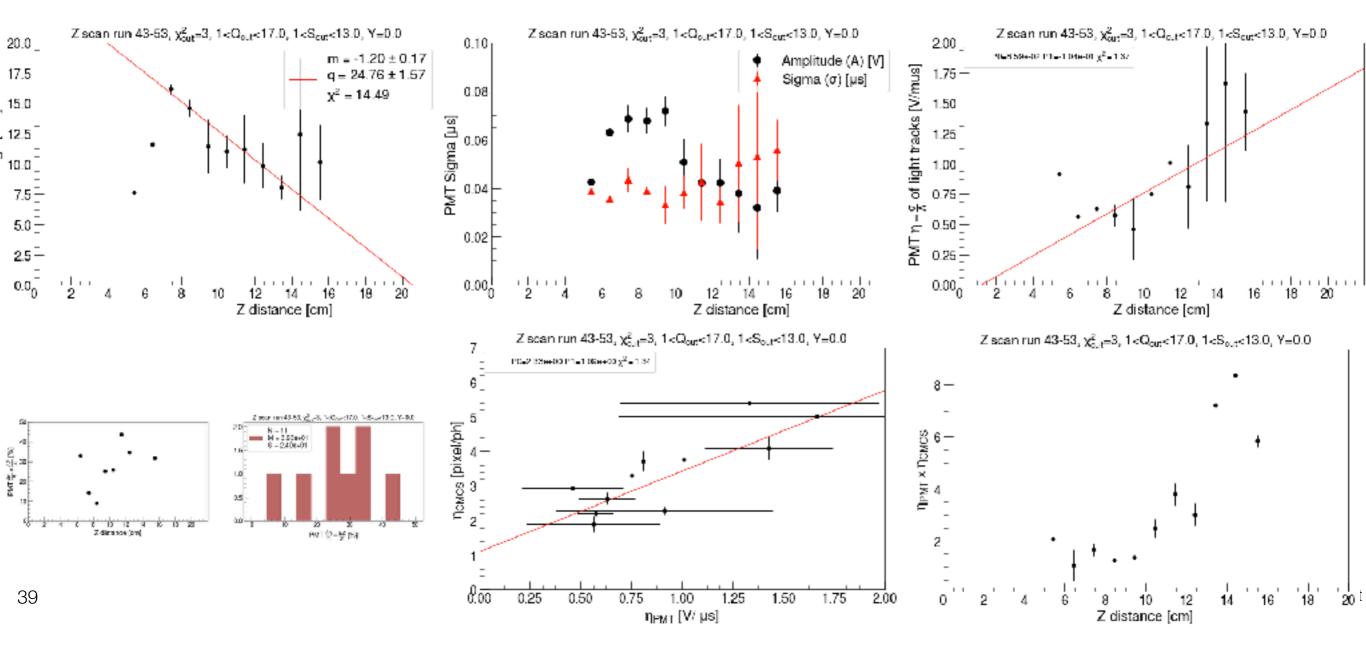
MIP 0.6kV/cm (10 segments)



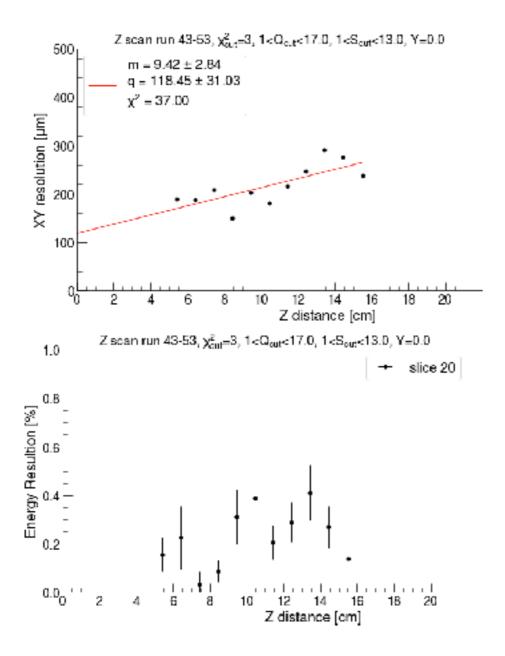
MIP 0.45kV/cm (34 segments)

