CERN-SPSC-2013-009
(SPSC-SR-115)

2013 NA62 Status report to the CERN SPSC

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for the NA62 Collaboration

NA62 Physics Goal

- **NA62 aims to measure precisely *BR*($K^+ \rightarrow \pi^+ \nu \bar{\nu}$) exploiting a novel in-flight technique based on:**

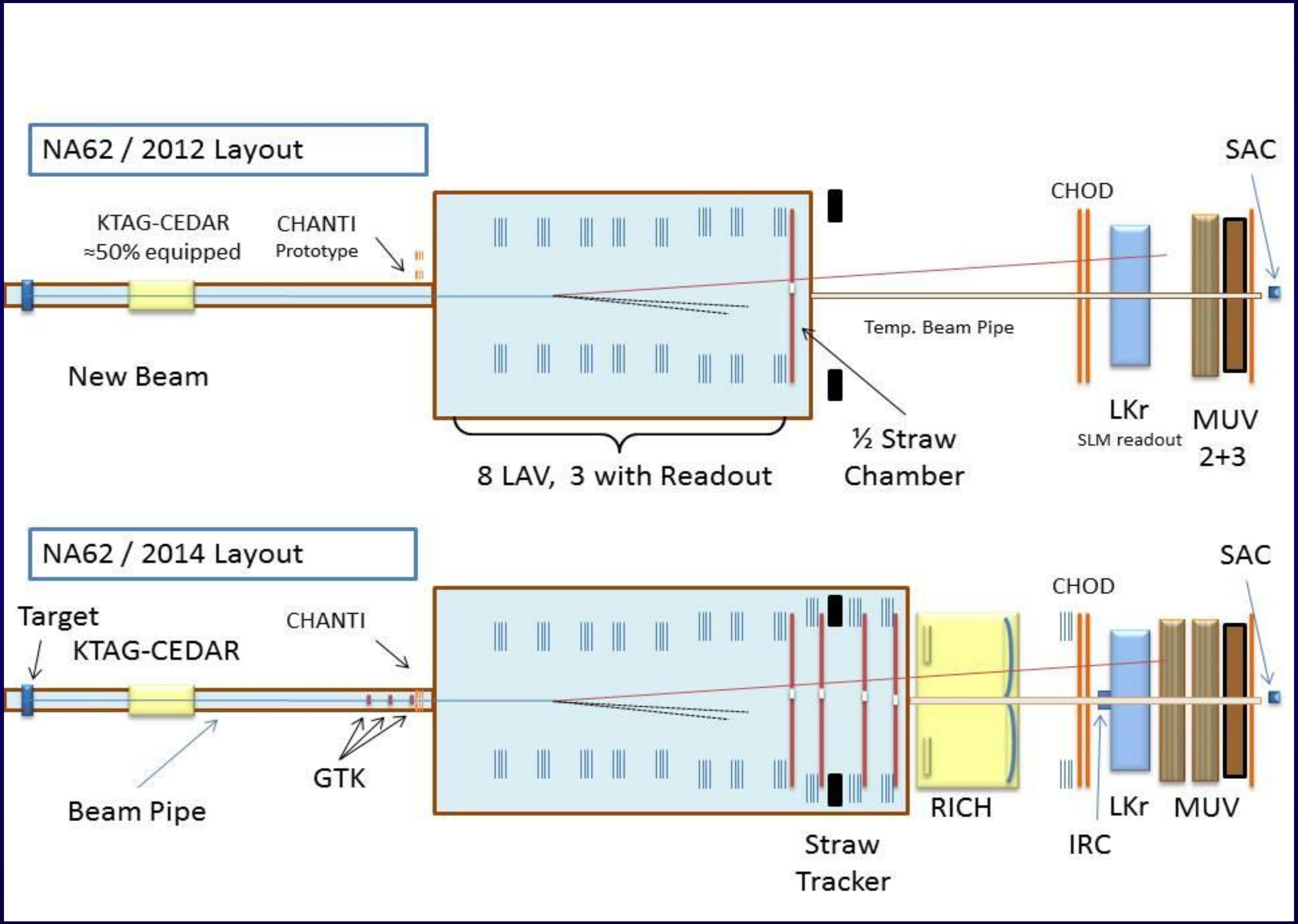
1. **calorimetry to veto extra particles**
2. **very light trackers to reconstruct the K^+ and the π^+ momenta**
3. **full particle identification**

- **State of the art:**

Decay	Branching Ratio ($\times 10^{10}$) Theory (SM)	Experiment
$K^+ \rightarrow \pi^+ \nu \bar{\nu}(\gamma)$	0.85 ± 0.07 [1]	$1.73^{+1.15}_{-1.05}$ [2]
$K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$	0.27 ± 0.04 [3]	< 260 (90% CL) [4]
$B_s^0 \rightarrow \mu^+ \mu^-$	32.3 ± 2.7 [5]	32^{+15}_{-12} [6]

[1] J.Brod, M.Gorbahn, PRD78, arXiv:0805.4119
[2] AGS-E787/E949 PRL101, arXiv:0808.2459
[3] M. Gorbahn, arXiv:0909.2221
[4] KEK-E391a, arXiv:0911.4789v1
[5] A.J. Buras et al., EPJ C72, arXiv:1208.0934
[6] LHCb, PRL110, arXiv:1211.2674

NA62 Layout: 2012 TR vs. 2014



NA62 Installation

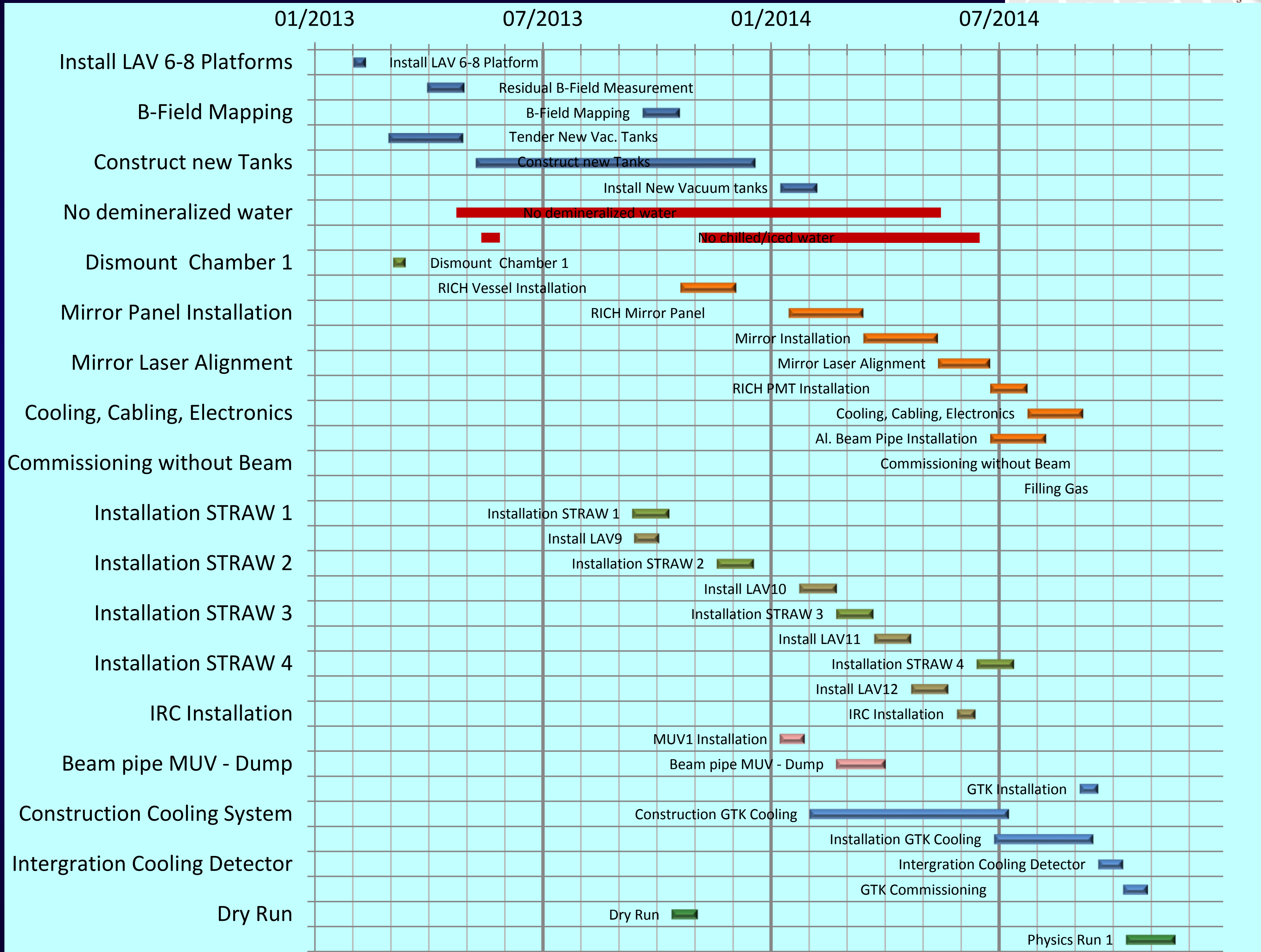
During the past year a lot of progress was made on the infrastructure, technical services, beam and detector installation

NA62 Experimental Area in October 2012

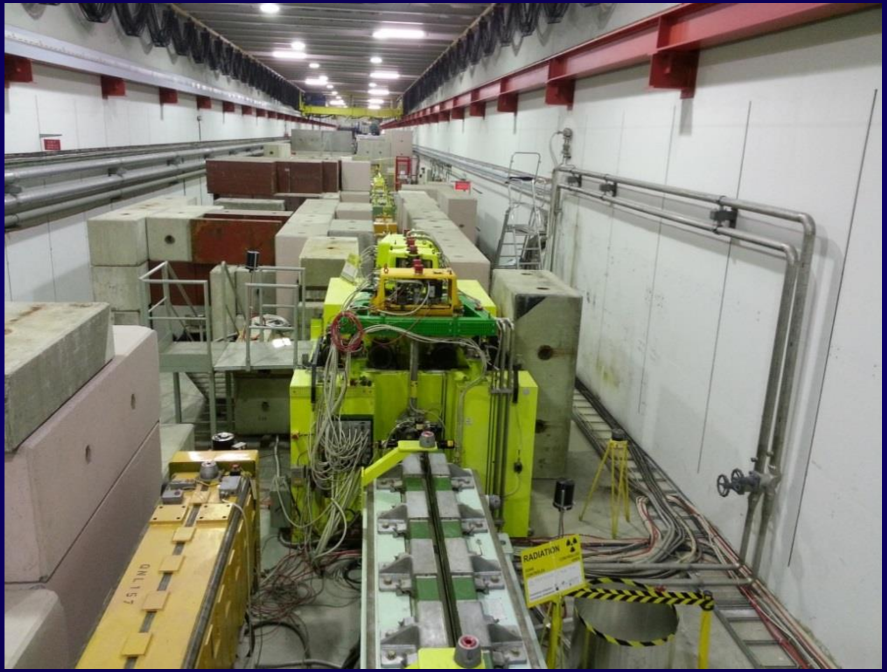
Plans Until October 2014

- **GTK:** the submission of the final ASIC design for fabrication is about to happen. In parallel we are tendering for chip thinning and flip-chip bonding
- **Straw Tracker:** the rate of the module assembly has increased significantly and is proceeding well on both production sites (CERN and Dubna). Six out of eight the modules will be completed at the end of 2013. The straw production in Dubna is in full swing and is foreseen to be completed by October 2013. Limited resources on the electronics have been a bottleneck in the preparation of the TR
- **RICH:** the subcontractor for the RICH vessel is making good progress and we look forward to receive it as foreseen in autumn this year. The fabrication of the mirror support panel as well as the design work for the mirror mounts are on the critical path
- **Photon Veto:** installation and commissioning of the last four LAV station, installation and commissioning of the IRC
- **LKr / CREAM readout:** The CAEN planning foresees the delivery of all modules between December 2013 and March 2014
- **Infrastructure:** we have started in January 2013 to prepare tenders for the remaining vacuum tanks the straw interface pieces and the aluminium beam pipe for the RICH

