LNF activity

JLAB12 7th Collaboration Meeting

April 16, 2012 - Rome

JLAB12 - LNF group

2012

Ricercatori/Tecnologi: 10.5 FTE

M. Aghasyan (Ass. Ric.)
S. Anefalos Pereira (Art. 23)
E. De Sanctis (Dir.)
D. Hasch (I Ric.)
L. Hovsepyan (Assoc.)
V. Lucherini (Dir.)
M. Mirazita (Ric.)
J. de Oliveira Echeimberg (Assoc.)
S. Pisano (Assoc.)
E. Polli (I Tecn.)
P. Rossi (Resp)

Tecnici: 0.8-1.0 FTE

A. Orlandi
A. Viticchie'

2013

Ricercatori/Tecnologi: 10 FTE

M. Aghasyan (Art. 23)
S. Anefalos Pereira (Ric. Ass.)
E. De Sanctis (Dir.)
D. Hasch (I Ric.)
L. Hovsepyan (Assoc.)
V. Lucherini (Dir.)
M. Mirazita (Resp.)
J. de Oliveira Echeimberg (Assoc.)
S. Pisano (Ass. Ric.)
E. Polli (I Tecn.)
M. Hoek, R. Montgomery , J. Phillips (Glasgow, Assoc.)
A. Courtoy (Liege, Assoc.)

Tecnici: 2.5 FTE

D. Orecchini, A. Orlandi, A. Viticchie', L. Trevisan (Bors. INFN)

OUTLINE

1. **Physics program: TMD measurements**
   - **Analysis completed**

     - Beam Spin Asymmetry in SIDIS $\pi 0$ (M. Aghasyan)
   - **analysis in progress at 6 GeV**

     - semi-inclusive production of two hadrons (S. Anefalos Pereira, S. Pisano)

     - Bessel analysis of SIDIS cross section (M. Aghasyan)

     - semi-inclusive analysis of Λ (M. Mirazita)
   - **new proposals at 12 GeV**

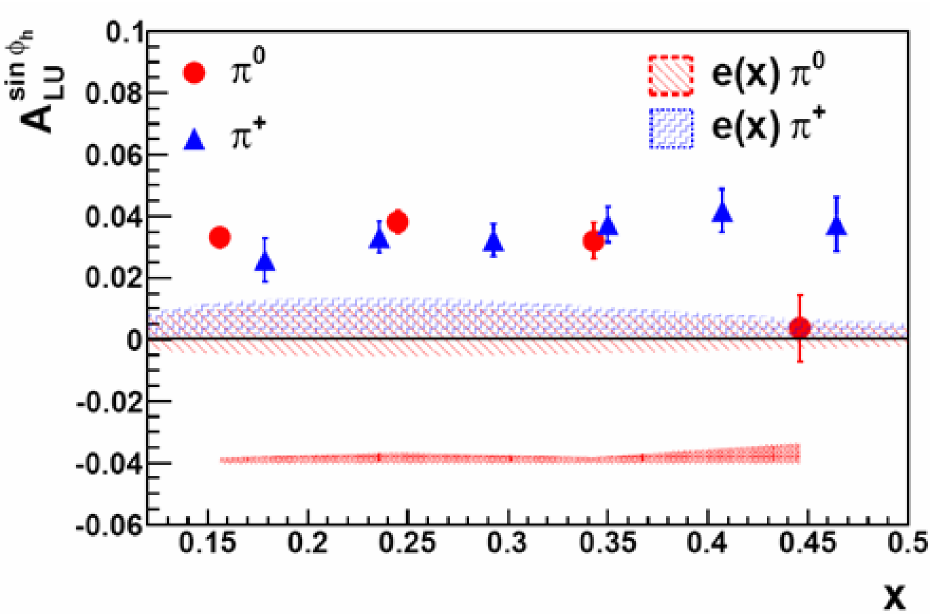
     - two hadron SIDIS production with transverse target

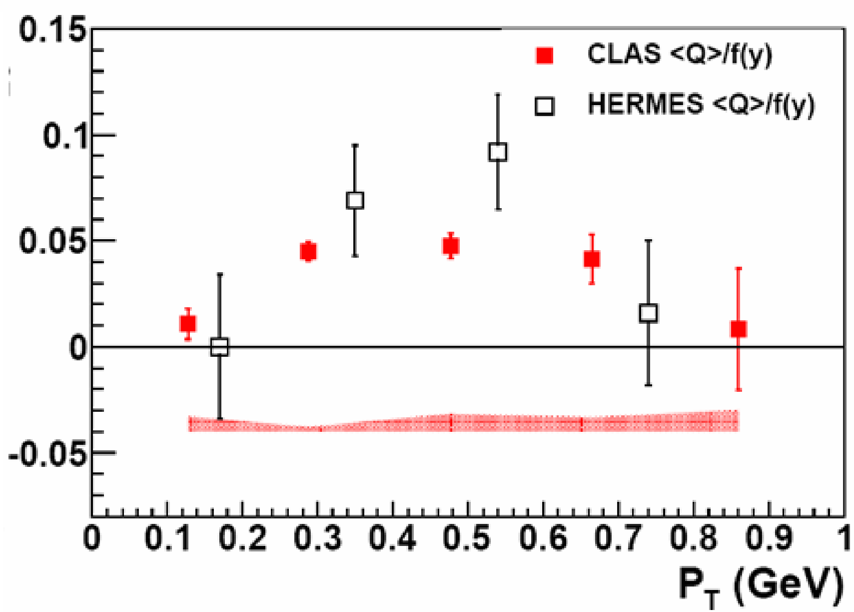
     - pion and kaon SIDIS with transverse target
2. **Hardware activity**
   - **RICH**

BSA in π0 SIDIS

M. Aghasyan

Paper published in Phys. Lett. B 704, 397 (2011)





e p → e π^0 X

$$F_{LU}^{\sin\phi_h} = \frac{2M}{Q}\int d^2\boldsymbol{p}_T\, d^2\boldsymbol{k}_T\, \delta^{(2)}\left(\boldsymbol{p}_T - \frac{\boldsymbol{P}_T}{z} - \boldsymbol{k}_T\right) \times \left\{ \frac{\hat{\boldsymbol{P}}_T\cdot\boldsymbol{p}_T}{M}\left[\frac{M_h}{M}h_1^\perp\frac{\tilde{E}}{z} + x\, g^\perp D_1\right] - \frac{\hat{\boldsymbol{P}}_T\cdot\boldsymbol{k}_T}{M_h}\left[\frac{M_h}{M}f_1\frac{\tilde{G}^\perp}{z} + xeH_1^\perp\right]\right\}.$$

Purely higher twist effect (~M/Q)
Non zero at CLAS energies

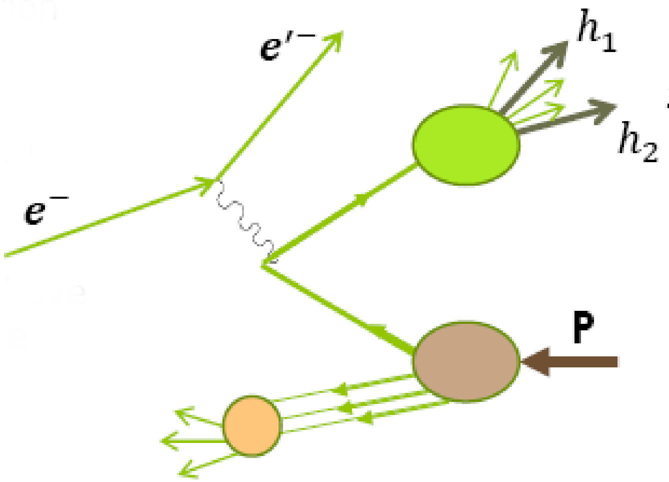
- similar size as for π+
- PT dependence measured

- null asymmetry from Collins models
- may be $g_\perp$ non-zero?

Two hadron production

e p → e π+ π- X

$$A_{DIS}(x,z,P_{h\perp}^2) = -\langle C_y \rangle \frac{\sum_q e_q^2\, h_1^q(x,p_T^2) \otimes_C H_{1,q}^{\perp}(z,k_T^2)}{\sum_q e_q^2\, f_1^q(x,p_T^2) \otimes D_{1,q}(z,k_T^2)}$$



$$A_{DIS}(x,z,M_h^2) = -\langle C_y \rangle \frac{\sum_q e_q^2\, h_1^q(x)\, \frac{|\mathbf{R}|}{M_h} H_{1,q}^{\sphericalangle}(z,M_h^2)}{\sum_q e_q^2\, f_1^q(x)\, D_{1,q}(z,M_h^2)}$$

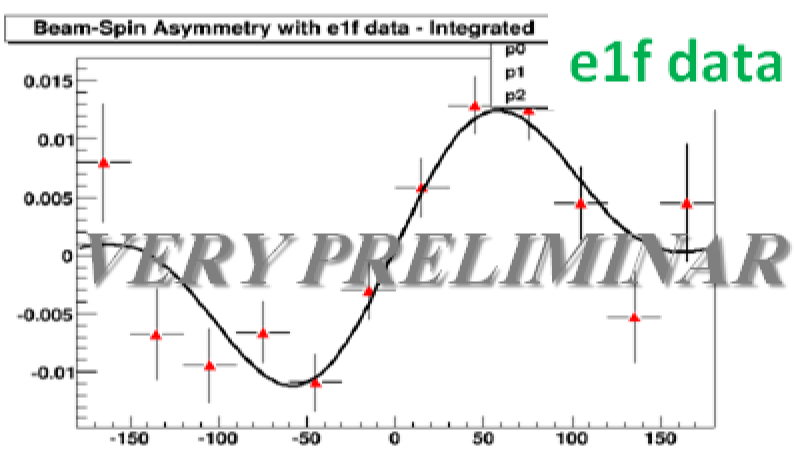
Simple product of PDF and DiFF

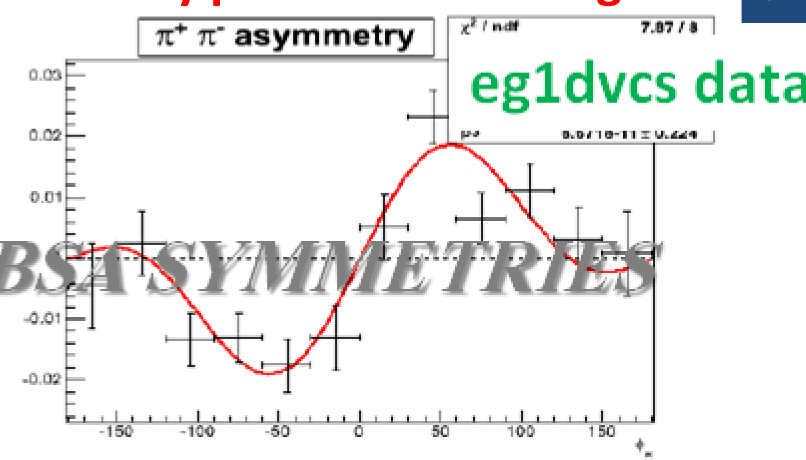
Analysis underway with two data sets

- **e1f data, polarized beam with unpolarized hydrogen target**
- **eg1dvcs data, polarized beam with longitudinally polarized NH3 target**

S. Pisano

S. Pereira





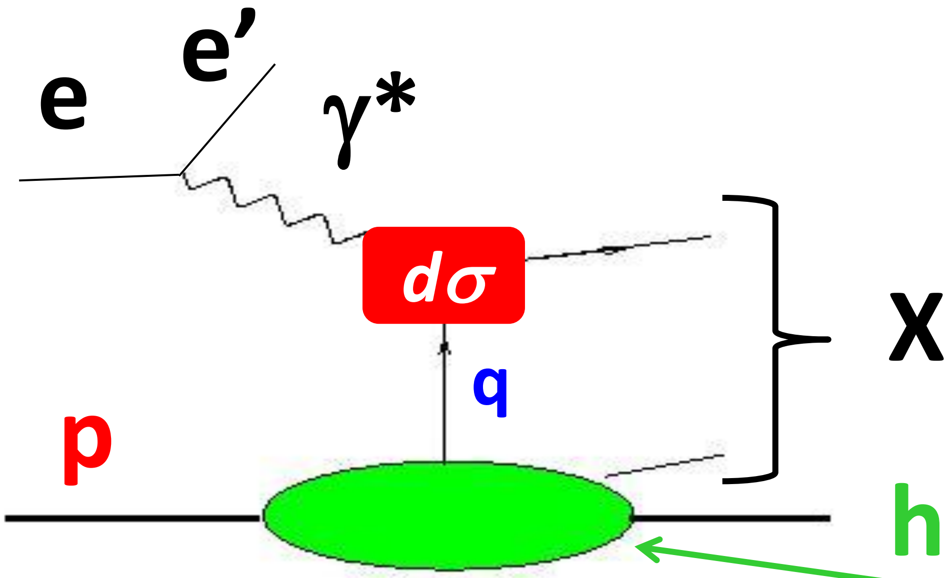
VERY PRELIMINARY BSA SYMMETRIES

SIDIS in the Target Fragmentation Region

Target Fragmentation Region

hadrons produced by the fragmentation of the nucleon target

M. Mirazita



$M^{h}_{q/N}\left(Q^2; x, z\right)$

elementary cross section

$$d\sigma \propto \sum_q M^{h}_{q/N} \otimes d\sigma^{eq\to e'q'}$$

Fracture Functions

Fracture Functions = Fragmentation + Structure

probability that when a quark q is struck in a proton target the hadron h is produced