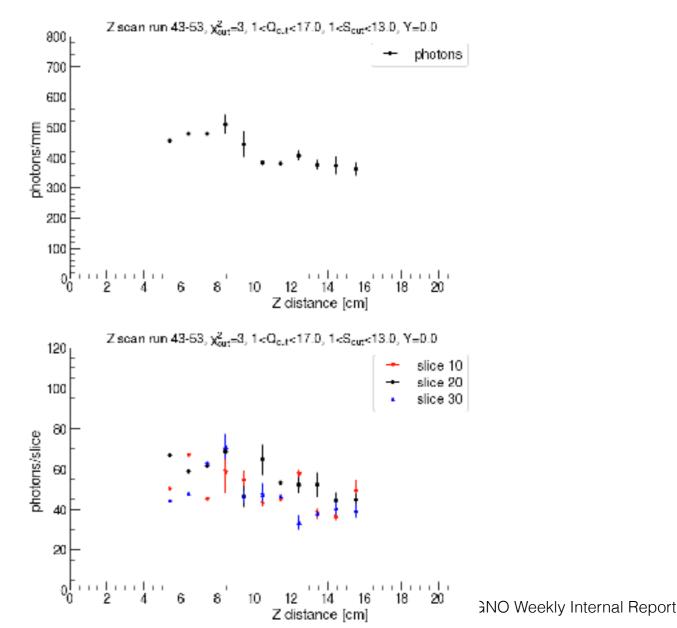


MIP 0.45kV/cm (34 segments)

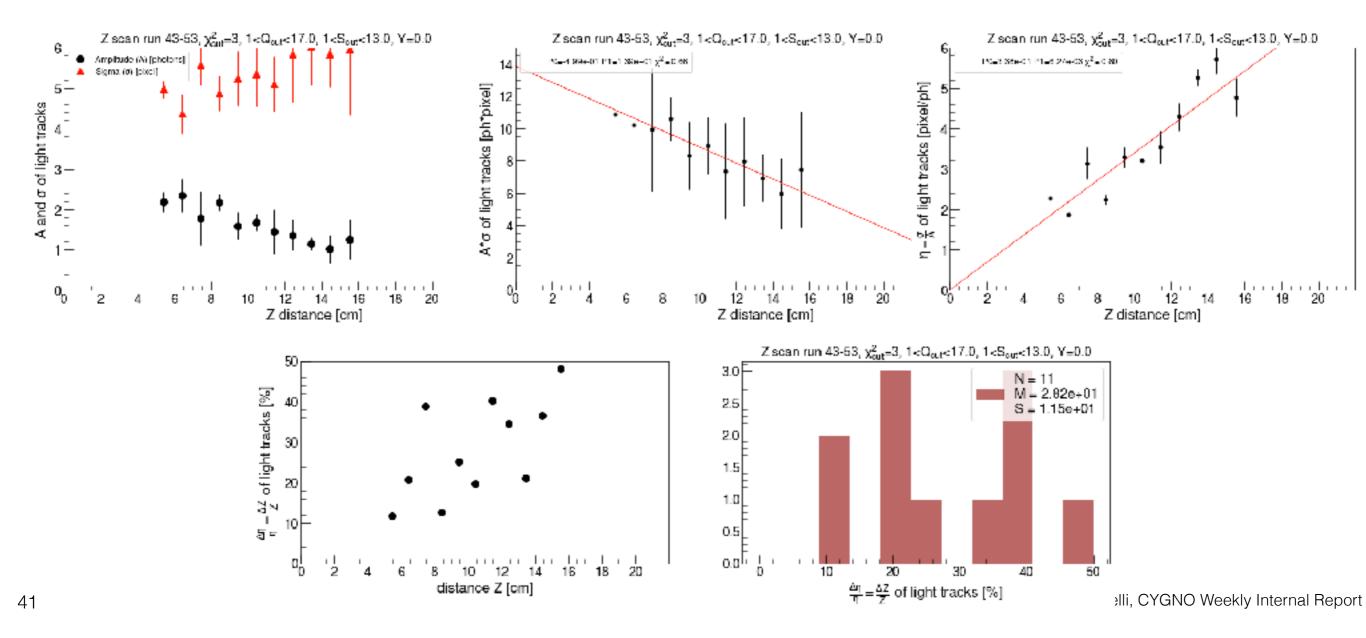


MIP 0.45kV/cm (34 segments)