NA62 Schedule



Installation and Commissioning of the new beam Line (EN/MEF)



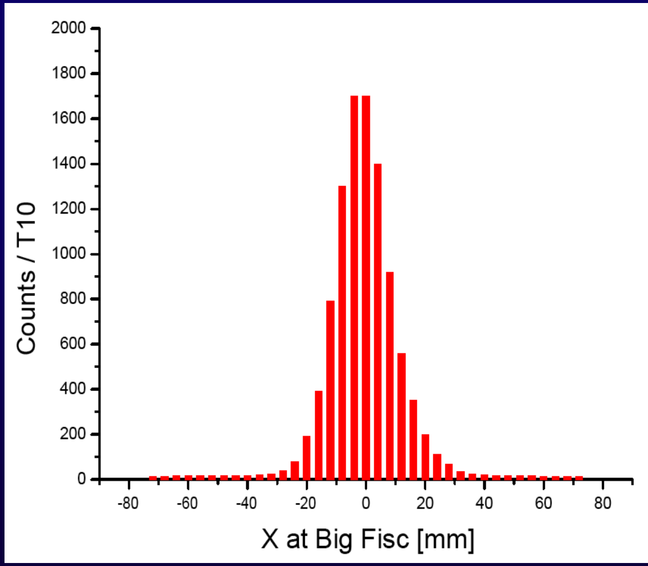
New K12:

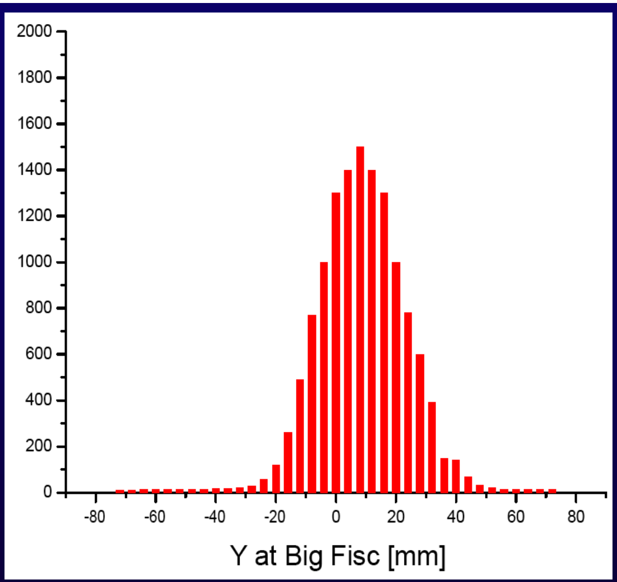
- 8 dipoles
- 5 correctors
- 10 quadrupoles
- 3 muon sweepers and magnetic collimators

Frontend of the beamline before installation of the top shielding

Measured and Simulated K12 Beam Parameters

Parameter	Measured	Simulated
2 RMS at CEDAR: X [mm]	28	27
2 RMS at CEDAR: Y [mm]	15	15
Intrinsic angular spread: X' [mrad]	< 80	70
Intrinsic angular spread: Y' [mrad]	< 80	70
RMS at Big Fisc: X [mm]	12	12.6
RMS at Big Fisc: Y [mm]	14.6	15.1
RMS at MWPC: X [mm]	14.3	14.0
RMS at MWPC: Y [mm]	17.3	17.5
Rate normalised to nominal T10 flux	$3.6\ 10^9$	$4.5\ 10^9$





Big Fisc Profiles (Measured)

NA62 TR: Use of Beam

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
28/10	29/10	30/10	31/10	01/11	02/11	03/11
	Complete installation		Beam permit	P42 tuning	K12 pencil beam	
04/11	05/11	06/11	07/11	08/11	09/11	10/11
		Long MD	No usable beam		K12 pencil beam	Kicker problem, Flooding
11/11	12/11	13/11	14/11	15/11	16/11	17/11
Flooding		Flooding ECN3	Complete pencil beam tuning	MD	BI detector tuning	
18/11	19/11	20/11	21/11	22/11	23/11	24/11
	UA9 MD	Vacuum BA2	'Full' K12 test	Full K12 beam tuning Pencil beam	Kickers	Get full beam OK
25/11	26/11	27/11	28/11	29/11	30/11	01/12
Fine tune full K12 beam	Parallel beam at CEDAR MD	Collimator tune Final K12 tune !	Beam quality studies low int.	Ion MD	Material effect measurements	
02/12	03/12	04/12	05/12	06/12	07/12	08/12
High rate studies				END OF RUN		

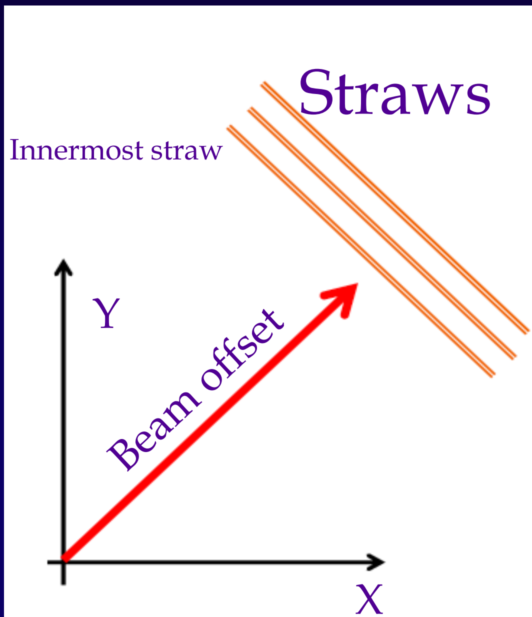
No beam
Beam tuning

NA62 muon running
NA62 kaon running

Morning
Afternoon
Evening+night

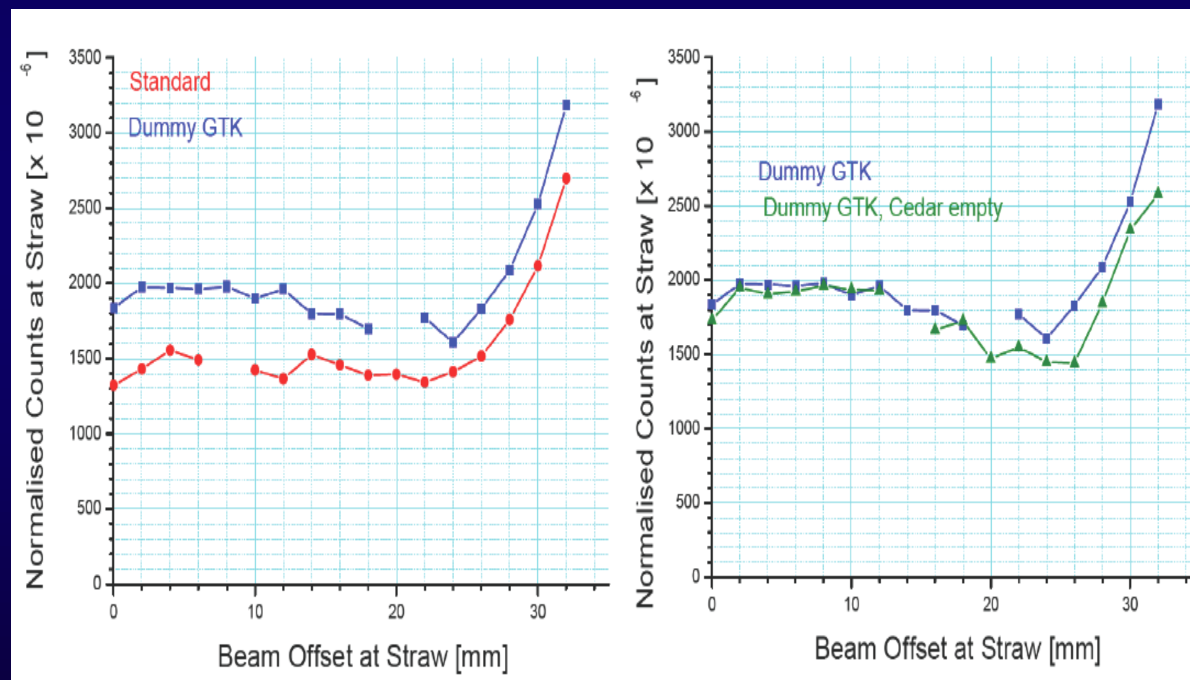
The technical run (TR) was not only a great opportunity to put together the different components of the detector but also a true occasion of integrating newcomers and fostering the Collaboration spirit

Rate on the innermost Straw as a function of beam position



Comparison of three conditions:

- "Standard": ~1.7 bar N_2 in CEDAR
- "Dummy GTK": "Standard" + 380 μm thick Si plate crossing the beam at GTK3 position
- "Dummy GTK, CEDAR empty": as above with evacuated CEDAR (to mimic H_2)