Λ SIDIS production

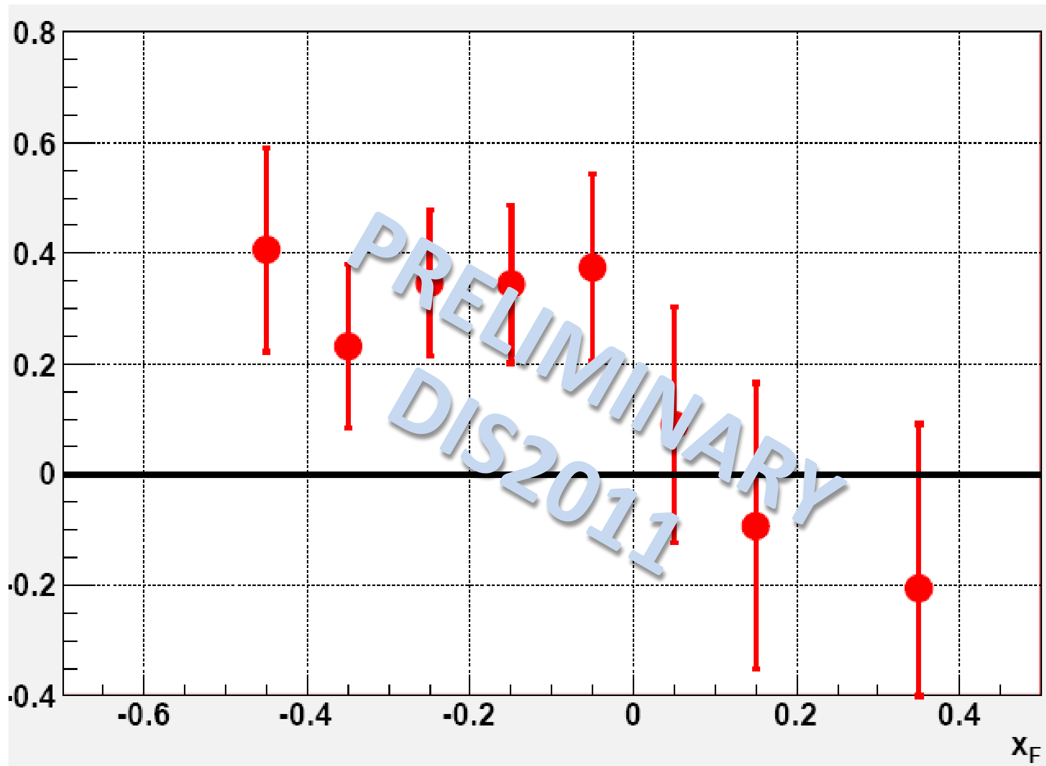
e1f data set :
polarized beam on unpolarized hydrogen

$$\vec{e}p \rightarrow e'\vec{\Lambda}X$$
$$\hookrightarrow p\pi^-$$

Longitudinal Spin transfer in TFR

$$D_{LL} \propto \frac{\sum e_a^2 \Delta M^L}{\sum e_a^2 M}$$

- **TFR, $x_F < 0$**
  $P_\Lambda \sim 0.3$
- **CFR, $x_F > 0$**
  $P_\Lambda \sim 0.$



Analysis almost completed

Bessel analysis of the SIDIS cross section

$$A_{XY}^{W}(x,y,z,B)=(2)\frac{\int dP_{h\perp}d\varphi_S d\varphi_h P_{h\perp}W_{XY}(P_{h\perp},\varphi_S,\varphi_h,B)(d\sigma^+ - d\sigma^-)}{\int dP_{h\perp}d\varphi_S d\varphi_h P_{h\perp}W_{UU}(P_{h\perp},\varphi_S,\varphi_h,B)(d\sigma^+ + d\sigma^-)}$$

B: Fourier conjugate of the transverse momentum → transverse position
it's the natural variable in lattice calculations

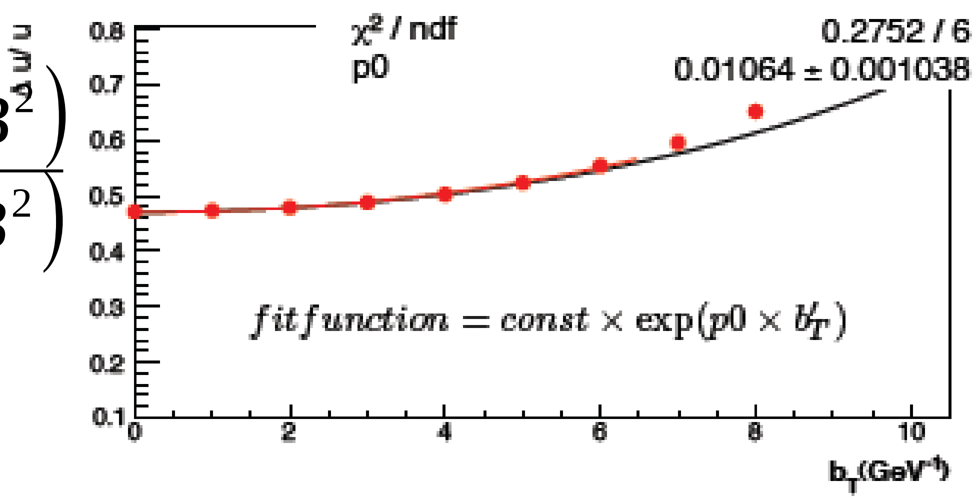
M. Aghasyan

Test of the procedure with Monte Carlo data

- **Double longitudinal spin asymmetry**

$$A_{LL}^{W}(x,y,z,B)=\sqrt{1-\varepsilon^2}\,\frac{\tilde{g}_1(x,z^2B^2)}{\tilde{f}_1(x,z^2B^2)}$$

Fourier transform of PDFs



Proposals for 12 GeV

To be resubmitted to next PAC

1. **Studies of Dihadron Electroproduction in DIS with transversely Polarized Hydrogen Target**
   (S. Pereira co-spokesperson, S. Pisano)
   ⇒ transversity

2. **Studies of pion and kaon Electroproduction in semi-inclusive DIS with Transversely Polarized Hydrogen and Deuterium Targets**
   (M. Aghasyan co-spokesperson)
   ⇒ Collins and Sivers effects

LNF plans for next years

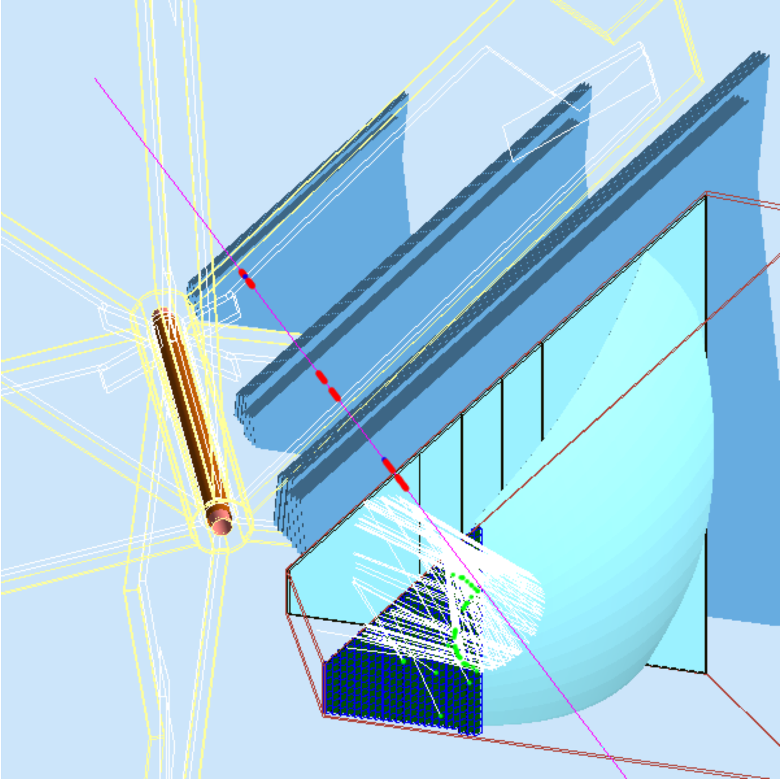
Proposal	Physics	Contact	Rating	Days	Group	New equipment	Energy	Group	Target
E12-06-108	Hard exclusive electro-production of π^0, η	P. Stoler	B	80	119	RICH IC Forward tagger	11	RG-A F. Sabatié	liquid H_2
E12-06-112	Proton's quark dynamics in SIDIS pion production	H. Avakian	A	60					
E12-06-119	Deeply Virtual Compton Scattering	F. Sabatie	A	80					
E12-09-103	Excitation of nucleon resonances at high Q^2	R. Gothe	B+	40					
E11-005	Hadron spectroscopy with forward tagger	M. Battaglieri	A-	119					
PR12-11-103	DVMP of ρ, ω, φ	M. Guidal		D					
E12-07-104	Neutron magnetic form factor	G. Gilfoyle	A-	30	90	Neutron detector RICH IC	11	RG-B K. Hafidi	liquid D_2 target
PEREIRA	Dihadron DIS production	Avakian		D					
MIRAZITA	Study of partonic distributions in SIDIS kaon production	K. Hafidi	A-	56					
E12-09-008	Boer-Mulders asymmetry in K SIDIS w/ H and D targets	M. Contalbrigo	A-	TBA					
11-003	DVCS on neutron target	S. Niccolai	A	90					
E12-06-109	Longitudinal Spin Structure of the Nucleon	S. Kuhn	A	80	170	Polarized target RICH IC	11	RG-C S. Kuhn	NH_3 ND_3
E12-06- 119(b)	DVCS on longitudinally polarized proton target	F. Sabatie	A	120					
ROSSI	Spin-Orbit Correl. with Longitudinally polarized target	H. Avakian	A-	103					
PEREIRA	Dihadron studies on long. polarized target	H. Avakian		D					
MIRAZITA	Study of partonic distributions using SIDIS K production	K. Hafidi	A-	110					
ROSSI	Spin-Orbit correlations in K production w/ pol. targets	H. Avakian	B+	103					
E12-06-106	Color transparency in exclusive vector meson production	K. Hafidi	B+	60	60		11	RG-D	Nuclear
E12-06-117	Quark propagation and hadron formation	W. Brooks	A-	60	60		11	RG-E	Nuclear
E12-10-102	Free Neutron structure at large x	S. Bueltman	A	40	40	Radial TPC	11	RG-F	Gas D_2
PR12-11-109	SIDIS on transverse polarized target	M. Contalbrigo		C2		Transverse target	11	RG-G	HD
TOTAL run time				1231	539				

The RICH detector for CLAS12

Identification of kaons with momenta up to 8 GeV/c necessary for the TMD physics → RICH replacing Low Threshold Cerenkov Counter

Current design:

- aerogel radiator to match the momentum range
- 1 m gap length
- multi-anode PMT for the light detection
- mirrors to focalize the Cerenkov photons in smaller area



Main issues to be addressed

1. Hamamatsu H8500 MAPMT as single photon detectors
2. multiple passage of the photons through the aerogel
3. effective K/π separation with direct and reflected light

Status of the project

1. CERN test of a simplified prototype (august 2011)
   - test of H8500 with Cerenkov photons
   - reconstruction of the Cerenkov rings for pions