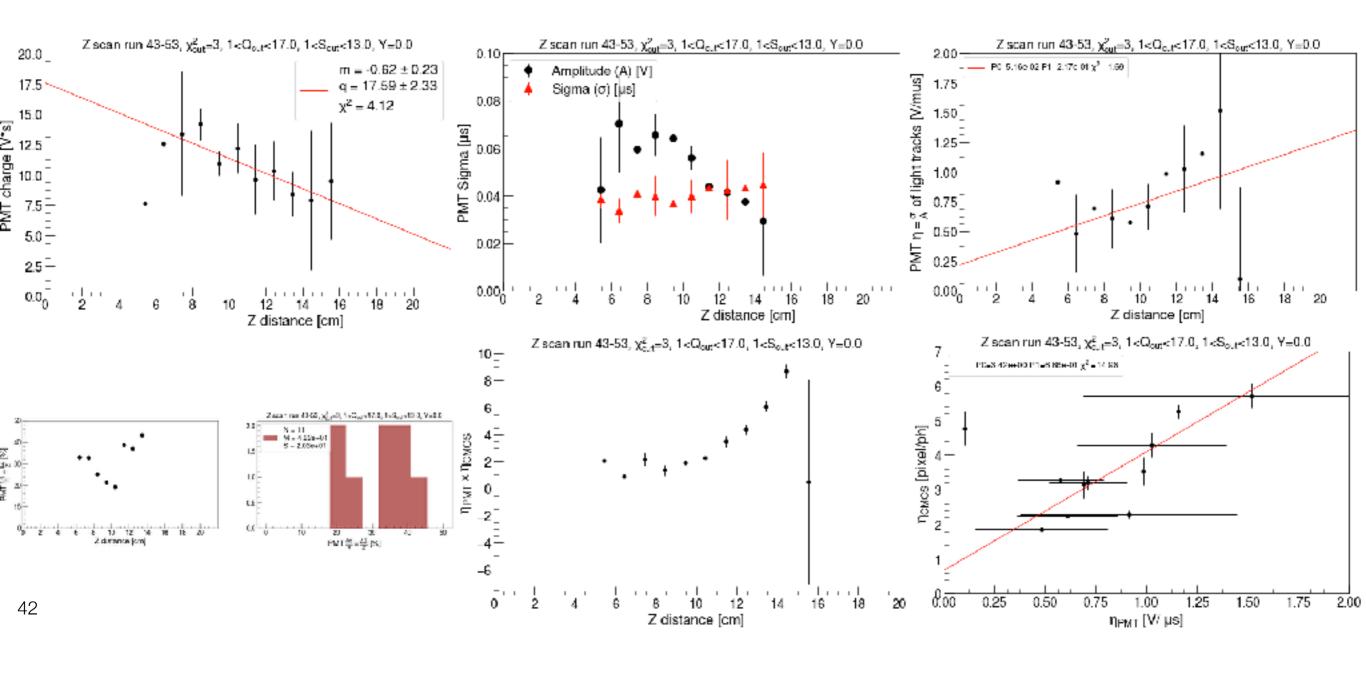




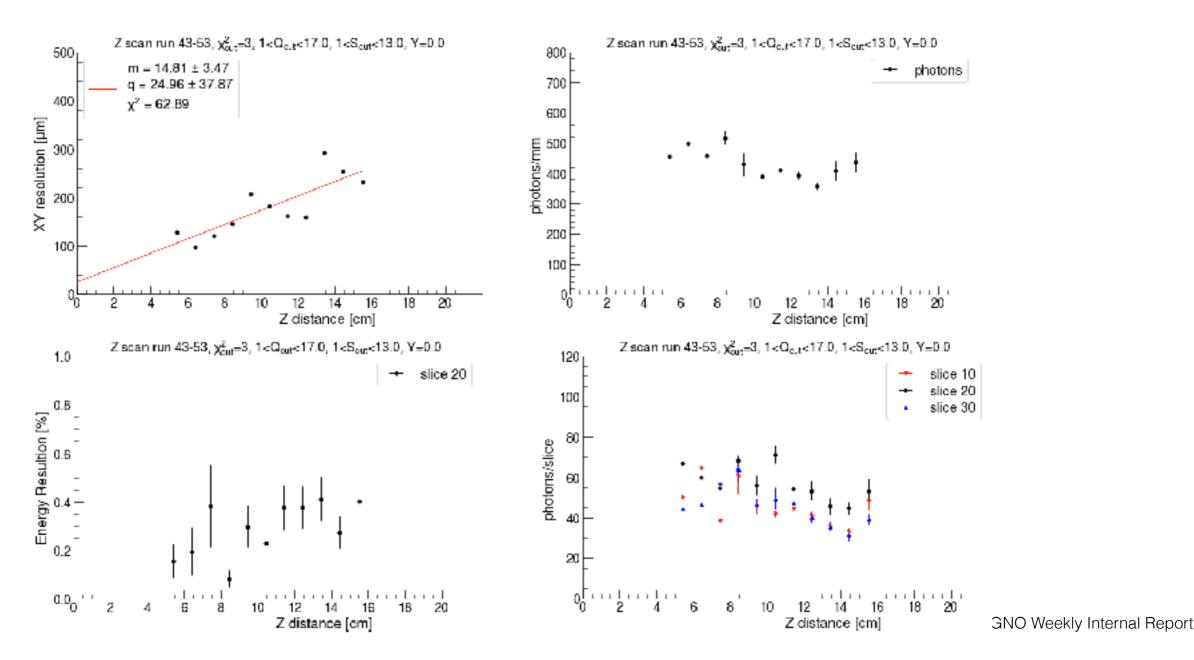