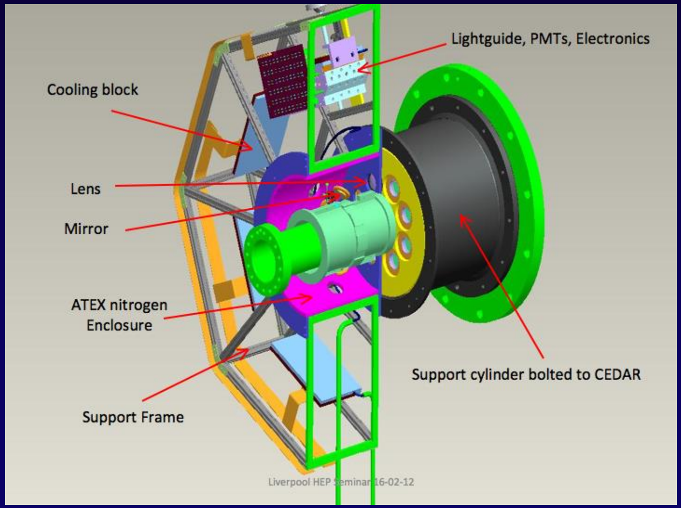


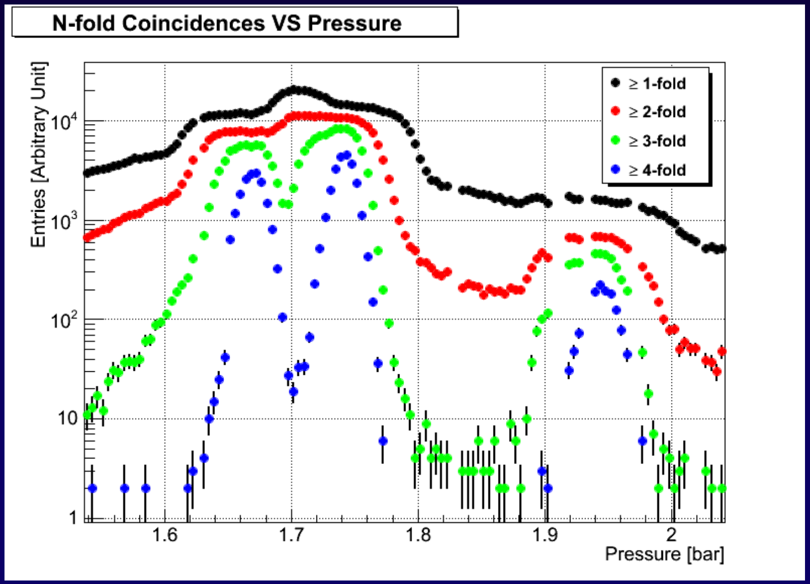
Observations:

•Si in the beam: overall increase of counting rate

•Emptying the CEDAR: Reduction of beam RMS

CEDAR / KTAG

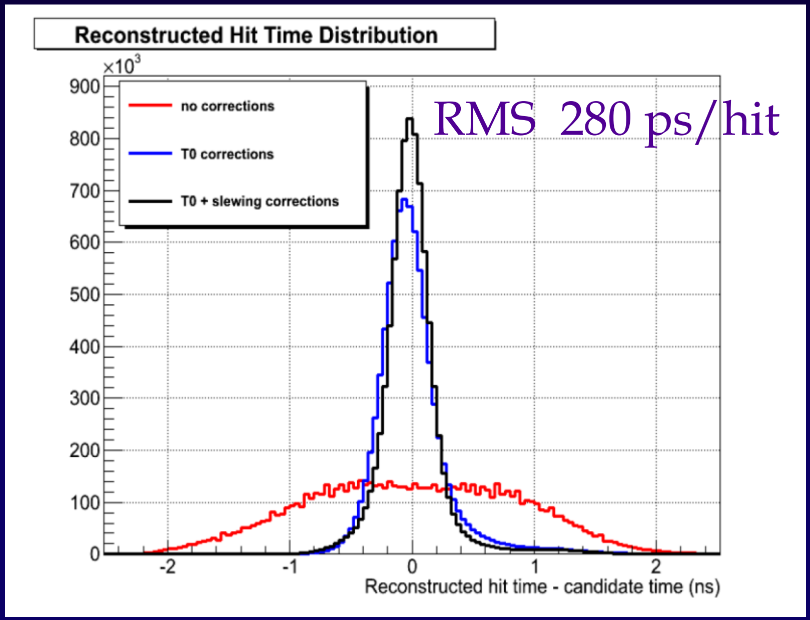


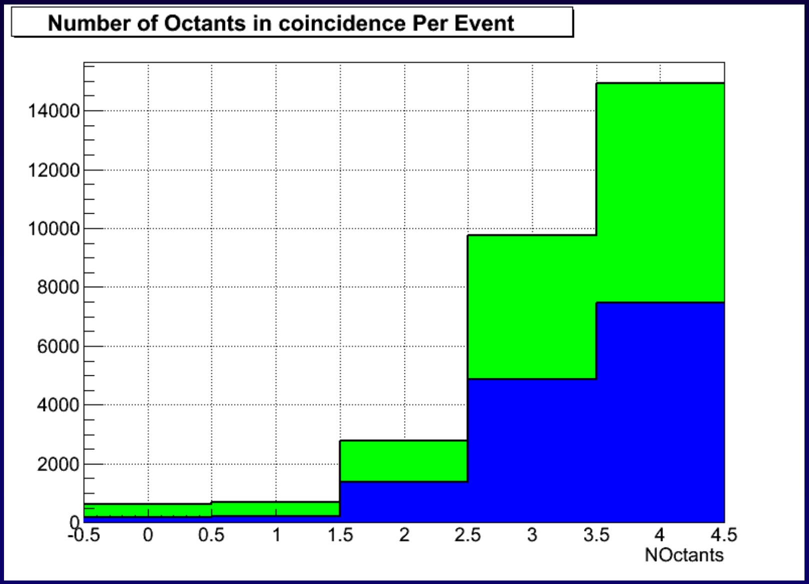


Varying the N_2 pressure the CEDAR is sensitive to pions, kaons, protons in the beam

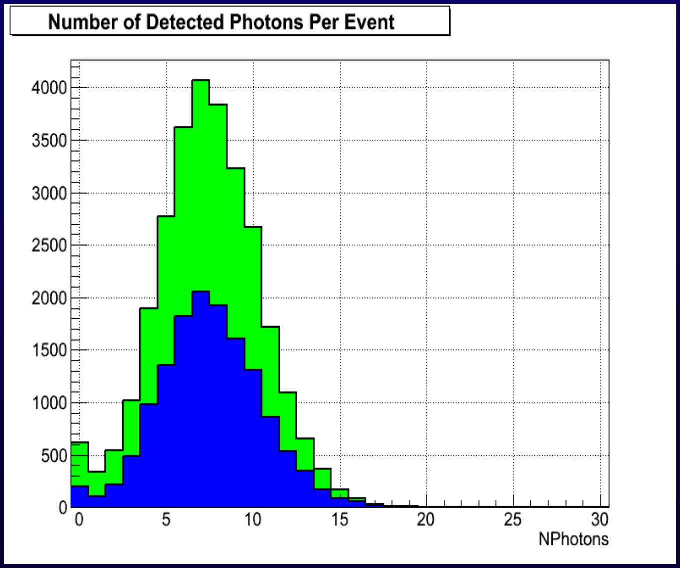
During the TR, four octants Were instrumented with 32 PMTs each

KTAG Performance in TR





CEDAR tuned to see Kaons



Green selection: π^0 in LKr

Blue selection: $K^+ \rightarrow \pi^+\pi^0$

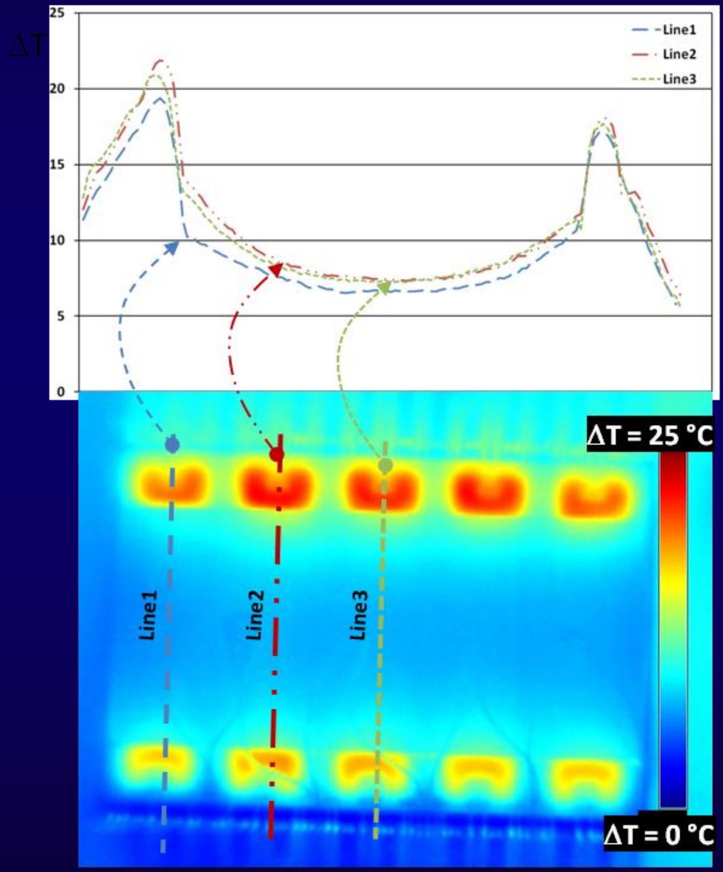
A few % of non-kaon contamination in the Green selection could be due, for instance, to π^0 originating from π^+ interactions in the dummy GTK

GigaTracKer (GTK)

- **Flip-Chip bump-bonding**
  - **Problems with glass carrier removal for dummy chips thinned down to 50 μm**
  - **Invitation to Tender submitted last week to the two qualified firms (IZM & VTT)**
  - **6 month development phase**
  - **If not successful, release specification to 150 or 200 μm for the 2014 run**
- **ASIC Design**
  - **The submission of the TDCpix ASIC in 130 nm IBM CMOS is imminent**
  - **The chip is <u>very complex</u>: 1800 fronted chains, 720 TDCs (100 ps bin) and a readout processor with**

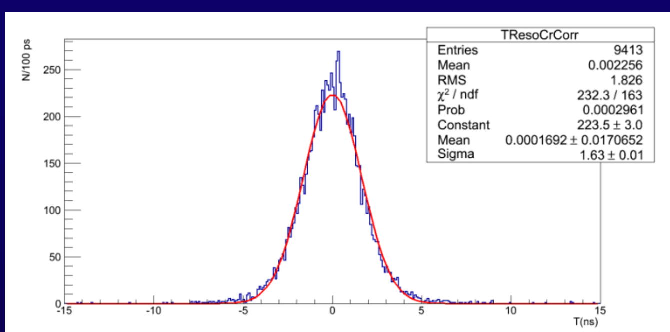
    4 × 3.2 Gbit / s bandwidth

GTK : micro channel cooling



- Baseline design: 150 parallel cooling channels
  (200 μm × 70 μm, C_6F_{14})
- Prototypes have been produced and tested under realistic conditions
- In the sensitive area the temperature variation over the whole surface is less than 6º C
- A contract has been placed with IceMOS (UK) for a pre-production run of Si-Si bonded devices