2. Test of the RICH components
   - MA-PMT
   - Aerogel (Ferrara)
   - Electronics and DAQ (con ISS)

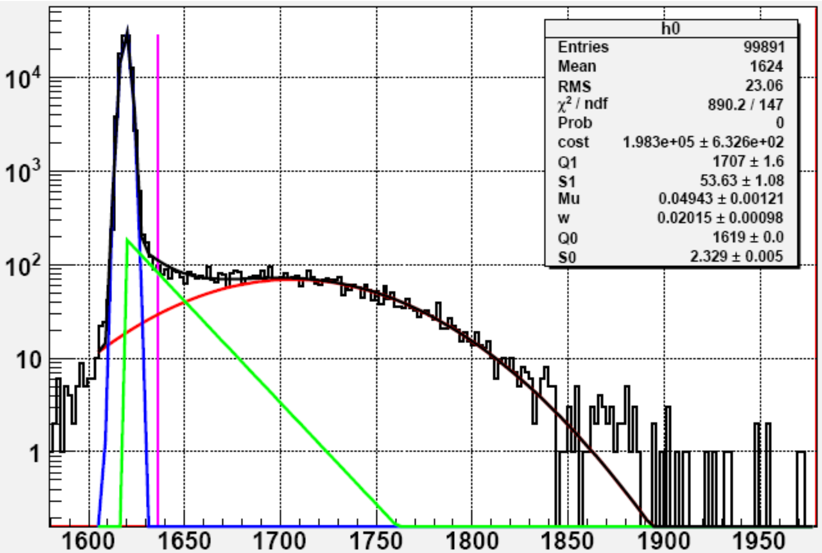
3. Preparation for the next test of a new prototype
   - electron beam at Frascati BTF (July 2-8, 2012)
     - general test of the setup (electronics, DAQ, etc)
   - hadron beam at CERN (July 23 – August 6, 2012)
     - K/π separation
     - direct vs reflected Cerenkov rings

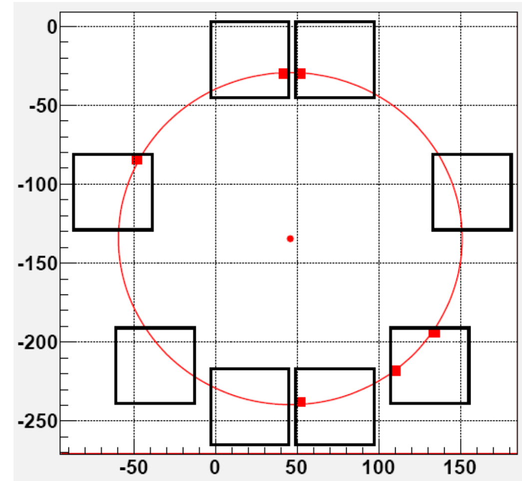
Hadron beam test at CERN

T9 test beam
π,K beam with P=4-10 GeV/c
N(π)/N(K) ~ 60

August 2011

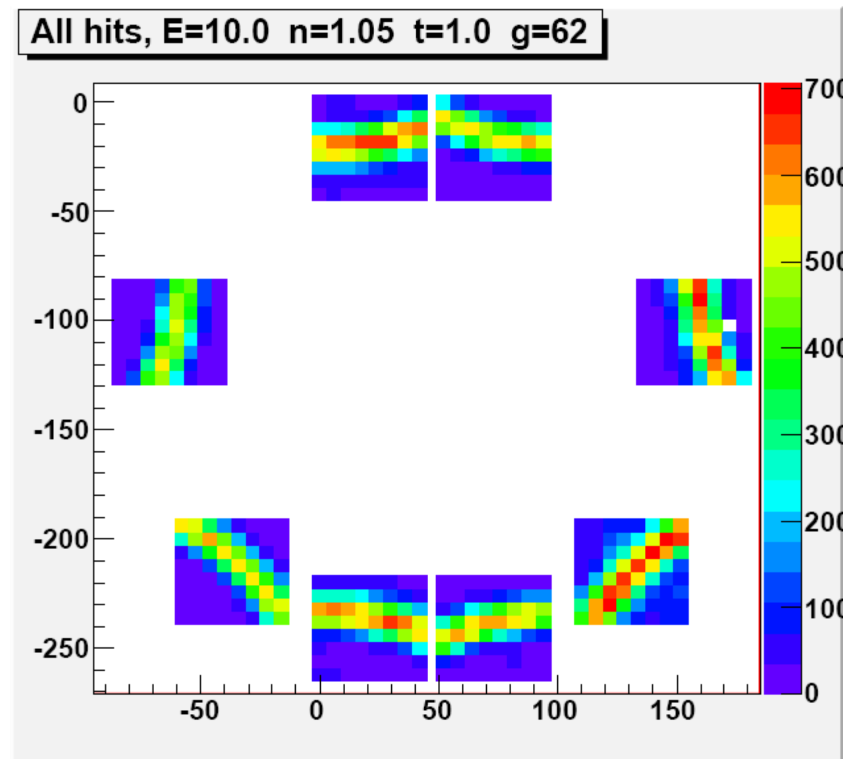
Cerenkov rings





Ring reconstruction through fit of the PMT hits above threshold

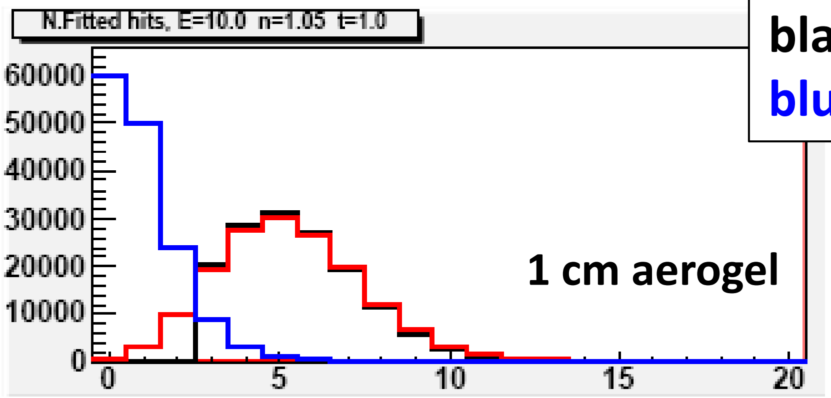
- pion rings successfully measured



- K/π separation not possible
  - no tracking system
  - too short gap (~35 cm)
- stable electronics only up to 8 MAPMTs

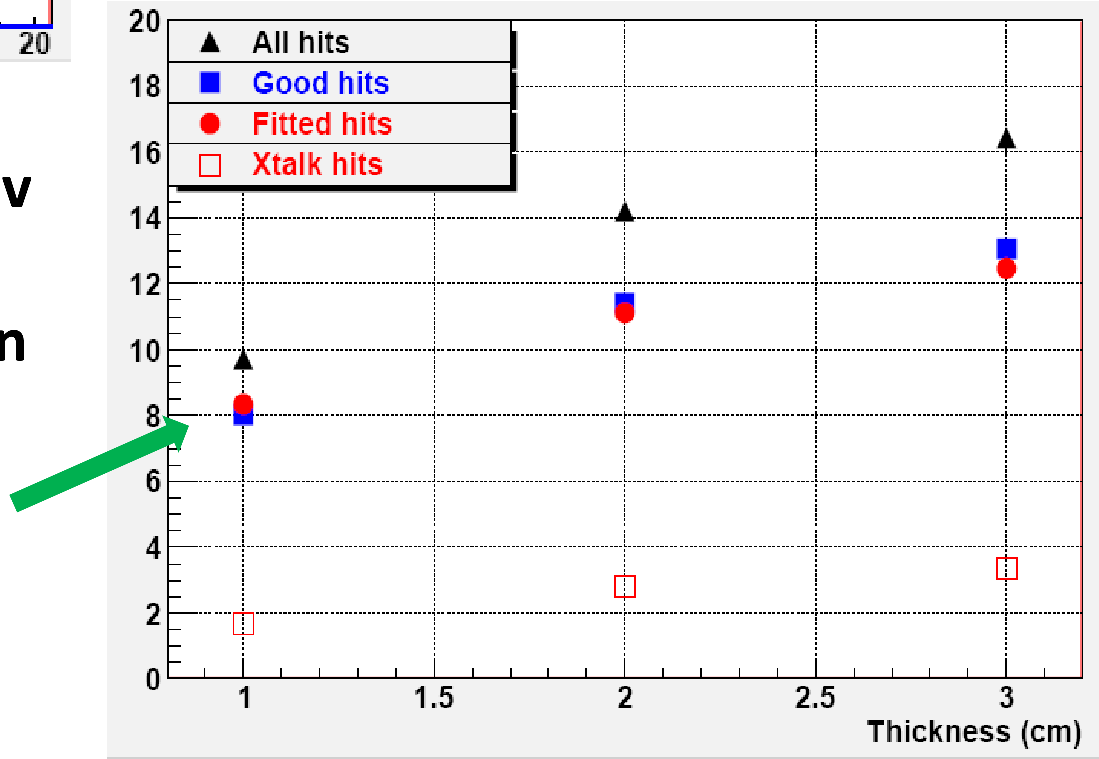
Number of Cerenkov photons

Number of hits per event

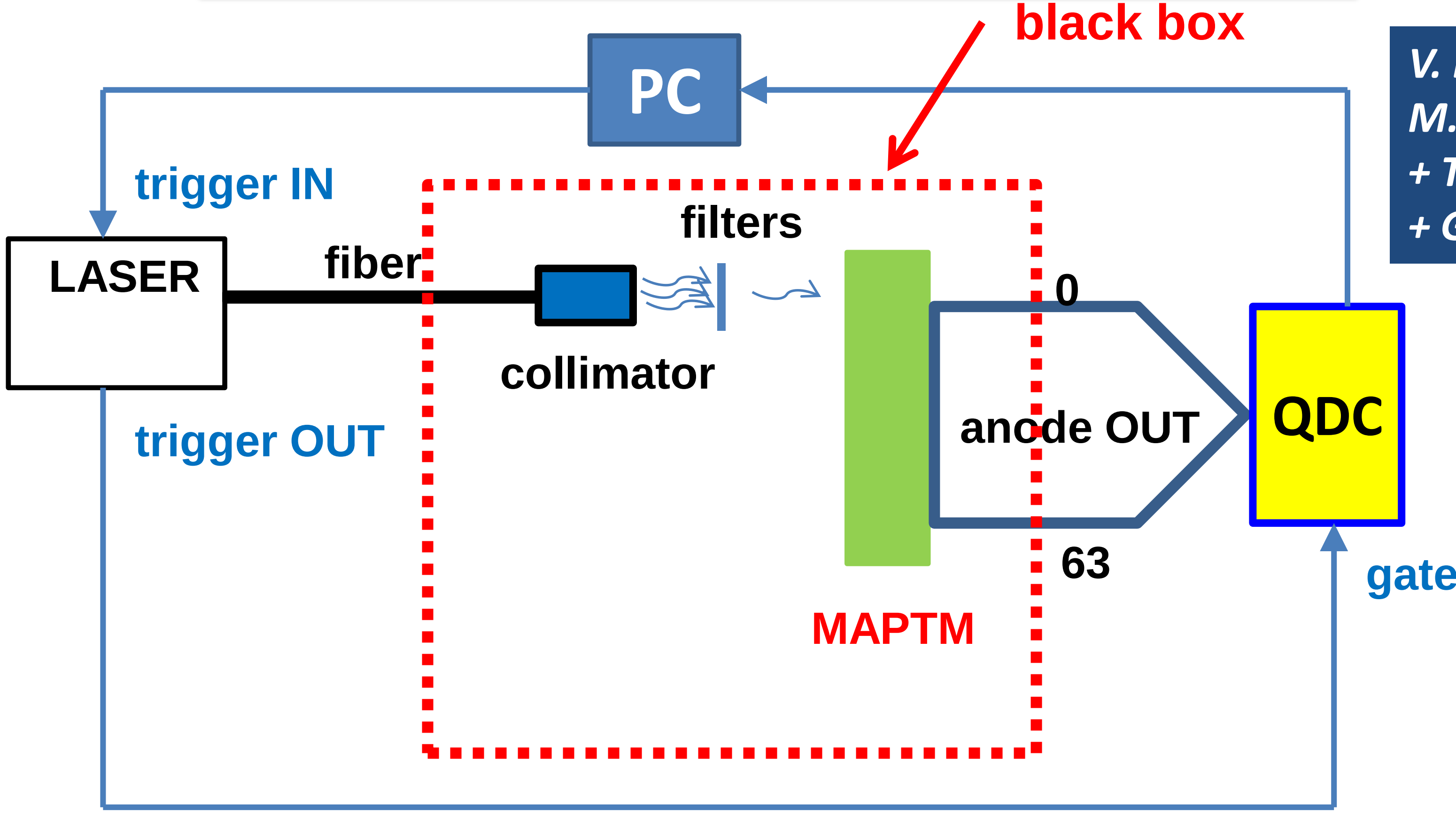


red: good hits
black: hits for the fitted ring (at least 3)
blue: cross talk hits