MIP 0.45kV/cm (10 segments)



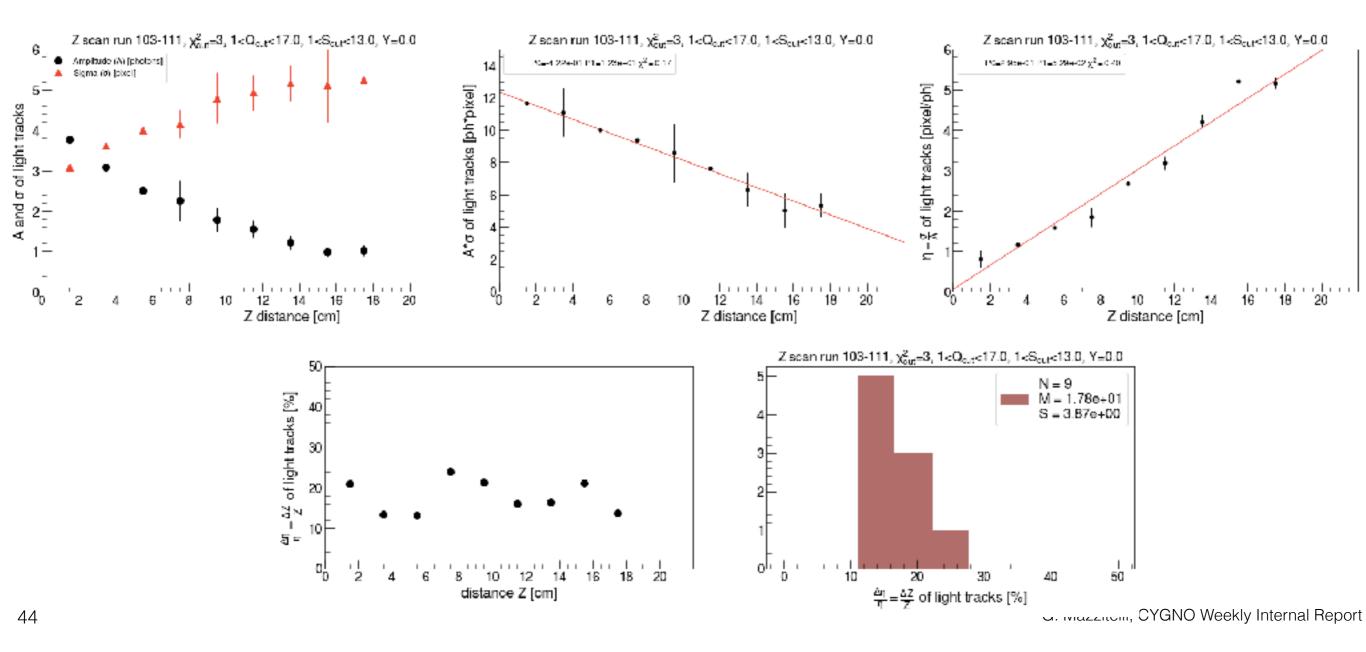
MIP 0.45kV/cm (10 segments)