CHANTI



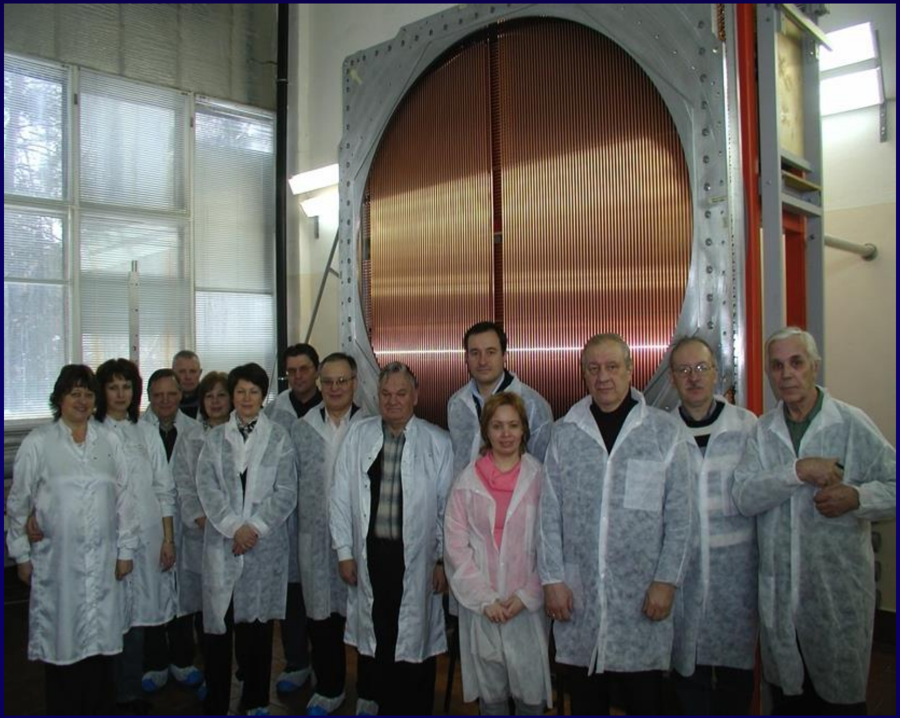
Time difference between two fired bars during the TR

The CHANTI detects the charged particles produced by inelastic interactions in GTK3

Straws

- A total of more than 4000 straws have been manufactured
- The completion of the straw production is foreseen for October 2013
- All mechanical components have been procured
- Module production has started in JINR Dubna (now two production sites: CERN and JINR)
- Module 1 was installed in the decay tank, together with its services
- During the TR Module 1 was operated under high voltage and rates measurements were performed as a function of the beam distance
- A limited amount of straws were read out