- between 8 and 12 Cerenkov photons per ring
- used to tune the simulation



Laser beam test of MAPMTs



V. Lucherini
M. Mirazita
+ Thech.
+ Glasgow

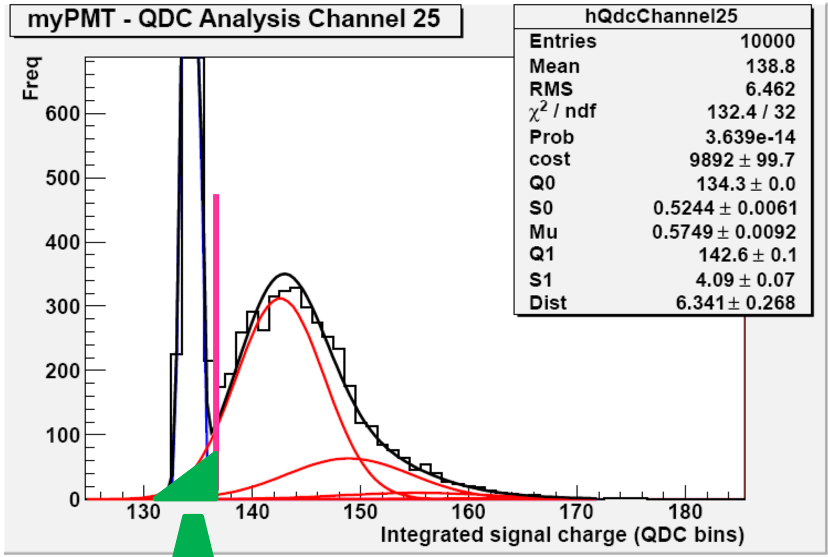
- **Laser intensity can be adjusted via the remote control and using neutral density filters**
- **The fiber head can be remotely moved in (x,y) to scan the PMT surface**
- **Conventional electronics for data acquisition (CAEN V792)**
- **DAQ rate fixed at 100 Hz**

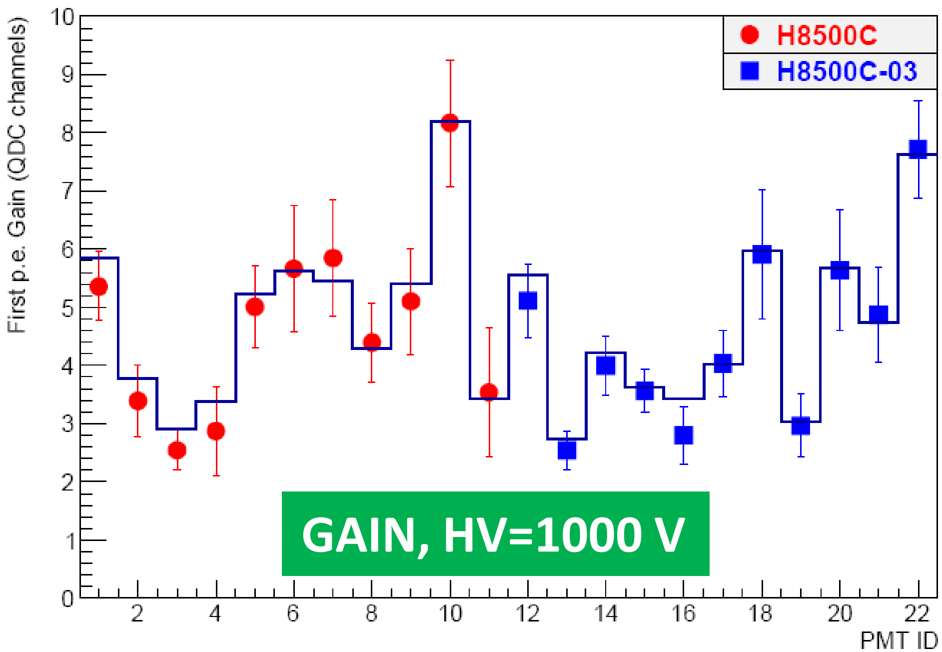
Data analysis

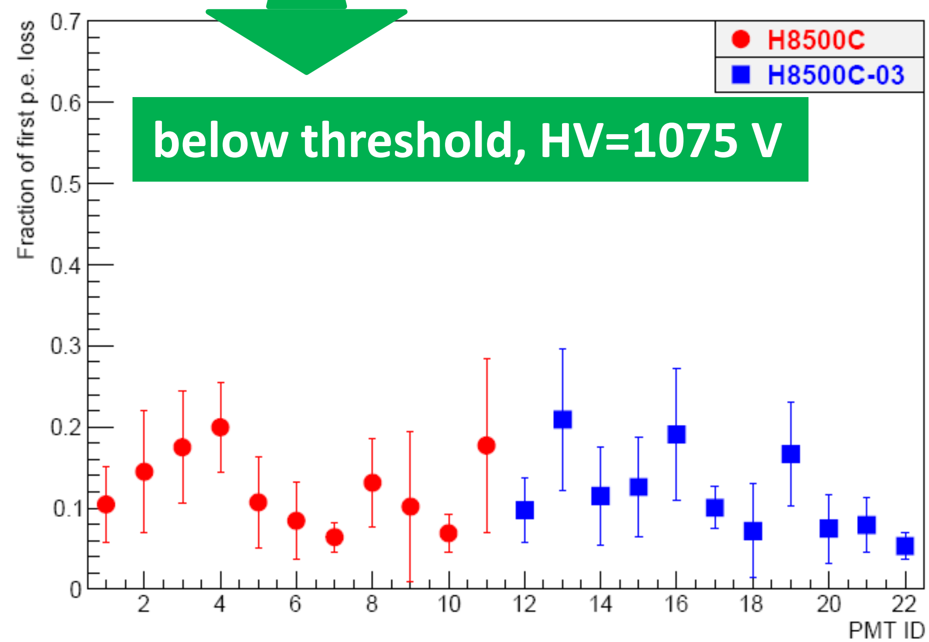
$$F(q)=A\left(e^{-\mu}PED(q)+\sum_{k=1}^{N}\frac{e^{-\mu}\mu^{k}}{k!}SIG_k(q)\right)$$

$$PED=G(q)\;\rightarrow\; m_0,\sigma_0$$

$$SIG_k(q)=G_k(q)\;\longrightarrow\; \begin{aligned} m_k &= m_1+d(k-1)\\ \sigma_k &= \sigma_1\sqrt{k}\end{aligned}$$







New RICH prototype

Goals of the new hadron beam tests:

1. verify K/π separation up to the highest relevant momentum
2. study the ring reconstruction in the totally reflected or direct+reflected configurations; possibly K/π separation

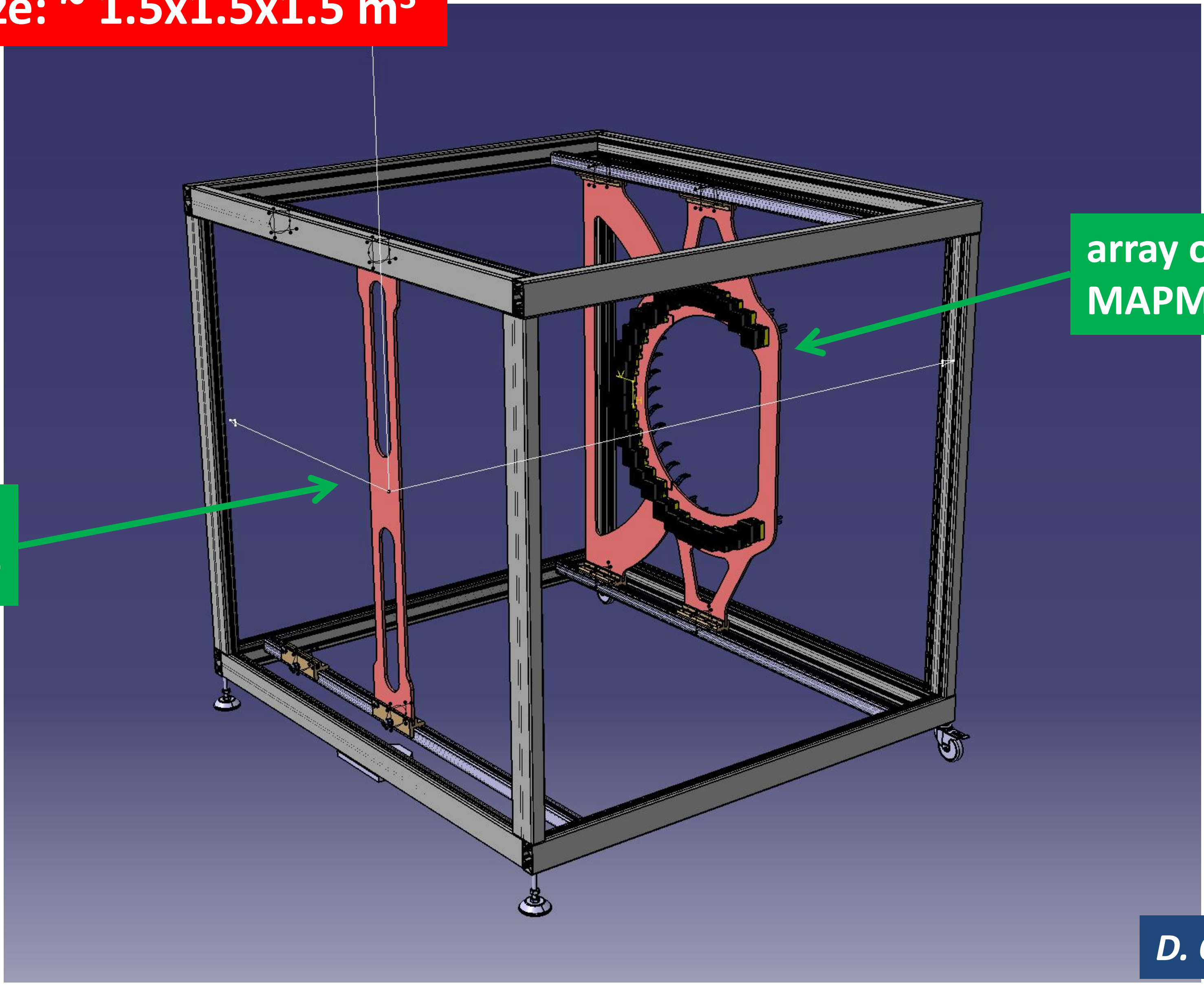
Constraints:

1. gap length for the direct light 1m
2. optimize ring coverage with 28 (+4?) MAPMTs
3. mirrors?
4. tracking system necessary