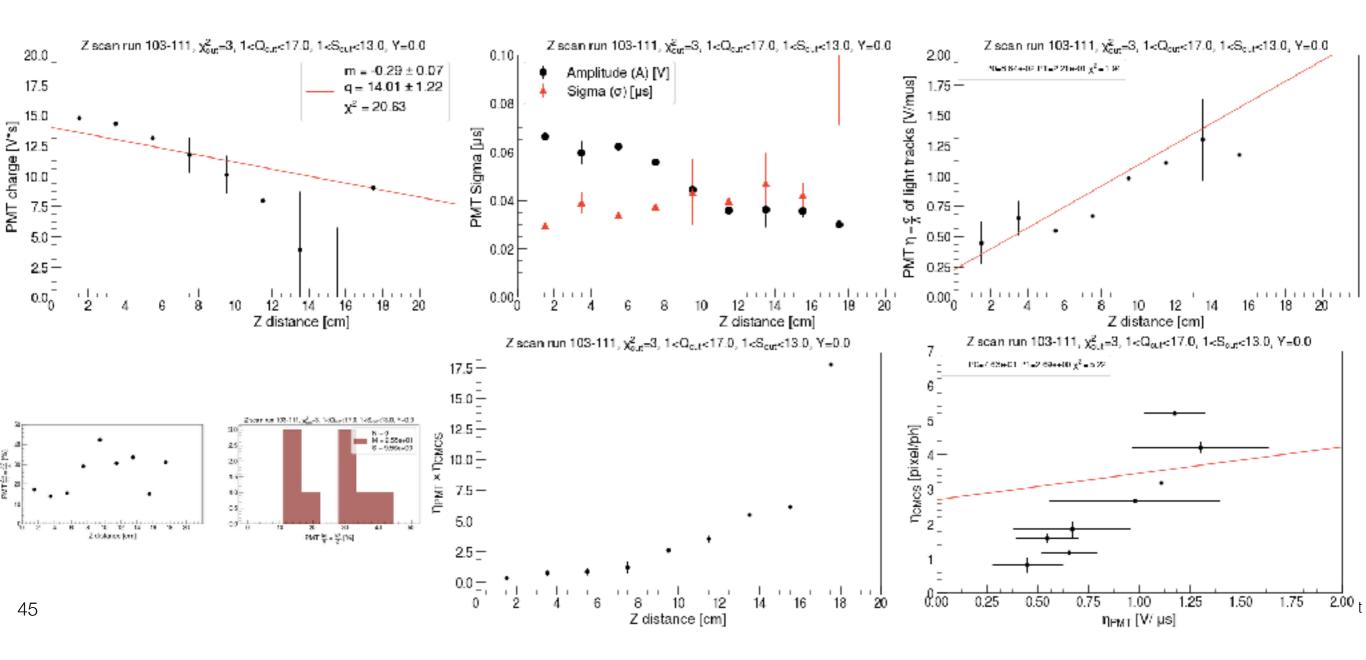
MIP 0.45kV/cm (10 segments)