Straws



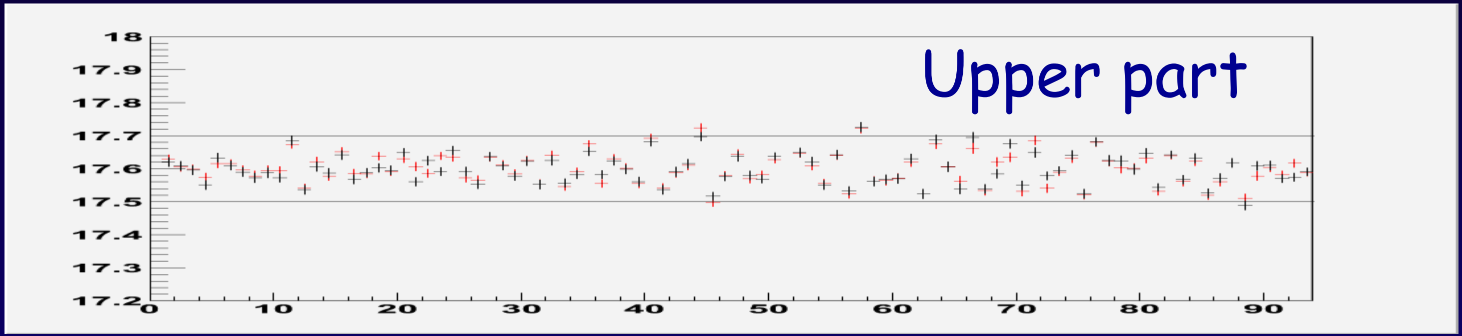
Module 3 completed in JINR Dubna

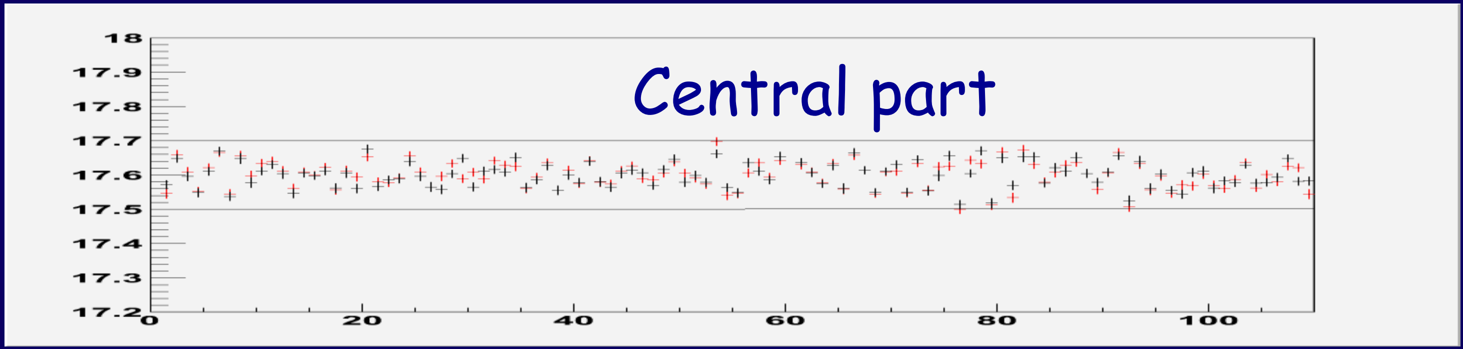
Module 1 installed in ECN3

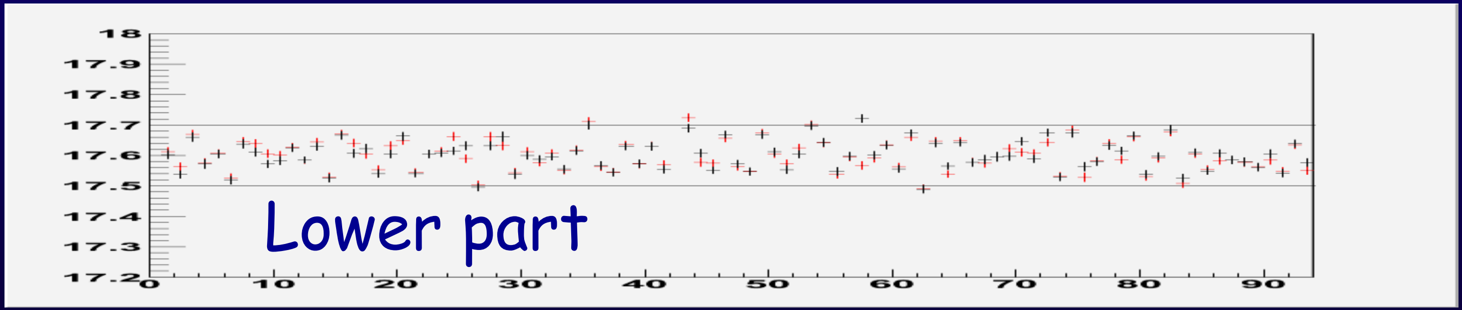
Precision of the Straw positioning

Layer 2, Module 3

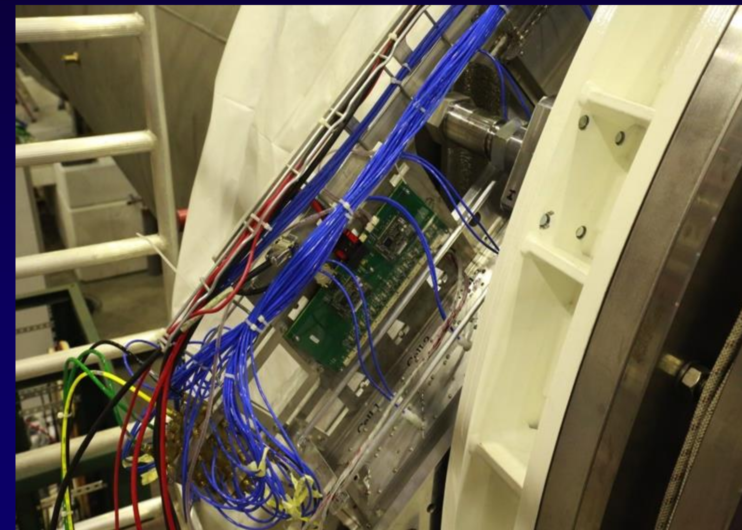
mm

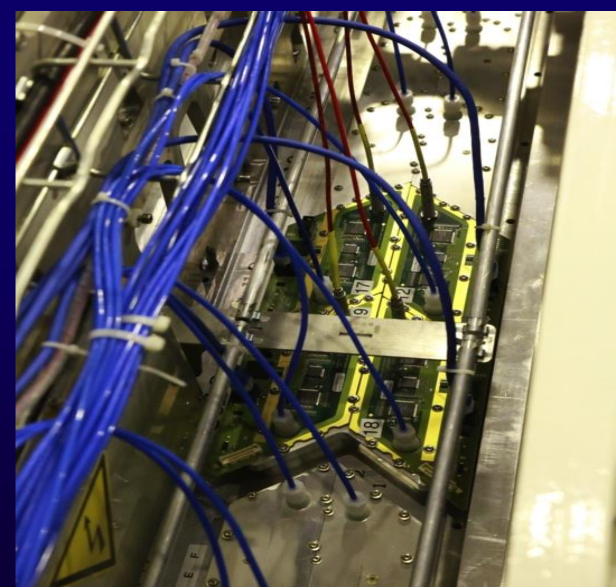






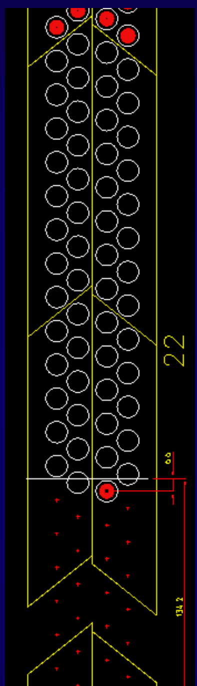
Straws

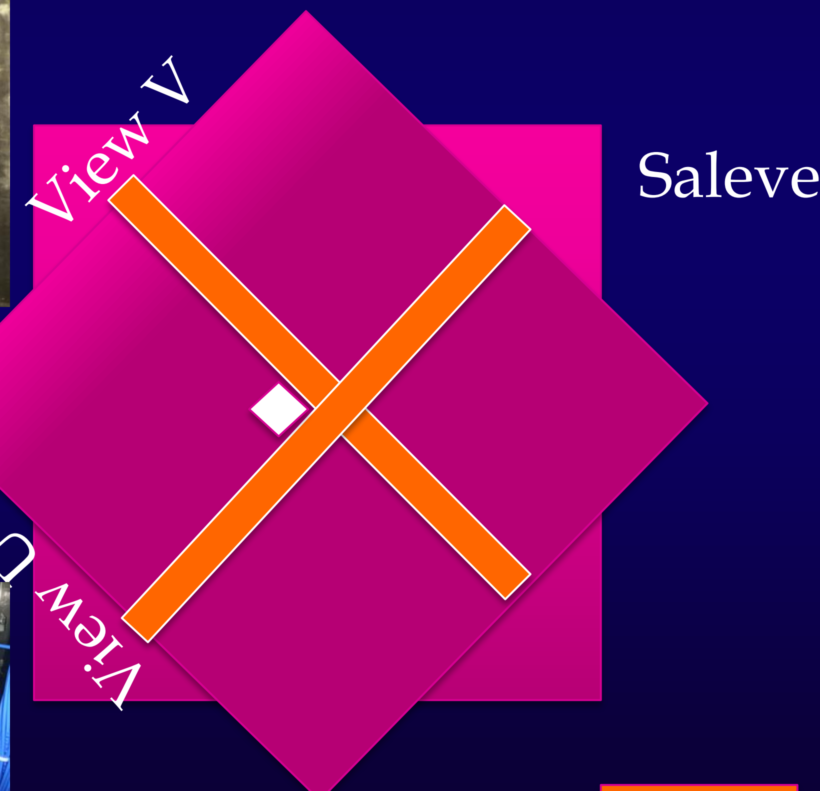


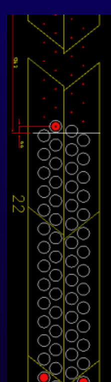


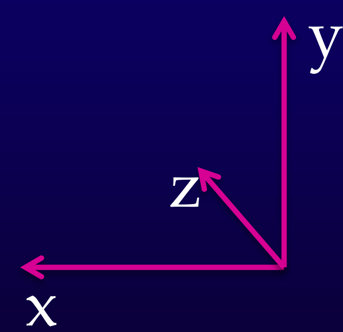
Straws at TR

- 2 views
- 4 covers per view
- 2 SRB read via VME





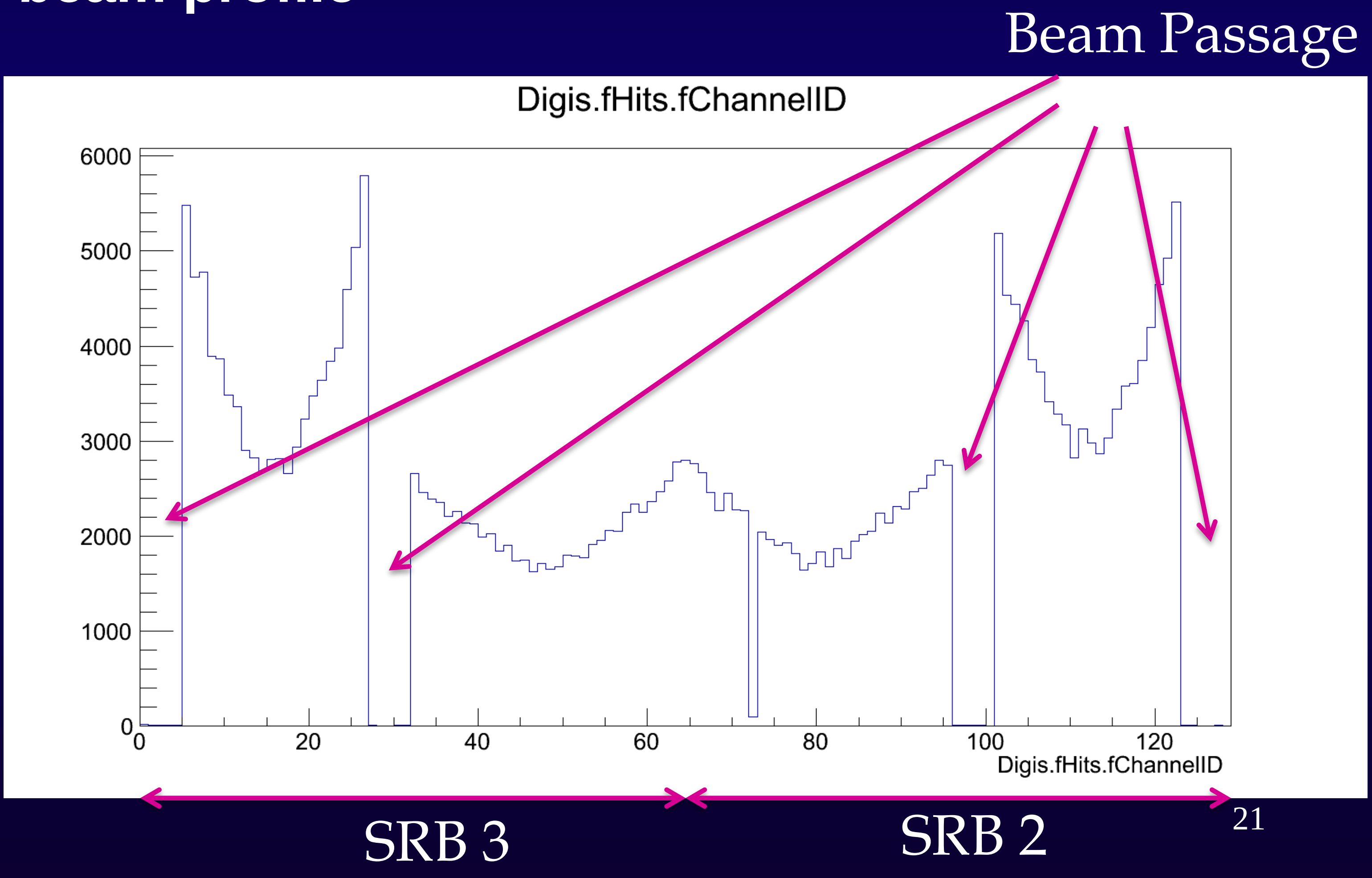




= active regions

Beam Profile seen by the Straws

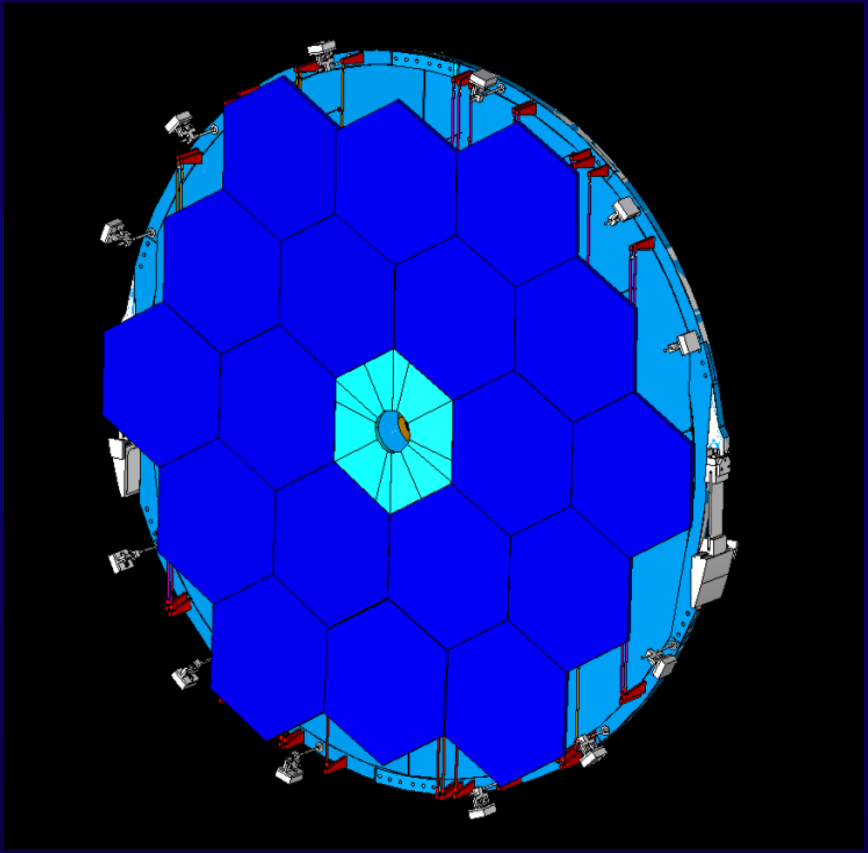
- **The straws instrumented have shown the radial beam profile**



RICH

- RICH Vessel
  - The order for the ~17 m long RICH vessel was submitted in November 2012
  - It is formed by four cylindrical sections with diameters from 3.9 m (upstream) to 3.2 m (downstream)
  - Delivery is expected by September 2013
  - The fabrication of the beam pipe and of the thin entrance window is underway
- Mirror mosaic and Support
  - Resources increased to meet the schedule
  - The honey comb panel, the support and the actuating elements are being prototyped
- PMTs and holding disks
  - Everything is procured, including the spare PMTs
  - All quartz widows and Winston cones are glued on the Al disks
- HV, Electronics
  - HV dividers are custom made and will be completed by June 2013
  - HV distribution boards are in production
  - After extensive checking, the readout electronics, based on the NINO ASIC, is now in production

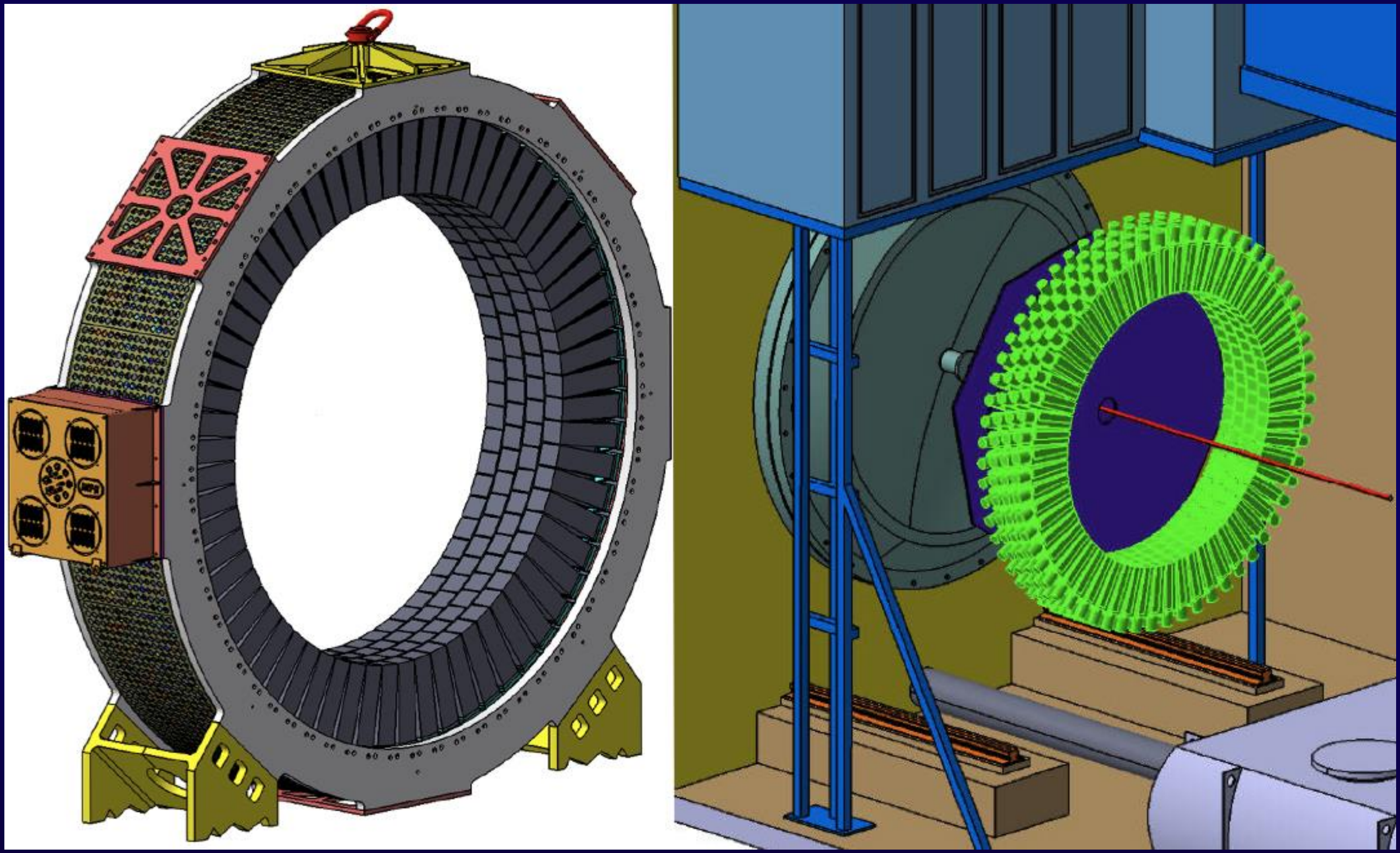
RICH



Photon Veto

- **Main Achievements in 2012:**
  - Processing of the lead glass blocks for A9, A10, A11
  - Assembly and transport to CERN of A8 and A11
  - Production of the final drawings for A12 which is operated in air and has a different design w.r.t. the other stations
  - Installation of the first eight stations
  - Commissioning the electronics for the first three stations
  - Development of the firmware for the L0 trigger for the LAV
  - Installation of the SAC detector in the final position and commissioning during the TR