Schematic layout

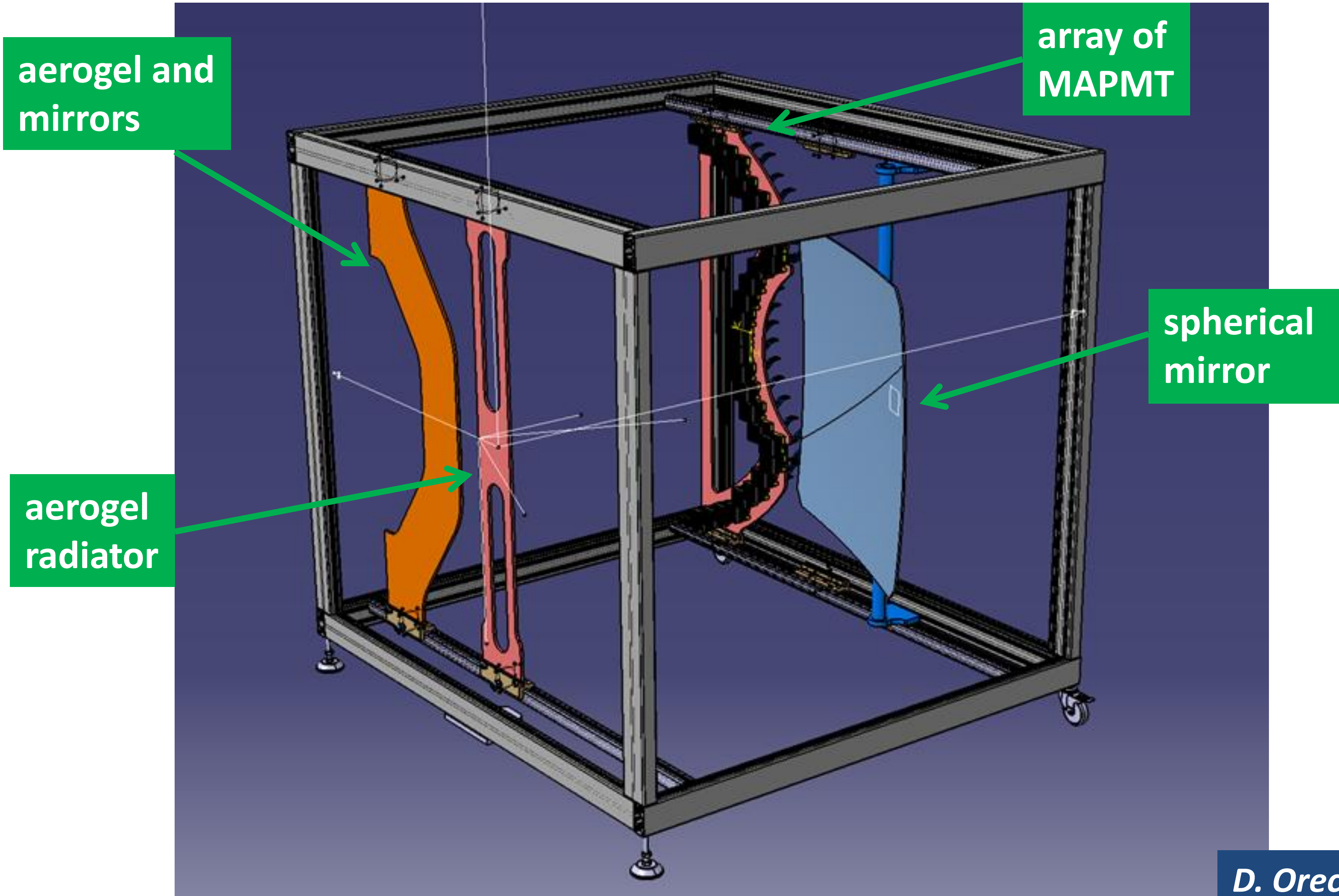
RICH prototype – direct light

Total size: ~ 1.5x1.5x1.5 m^3



D. Orecchini

RICH prototype – reflected light



D. Orecchini

RICH timeline

ITEM	2012 1st h	2012 2nd h	2013 1st h	2013 2nd h	2014 1st h	2014 2nd h	2015 1st h	FTE/ year	Institutions
Simulations	X	X						2	ARGONNE+INFN+ UConn
Test components & prototyping	X	X						4	INFN+CNU+JLAB
TDR	X	X						1.5	INFN
Procurement and test aerogel		X	X	X	X	X		1.5	INFN+JLAB
R&D electronics	X	X	X					2	INFN+UTFSM
Procurement & test electronics				X	X	X		1.5	INFN+JLAB+UTFSM
Slow control			X	X	X	X			?
Procurement & test MA-PMTs		X	X	X	X	X	X	1.5	INFN+GLASGOW+ JLAB
Mechanics+gas system			X	X	X	X		1.5	ARGONNE+INFN+ JLAB
R&D Mirrors	X	X	X					1.5	INFN+JLAB
Mirrors				X	X	X		1	JLAB
RICH assembly						X	X	5	ALL

1 RICH sector: Cost

ITEM	COST (K$)	NOTE
AEROGEL	256	RICH surface = 4.7 m^2
MA-PMT H8500	916	400 MA-PMTs /1 m^2 ; ϑ_{max} ~12.5 deg
ELECTRONICS	333	
HV	60	
MIRRORS	280	~7 m^2
MECHANICS	40	
GAS SYSTEM	30	
SLOW CONTROL	70	
TOTAL	**1985**	

Conclusions

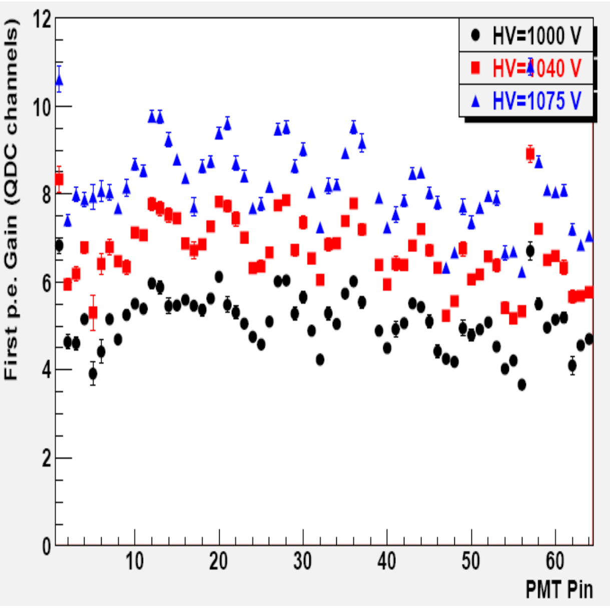
The LNF group has a physics program fully dedicated to the TMD study

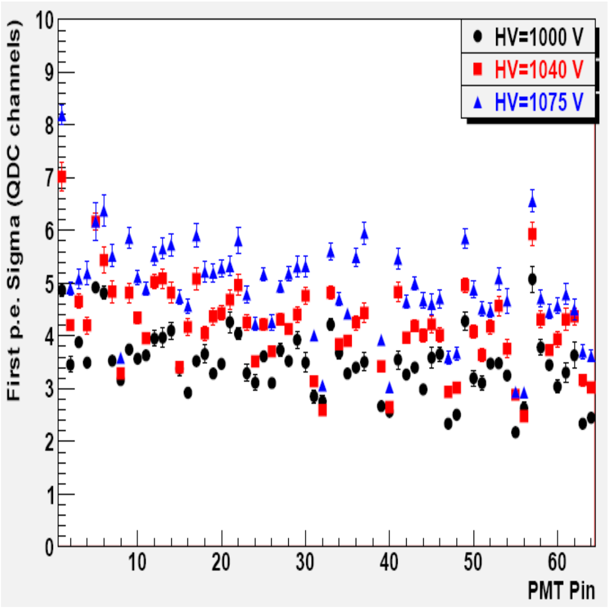
- with 6 GeV data, several analysis underway
- for the 12 GeV upgrade, co-spokeperson of experiments that will run in the first 5 years

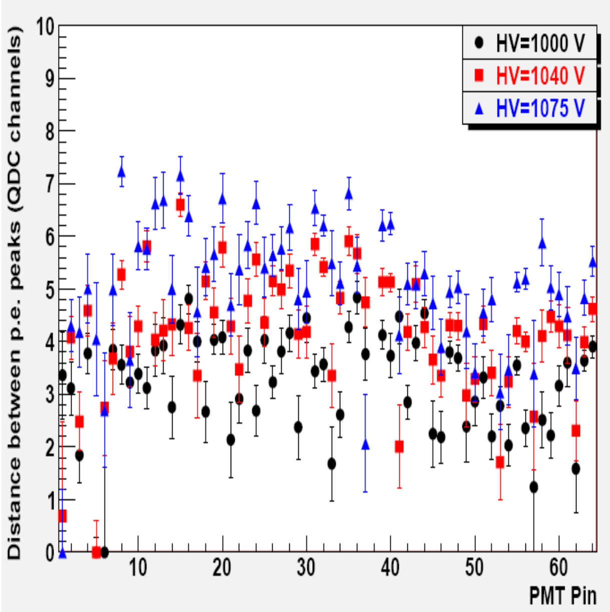
Hardware activity for the RICH detector

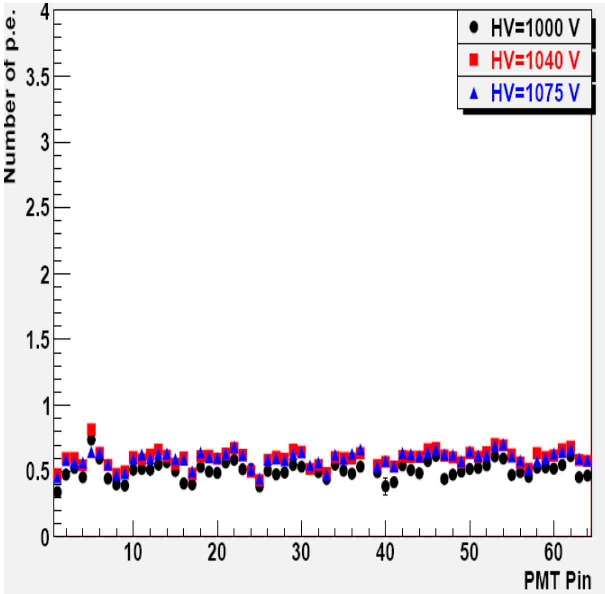
- functionality test of the detector in the summer
- plan to ask for one RICH sector funding from INFN and one sector from DOE