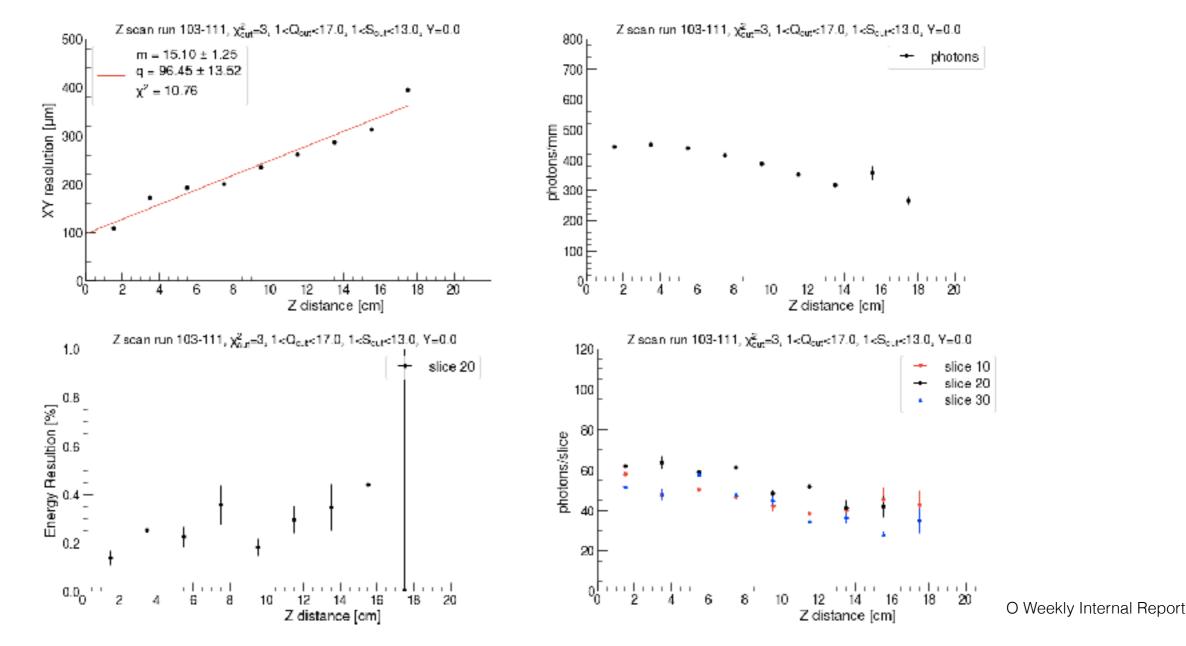
MIP 0.3kV/cm (34 segments)



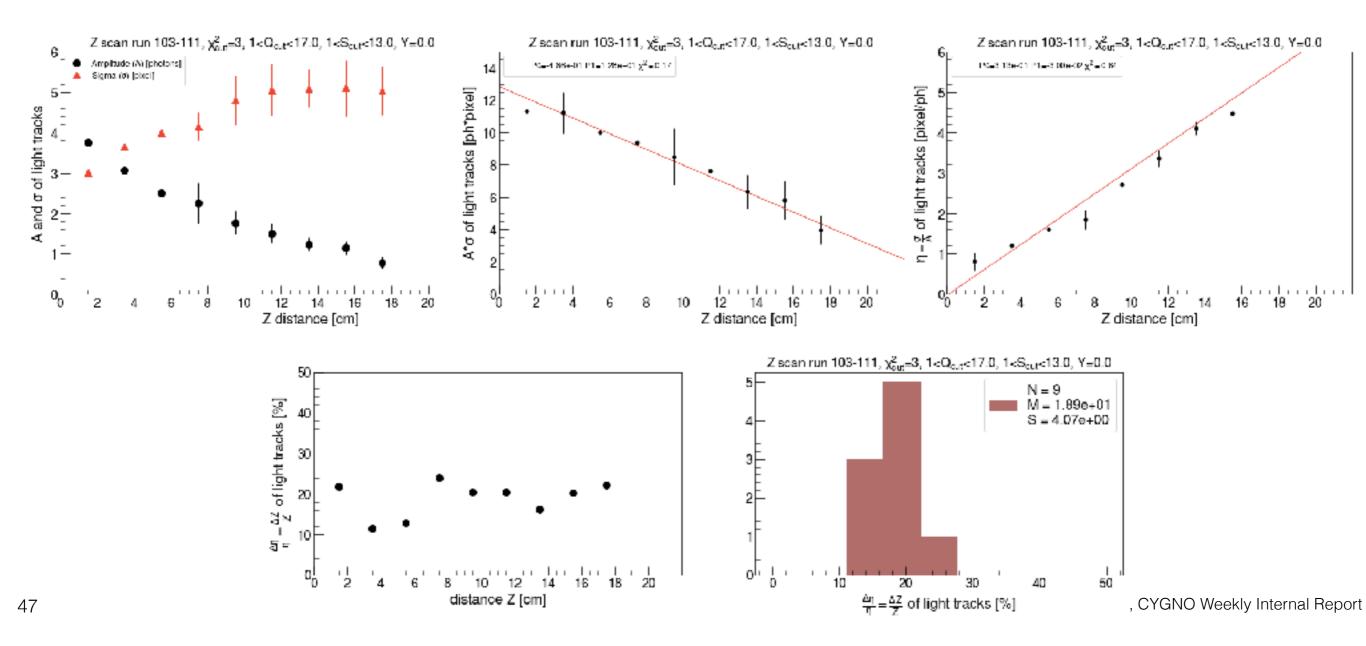
MIP 0.3kV/cm (34 segments)