LAV: A12 Design



IRC PLANS

	2013			2014		
Activity	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**
Production of scintillator tiles	■					
Machining of the tile shape and holes		■				
Assembly of the IRC			■			
Commercial digitizers study and decision on the IRC/SAC RO system	■					
Integration of the RO in the NA62 DAQ			■	■		
Integration of IRC in the NA62 setup					■	
Final test and commissioning					■	

The elements of the IRC detector are:

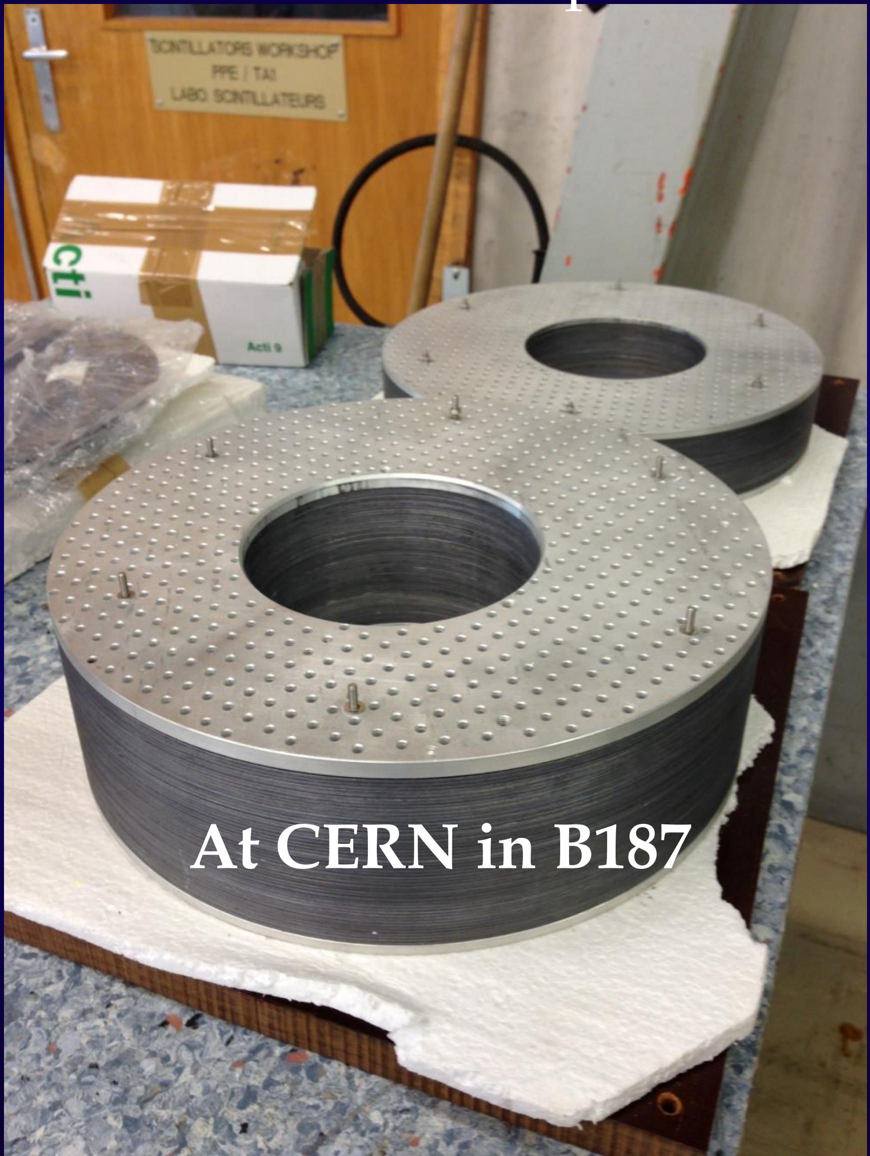
- mechanics and lead plates: produced and transported to CERN in 2012. The lead plates are made of Lead-Antimony alloy which has higher Brinnel index and is more appropriate for work.
- PMTs: the four PMTs for the IRC are available in the LNF-INFN laboratory and are Hamamatsu R6427 type. They provide high gain (>10^6) and fast signal risetime (1.7ns)
- Scintillating fibers: BCF92 from Bicron ordered in December 2012, expected to be delivered in June 2013
- Scintillating tiles: BC-400 type of scintillator from Bicron ordered at the end of March 2013. Expected delivery is June, 2013.

After the painting of the scintillating tiles at CERN they will be transported to Sofia for machining (cutting and drilling) profiting from the existing drilling matrix used for the machining of the lead plates.

IRC

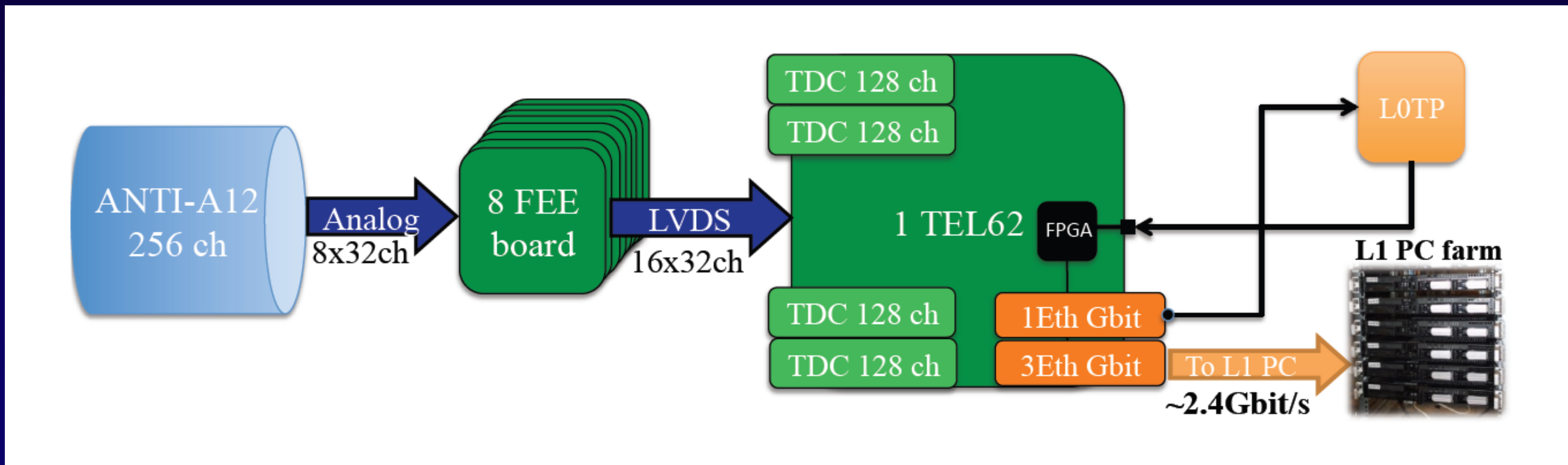
Beampipe

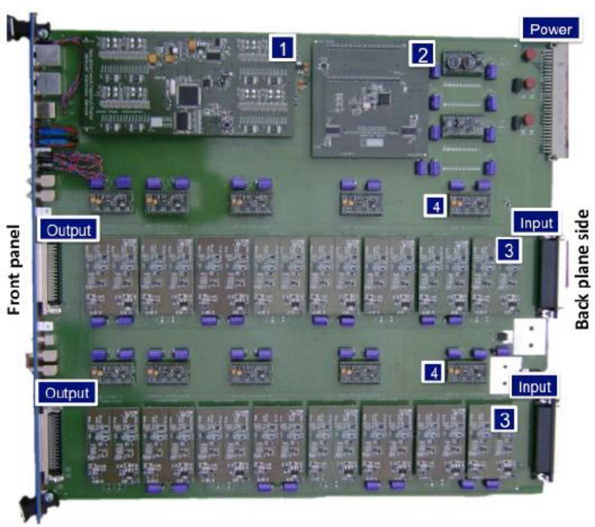
Drilled lead plates

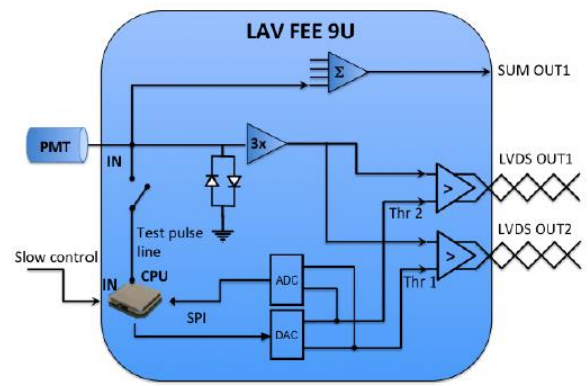


At CERN in B187

LAV FEE


ANTI-A12
256 ch
Analog
8x32ch
8 FEE
board
LVDS
16x32ch
TDC 128 ch
TDC 128 ch
1 TEL62
FPGA
TDC 128 ch
TDC 128 ch
1Eth Gbit
3Eth Gbit
L0TP
L1 PC farm
To L1 PC
~2.4Gbit/s