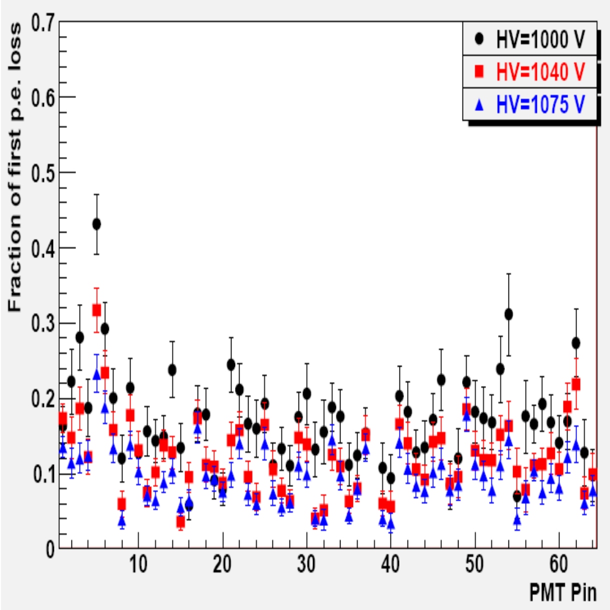
PMT da0168 vs HV



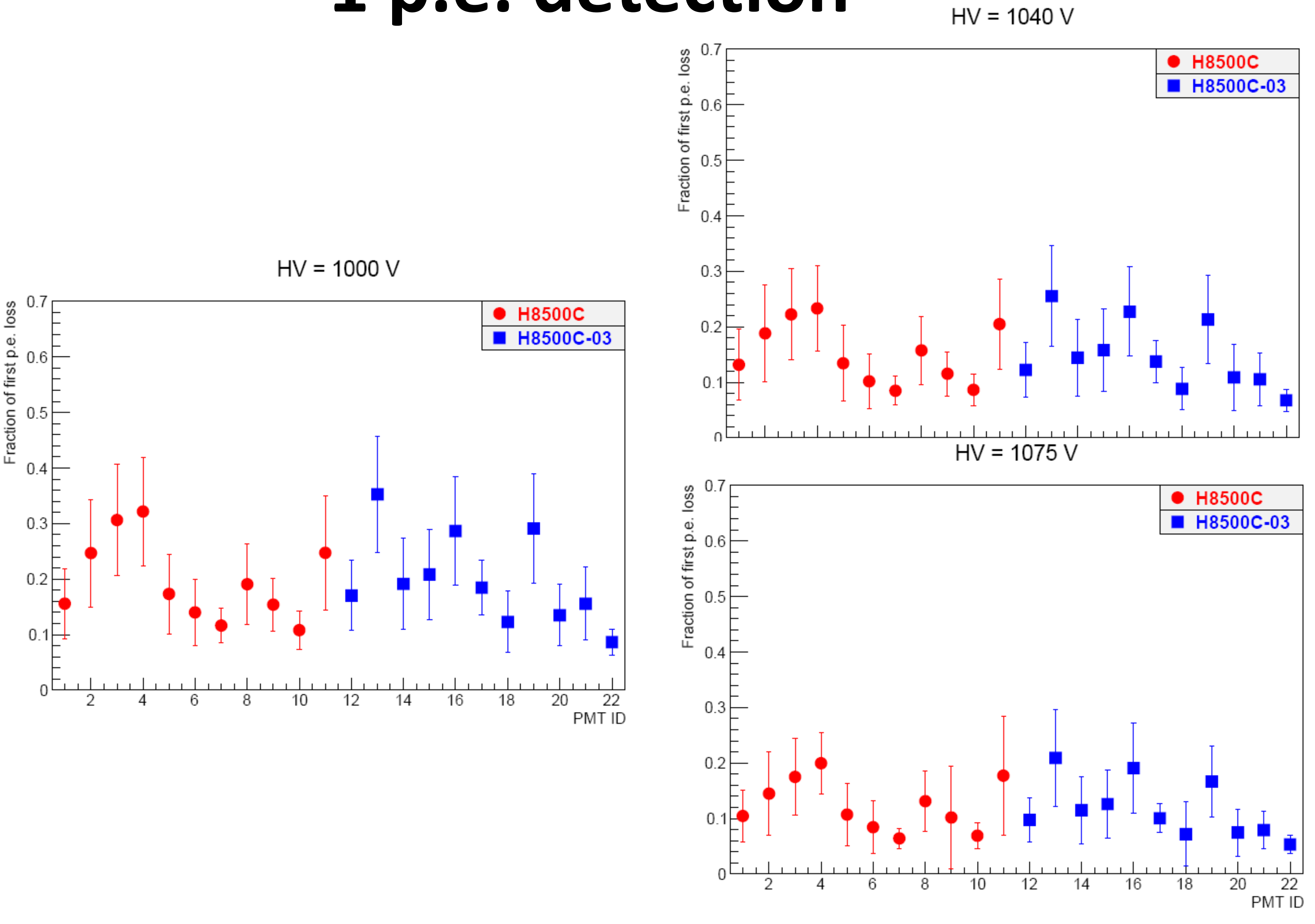




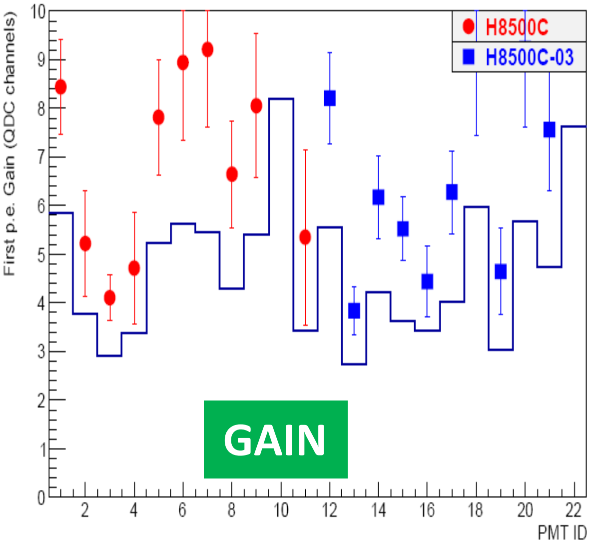


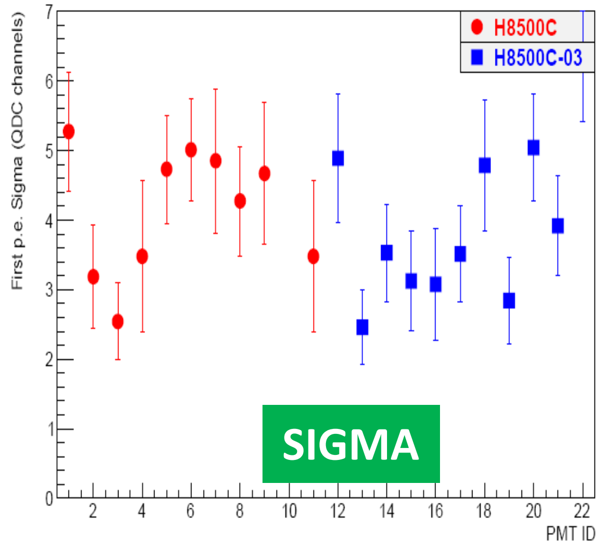


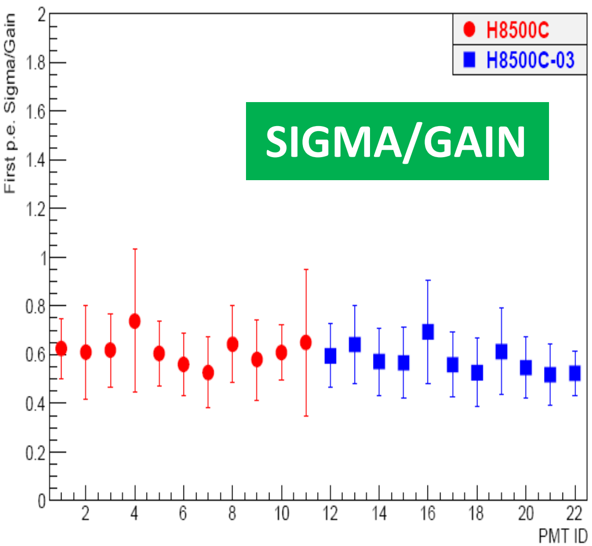
1 p.e. detection

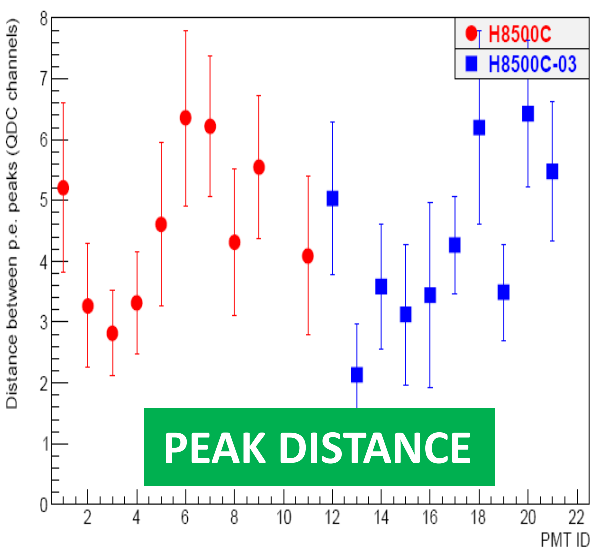


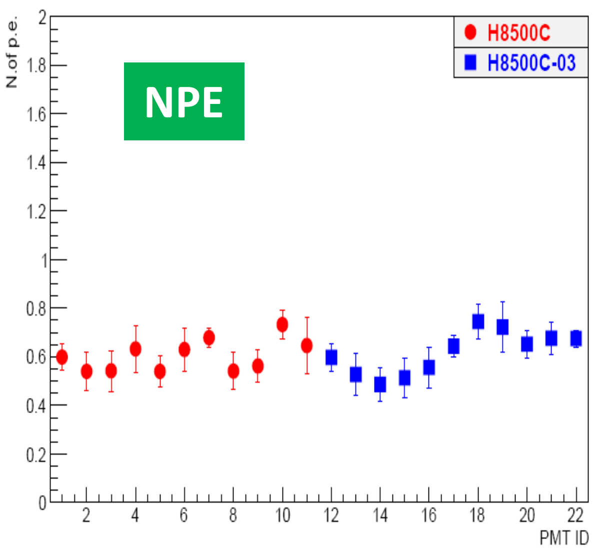
HV=1075 V

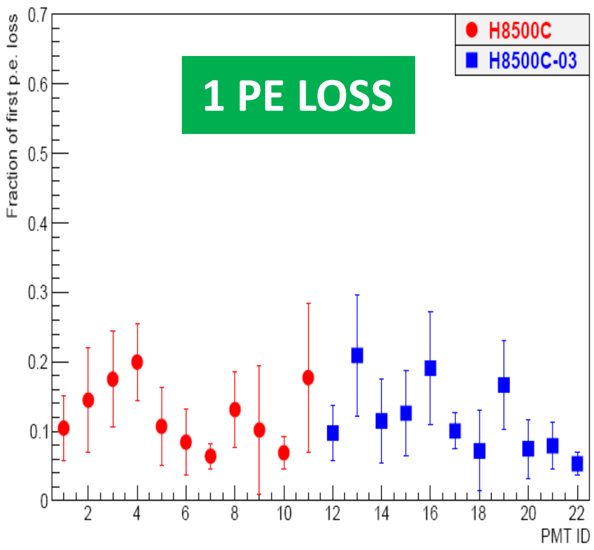

GAIN
First p.e. Gain (QDC channels)
PMT ID
H8500C
H8500C-03


SIGMA
First p.e. Sigma (QDC channels)
PMT ID
H8500C
H8500C-03


SIGMA/GAIN
First p.e. Sigma/Gain
PMT ID
H8500C
H8500C-03

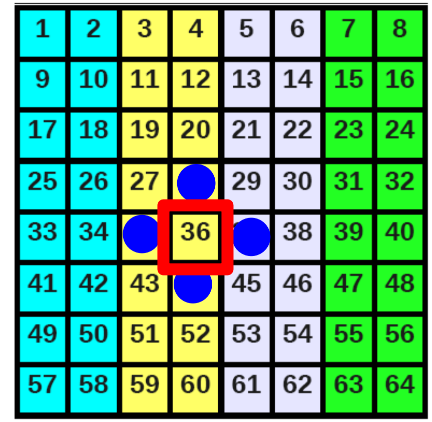

PEAK DISTANCE
Distance between p.e. peaks (QDC channels)
PMT ID
H8500C
H8500C-03

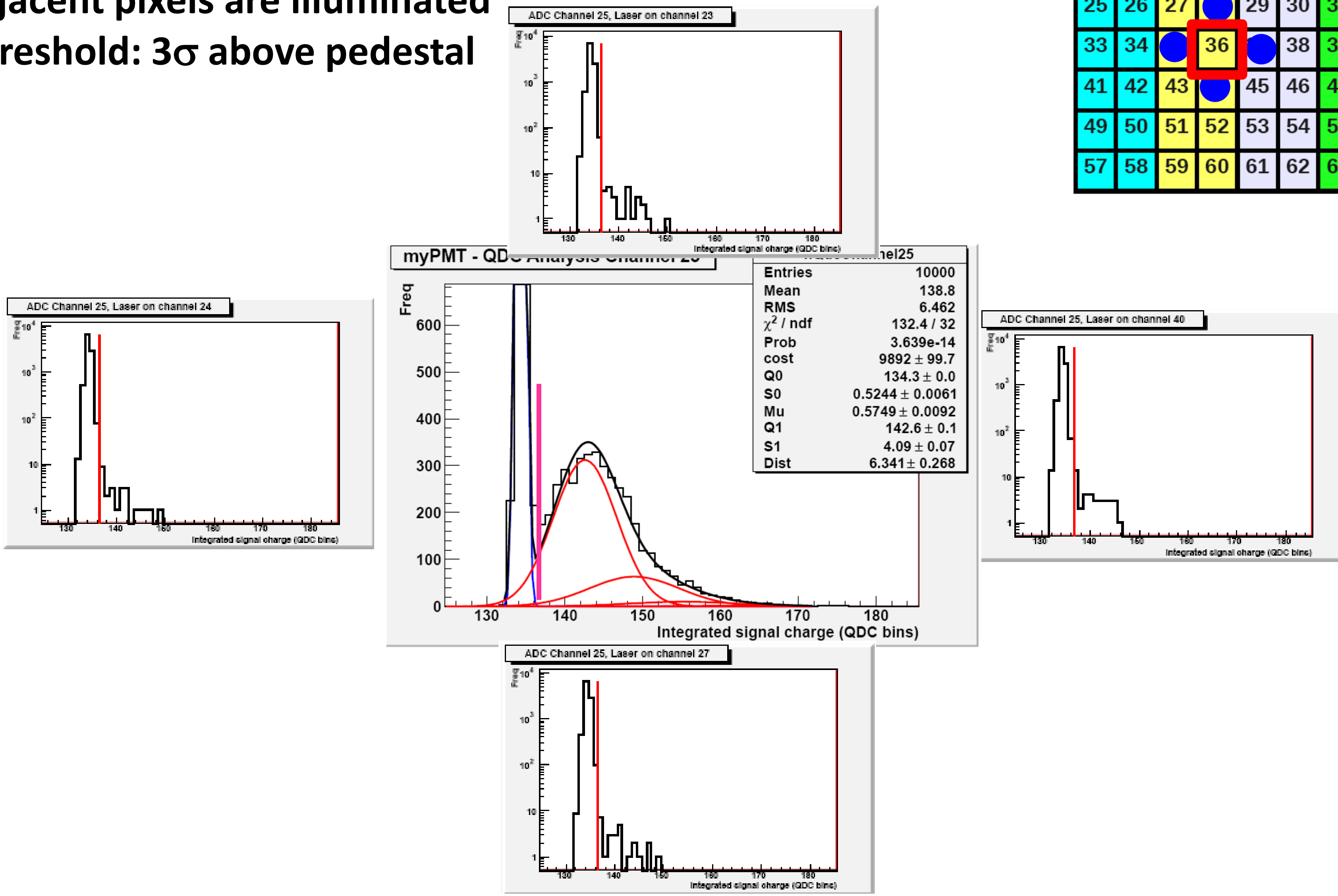

NPE
N.of p.e.
PMT ID
H8500C
H8500C-03


1 PE LOSS
Fraction of first p.e. loss
PMT ID
H8500C
H8500C-03

Cross-talk analysis

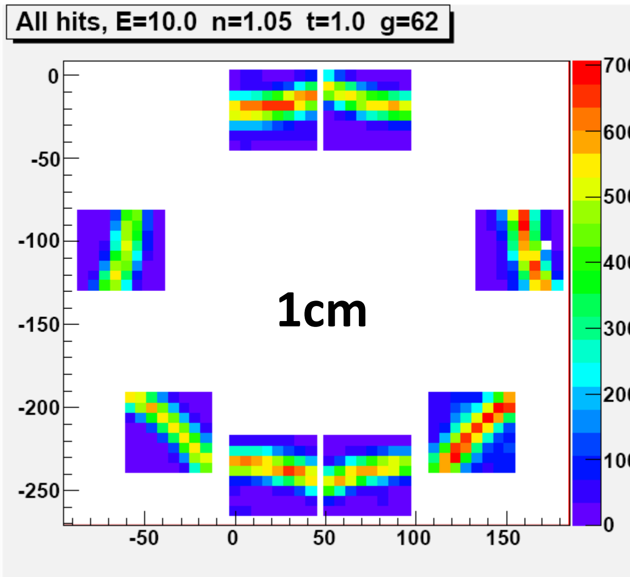
- Compare the pixel response when
- it is directly illuminated by the laser
- adjacent pixels are illuminated
- Threshold: 3σ above pedestal