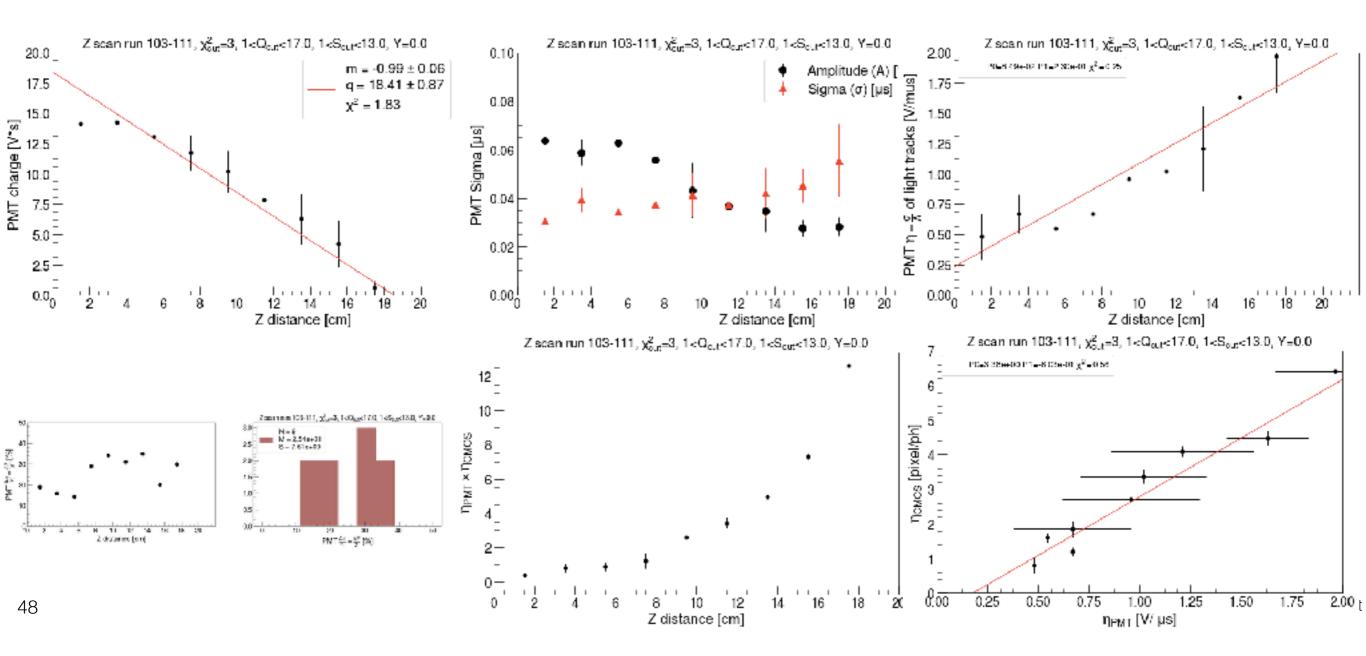
MIP 0.3kV/cm (34 segments)



MIP 0.3kV/cm (10 segments)



MIP 0.3kV/cm (10 segments)



MIP 0.3kV/cm (10 segments)