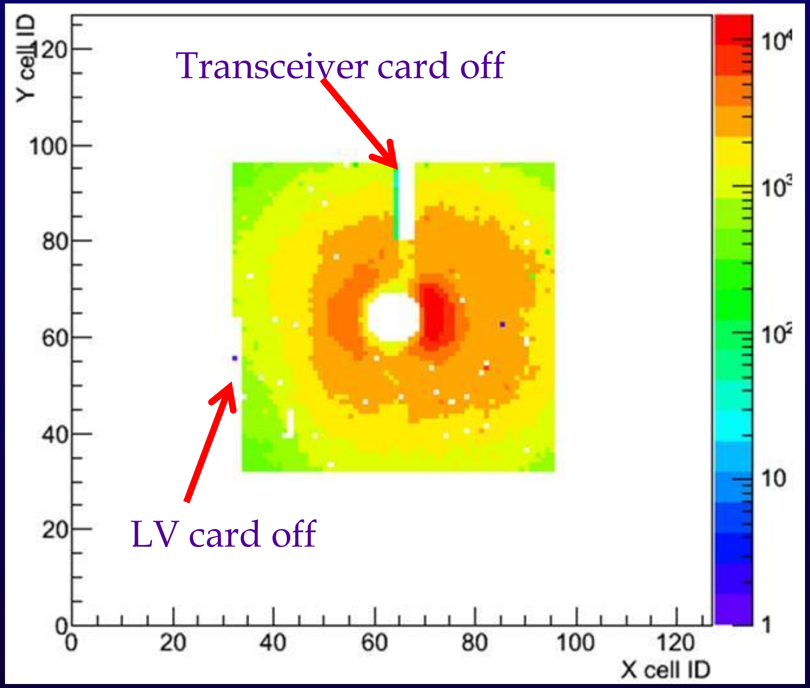

Power
1
2
4
Input
3
Output
Front panel
Back plane side
4
Input
Output
3

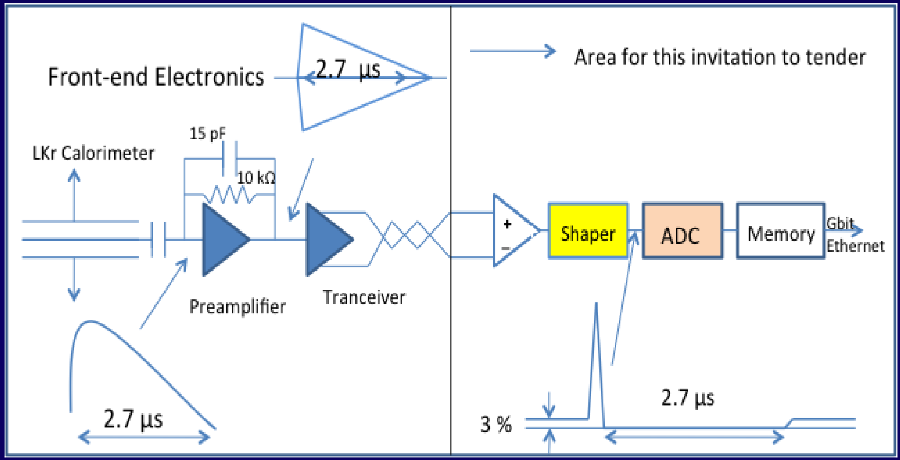

LAV FEE 9U
SUM OUT1
PMT
IN
3x
LVDS OUT1
Thr 2
Test pulse
line
LVDS OUT2
Slow control
IN
CPU
ADC
Thr 1
SPI
DAC

LKr

To reconstruct kaon decays and check the the performances of the LKr (unused since 2008), a 64 x 64 cell region was read out during the TR using the old readout

~20 tons liquid Kr calorimeter
NA48 legacy, cold amplifier

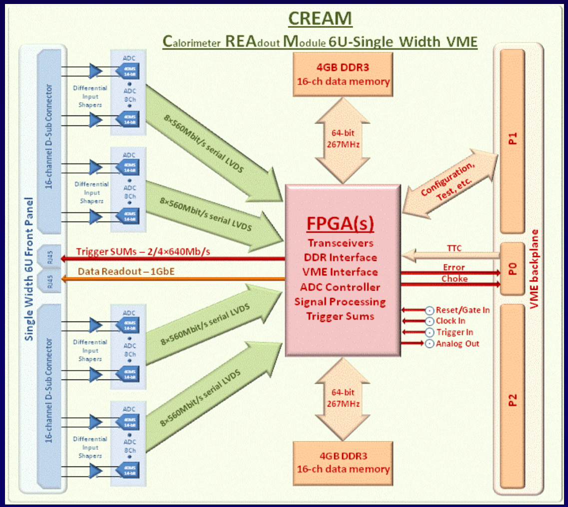


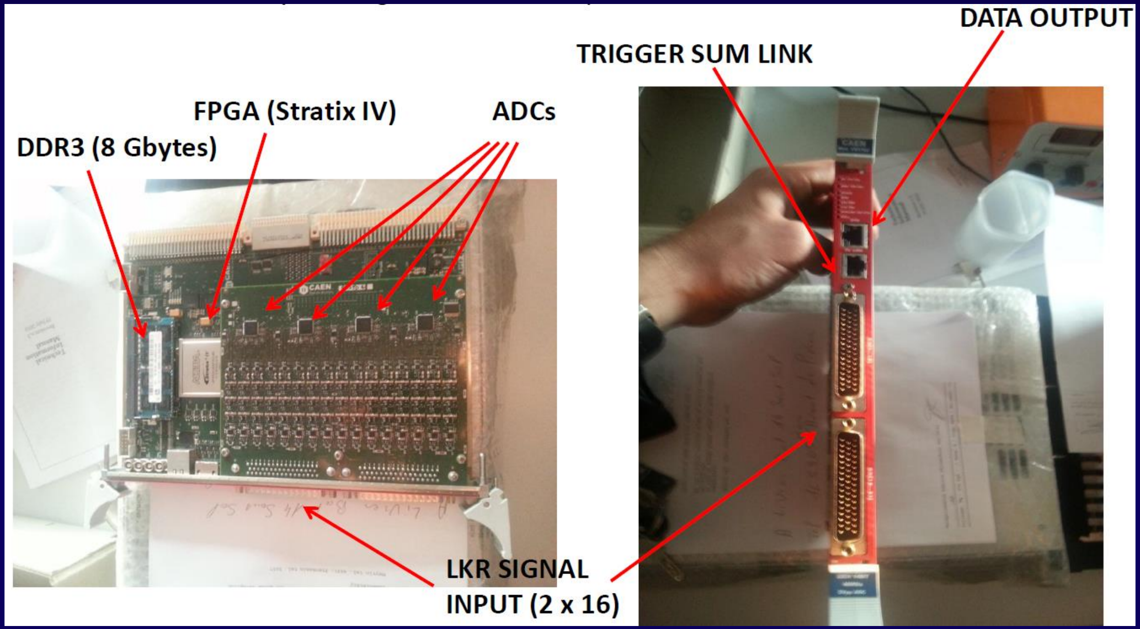


A campaign is underway to check the entire Lkr to make sure that possible malfunctioning electronics is repaired before the 2014 run

Lkr New Readout: CREAM

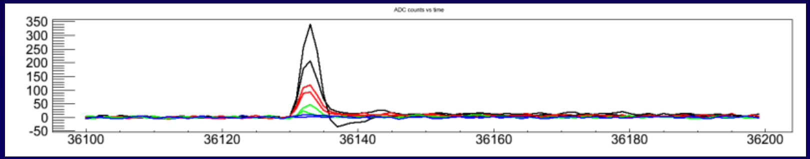
CAEN CREAM Prototype

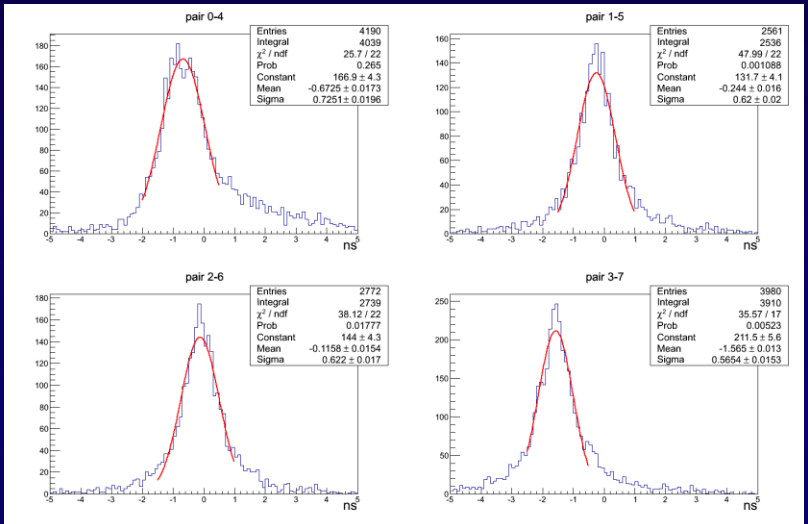




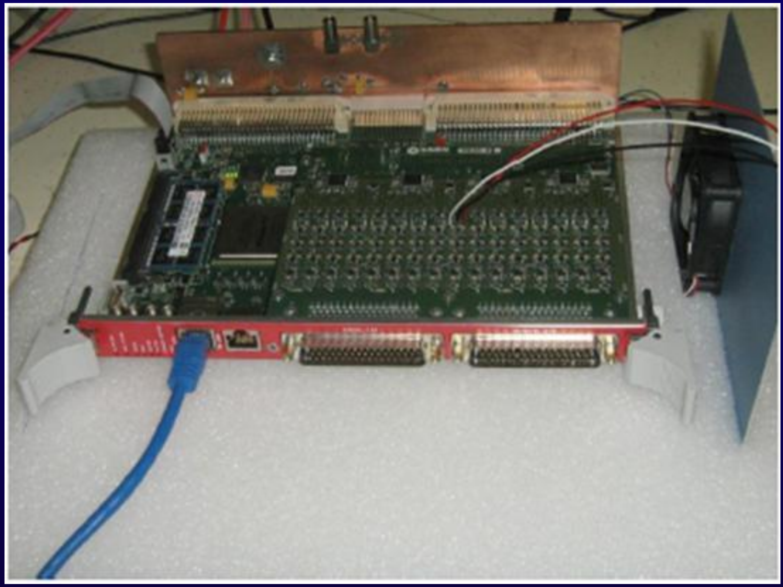
We need ~500 CREAM to readout the LKr
14 bit linear 40 Ms/s FADC
Four prototypes delivered on March 27 2013
Full Production ~ One Year
Crates, VME Bridges already purchased