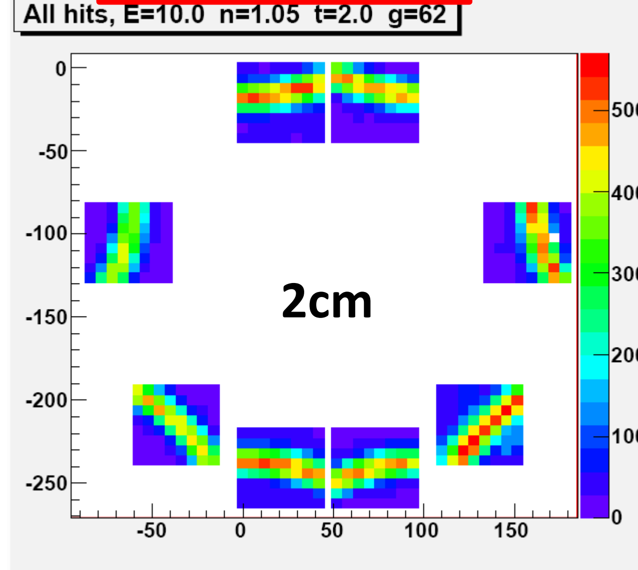


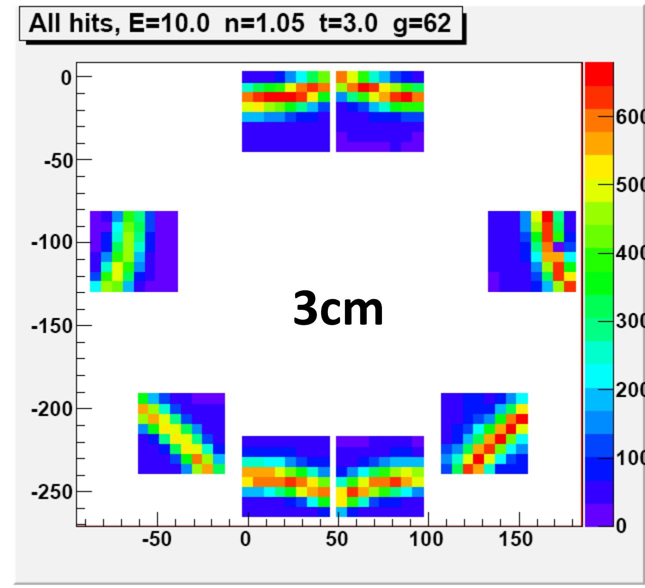


Hit distributions

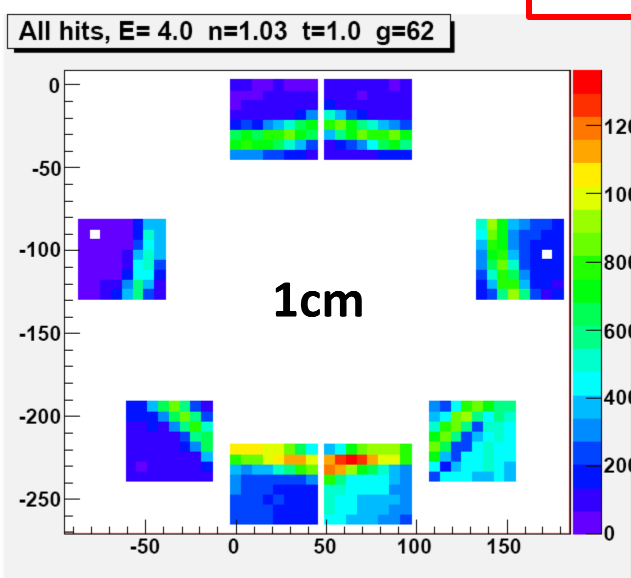
aerogel n=1.05

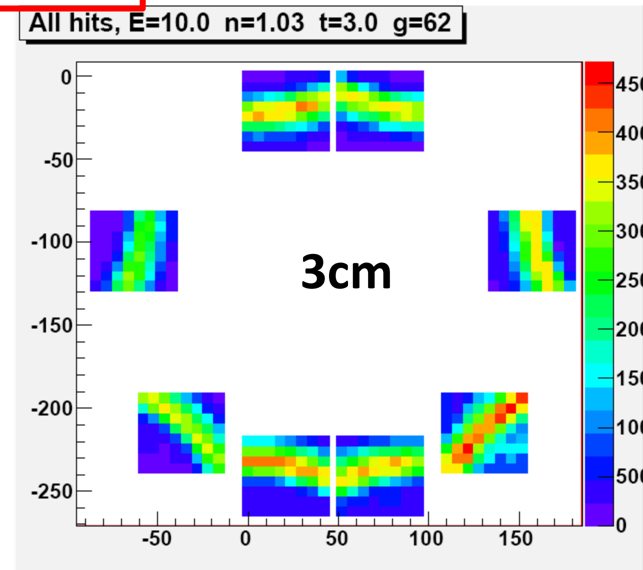






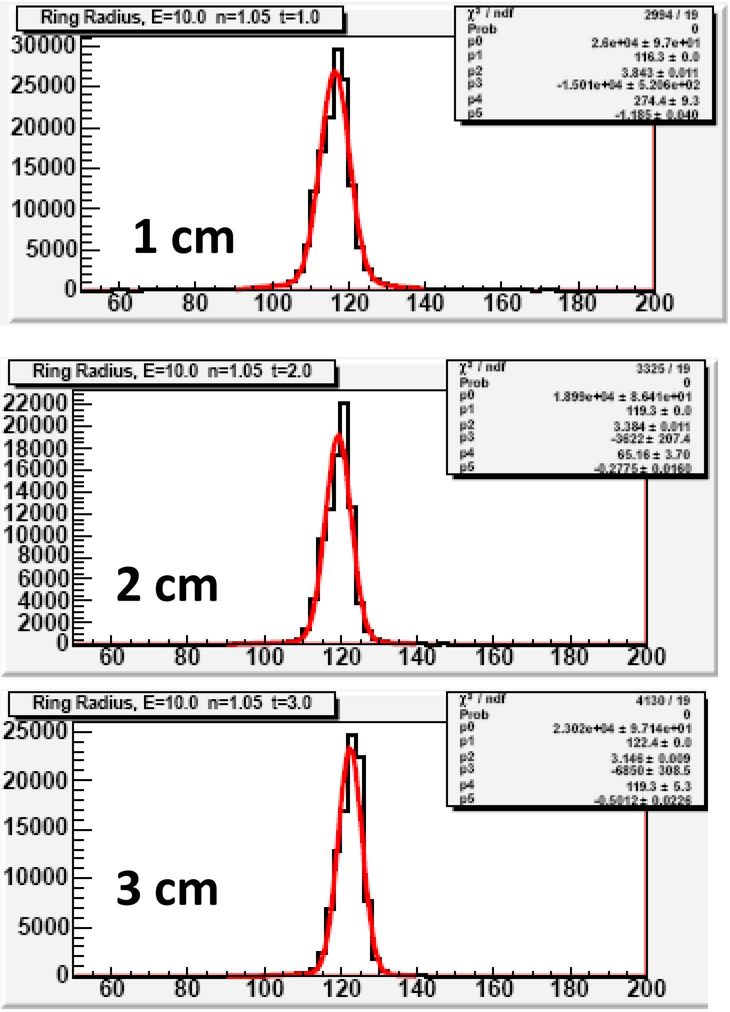
aerogel n=1.03

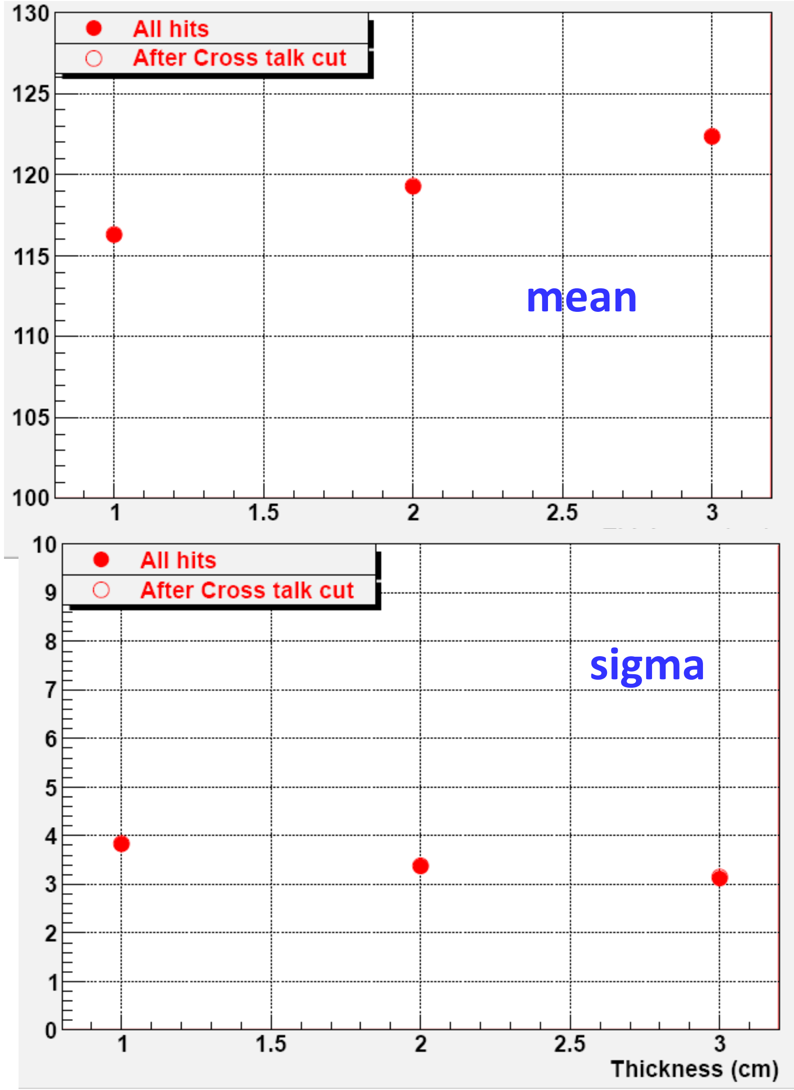




integrated distributions of hits above threshold

Aerogel with n=1.05: radius



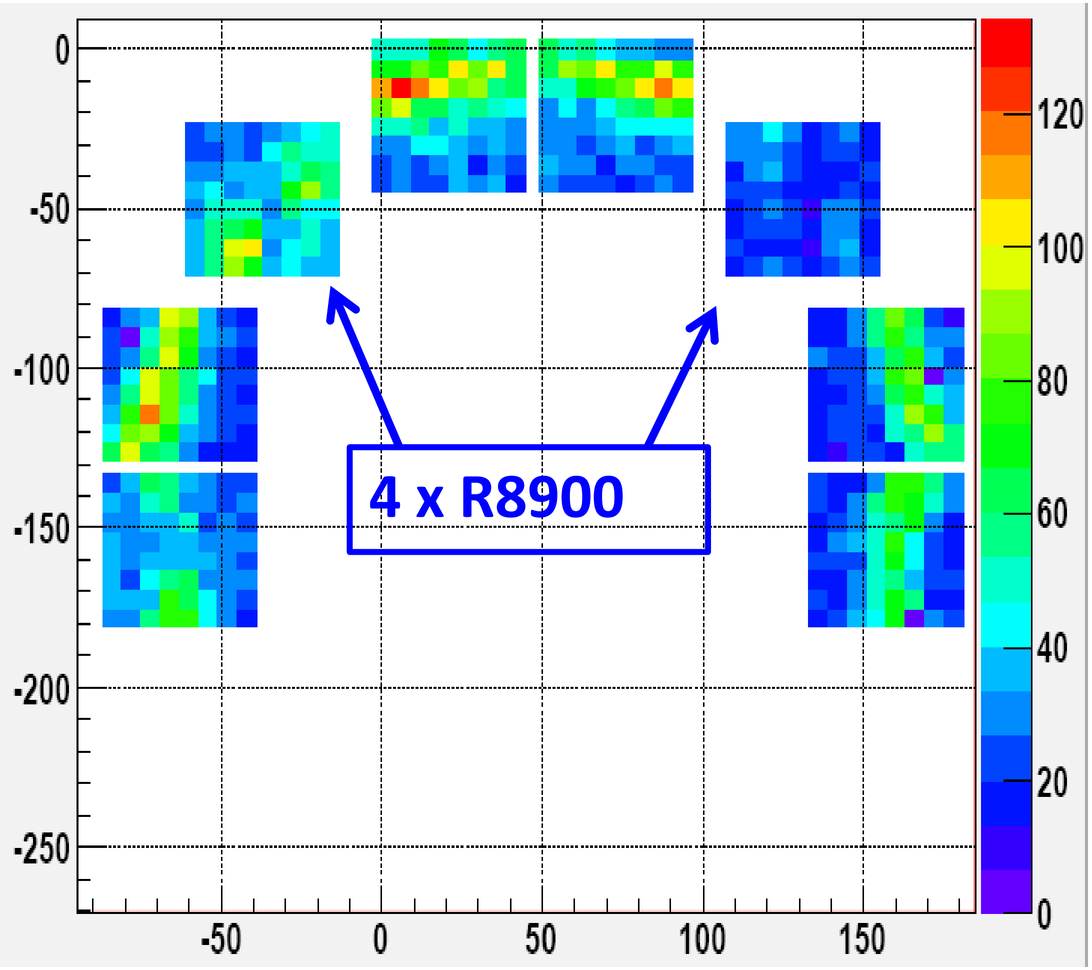


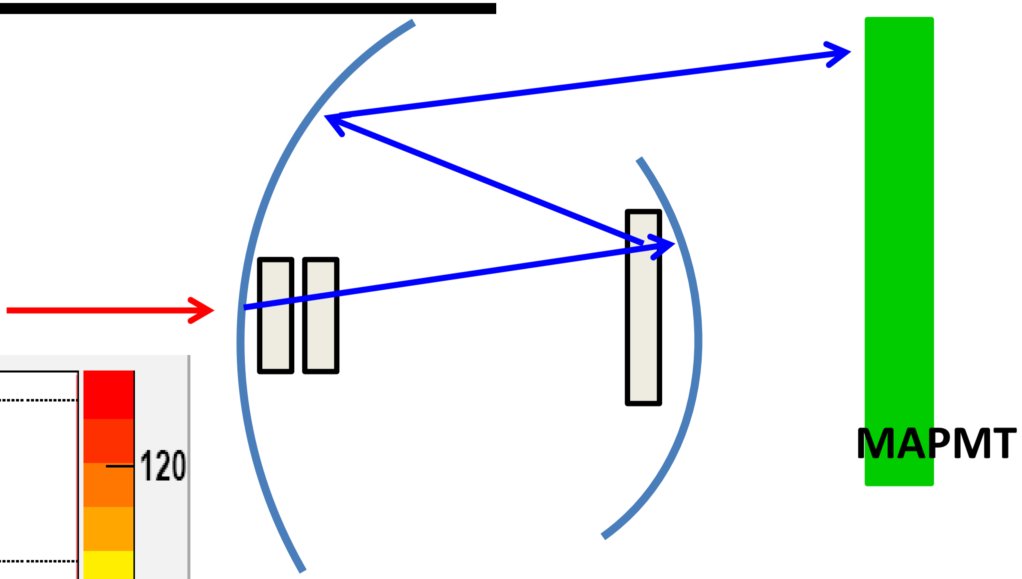
- Expected radius for pions ~110mm ⇒ measured ~120mm
  ⇒ increasing with t
- Larger radius, better resolution for larger t ⇐ more p.e.

Runs with mirrors

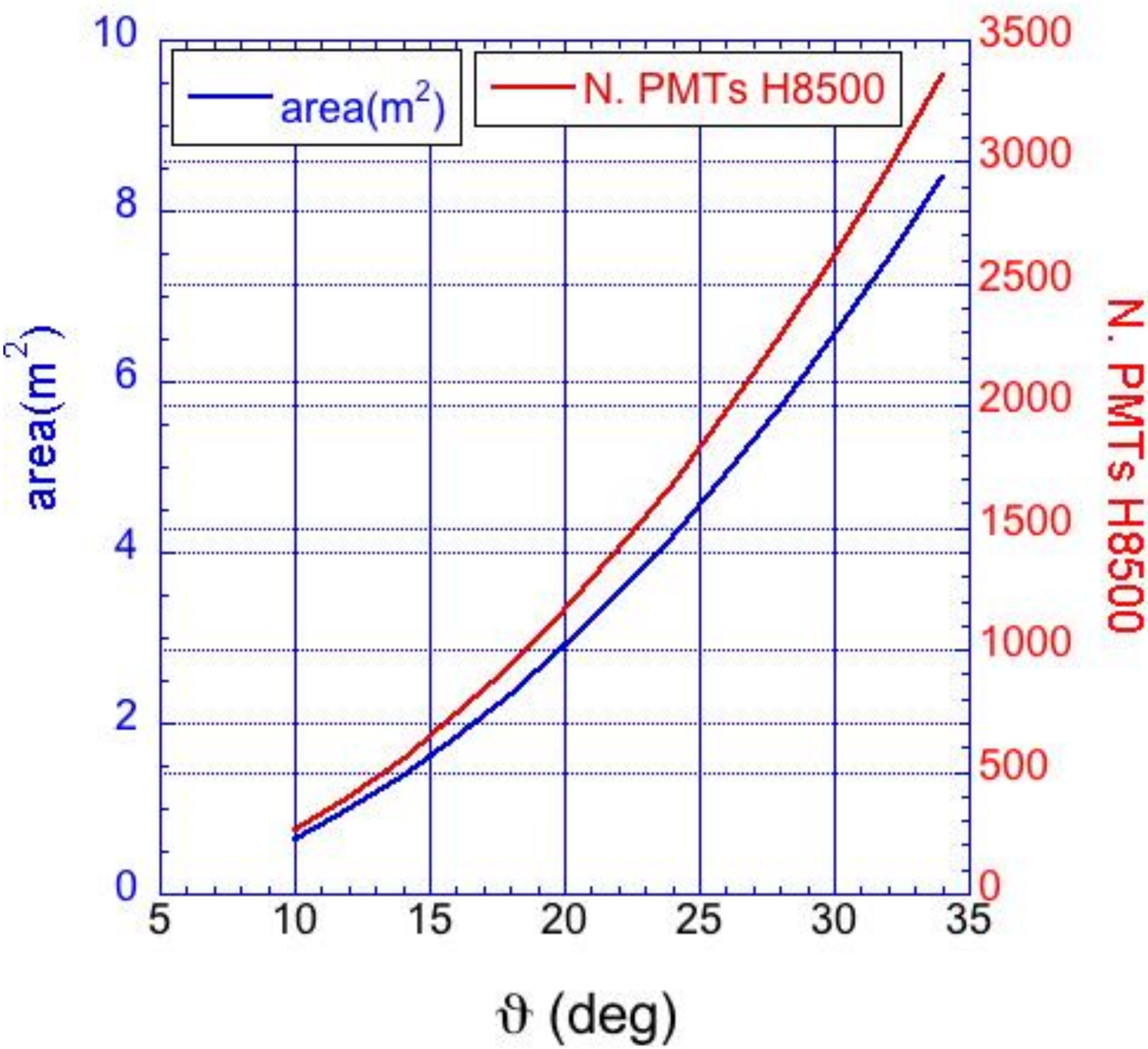
PRELIMINARY ANALYSIS

E = 1.5 GeV



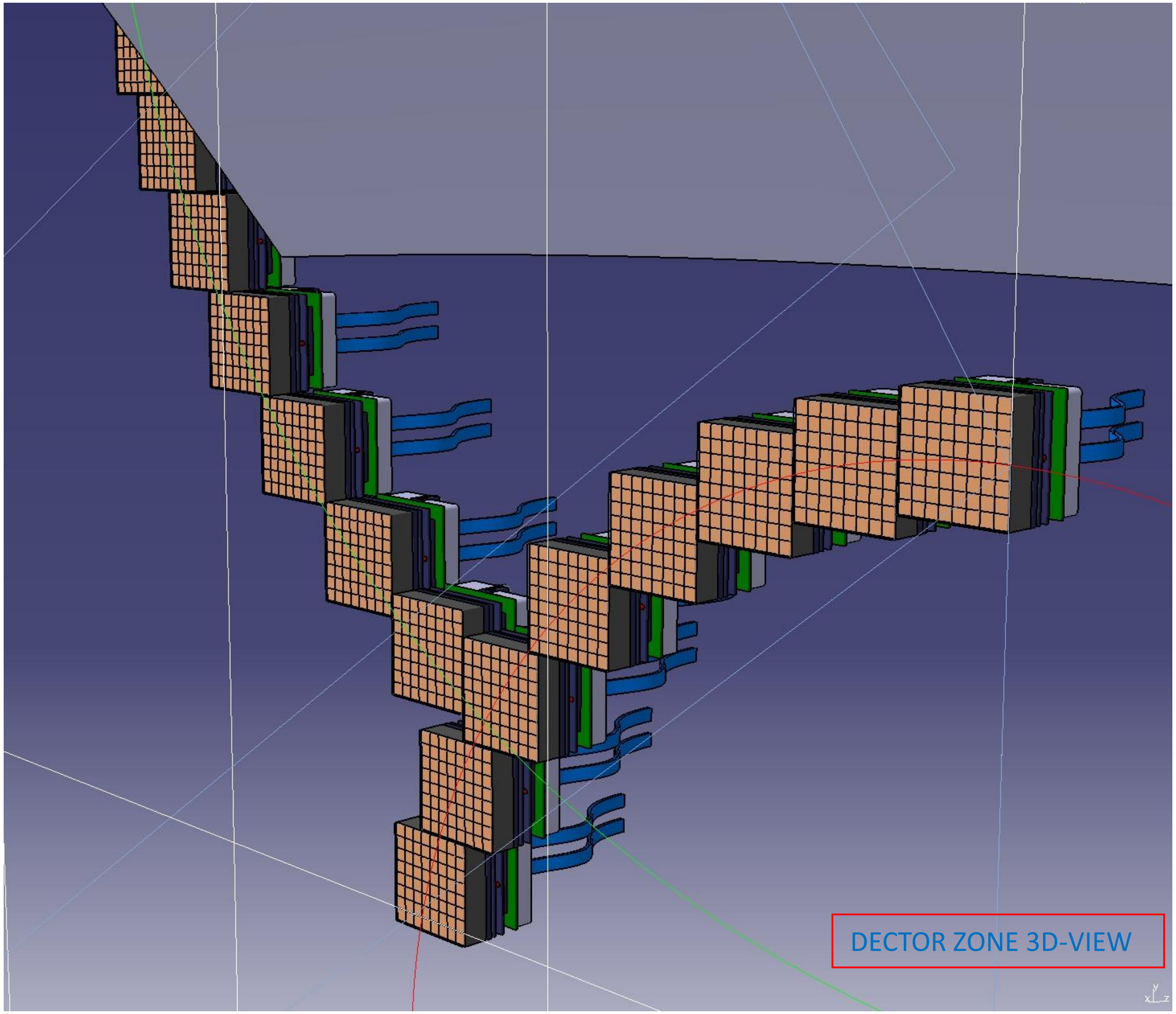


1 sector RICH



ϑ max	Area (m^2)	N. PMT	Cost K$ (H8500)
12.5	1	400	917
16	1.84	735	1684
20	2.9	1162	2662

- Reduce photon detection area as much as possible
- Use MA-PMT H8500


DECTOR ZONE 3D-VIEW