LKR CREAM in TR



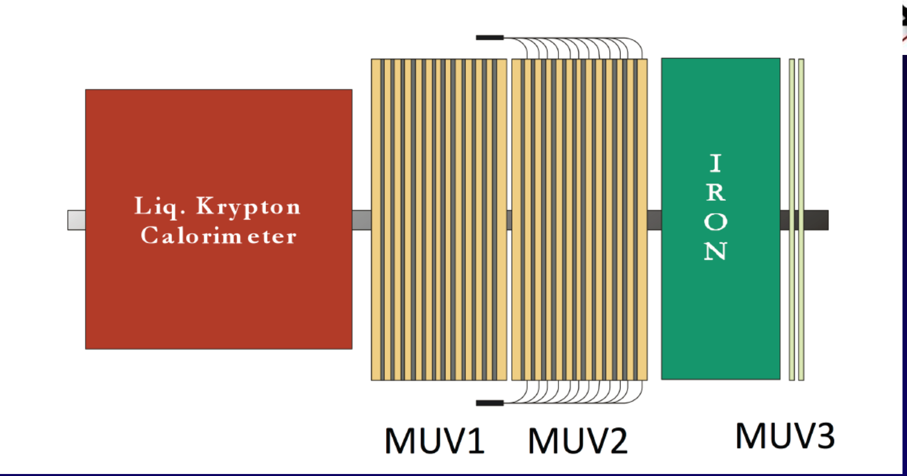


Good timing performance



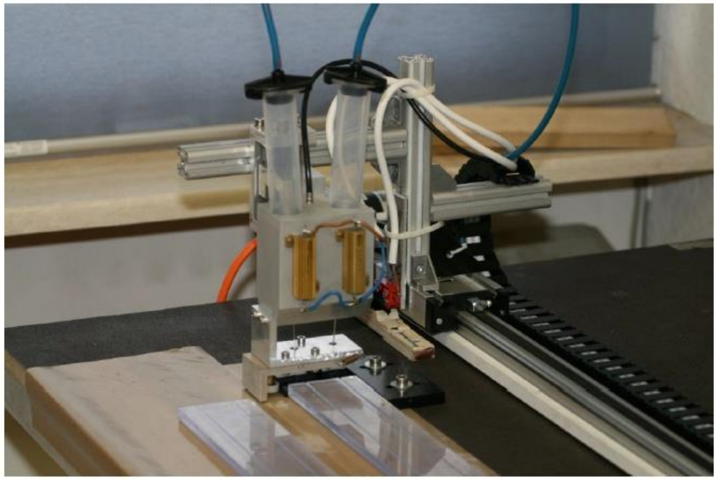
A few channels of the LKr were connected to a CREAM pre-prototype before the end of the TR

MUV



- **MUV1**
  - **25 iron, 24 scintillating layers, ~1100 scintillating strips**
  - **Melted polystyrene granulate with scintillating additives**
  - **Allows for the production of ~270 cm long strips avoiding expensive extrusion from large blocks**
- **MUV2**
  - **One of the former NA48 HAC modules**
  - **Best PMTs from HAC modules installed in MUV2**
- **MUV3**
  - **Brand new detector**
  - **Fast Plane for veto**

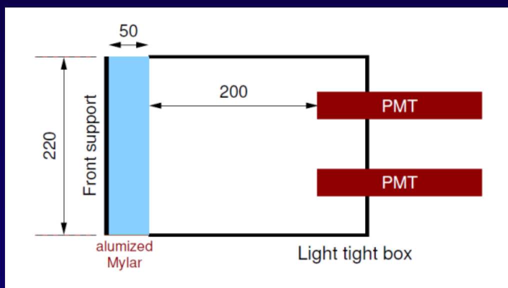
MUV1 Construction

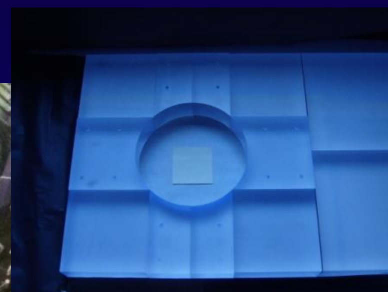


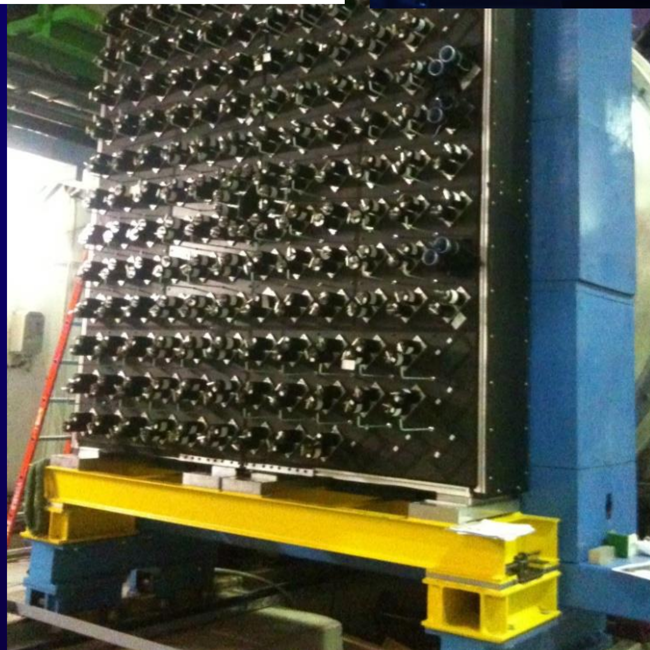
Milling machine for the fibre grooves

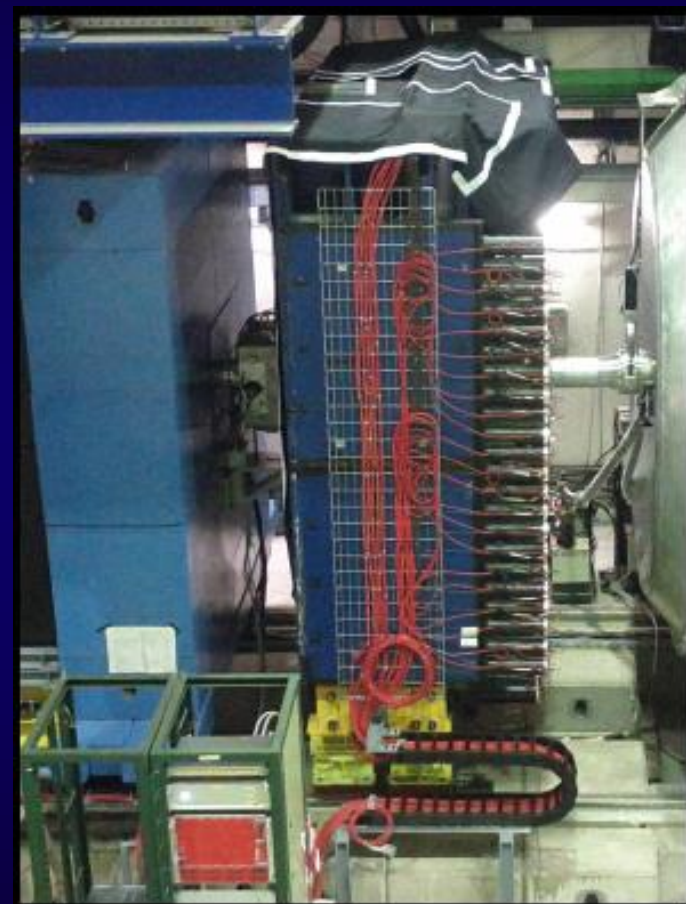
Machine to distribute the optical glue into the grooves

MUV2 and MUV3 in TR









MUV3

MUV2

MUV in TR: Conclusions

- **Good performance, MUV3 time resolution ~ 0.5 ns**
- **To improve the robustness of the HV supplies**
- **Improve read-out for MUV2 to take into account the width of the signals**
- **Validated CFD/TRAM read-out for MUV3; solve dual peak feature observed in some channels by slight modification of the CFD design**

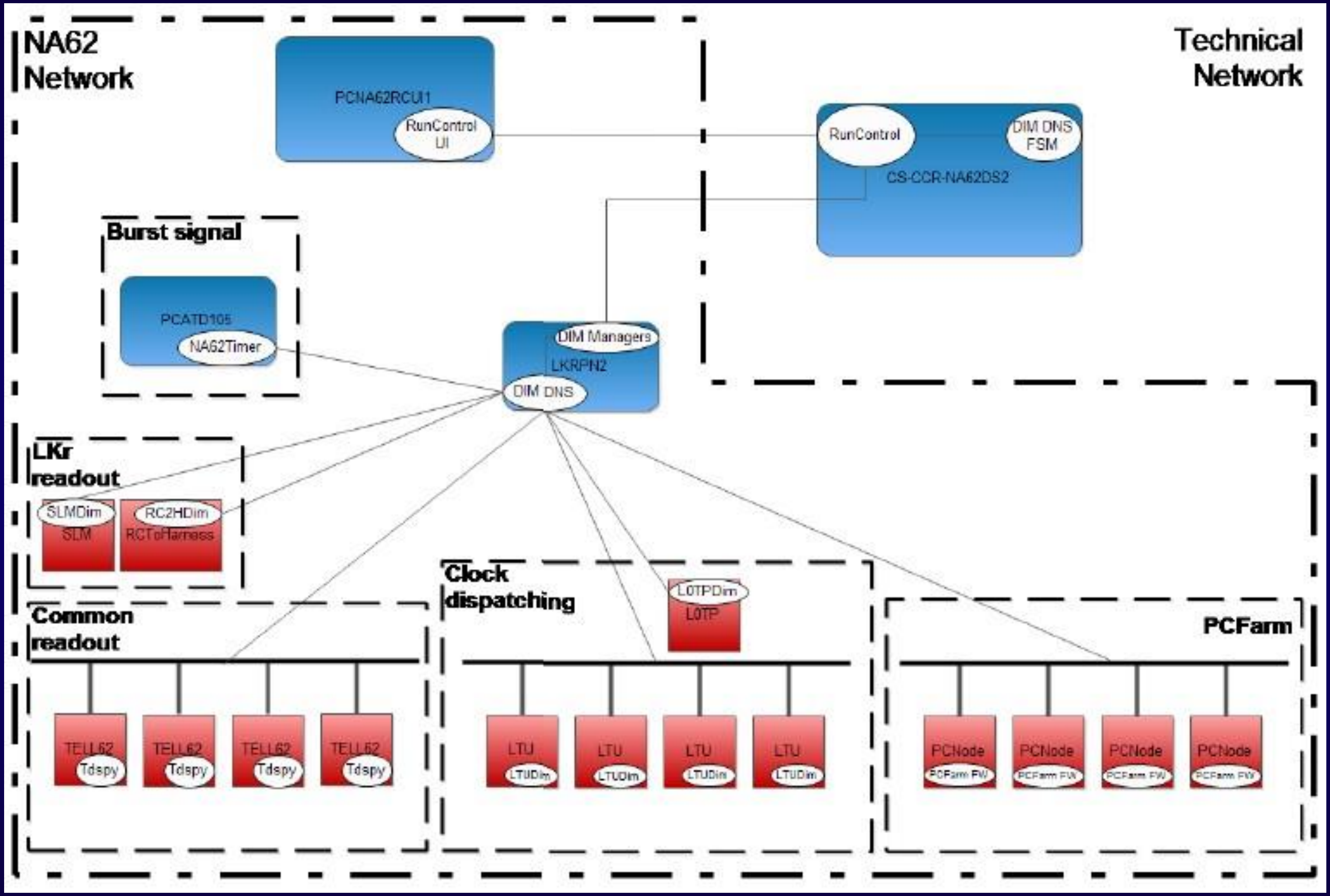
NA62 TDAQ

- **Successful deployment of NA62 TDAQ equipment in ECN3**
- **TDCB finalized: 15 boards used in dry/ technical run**
- **TEL62: DDR2 dynamic memory for data storage validated**
- **15 TEL62 deployed**
- **Readout not tested at high (1 MHz) rate**
- **Issues with crates to be fixed**

TEL62 and TDCB

TEL62 crate ready for data taking

NA62 TDAQ: Run Control



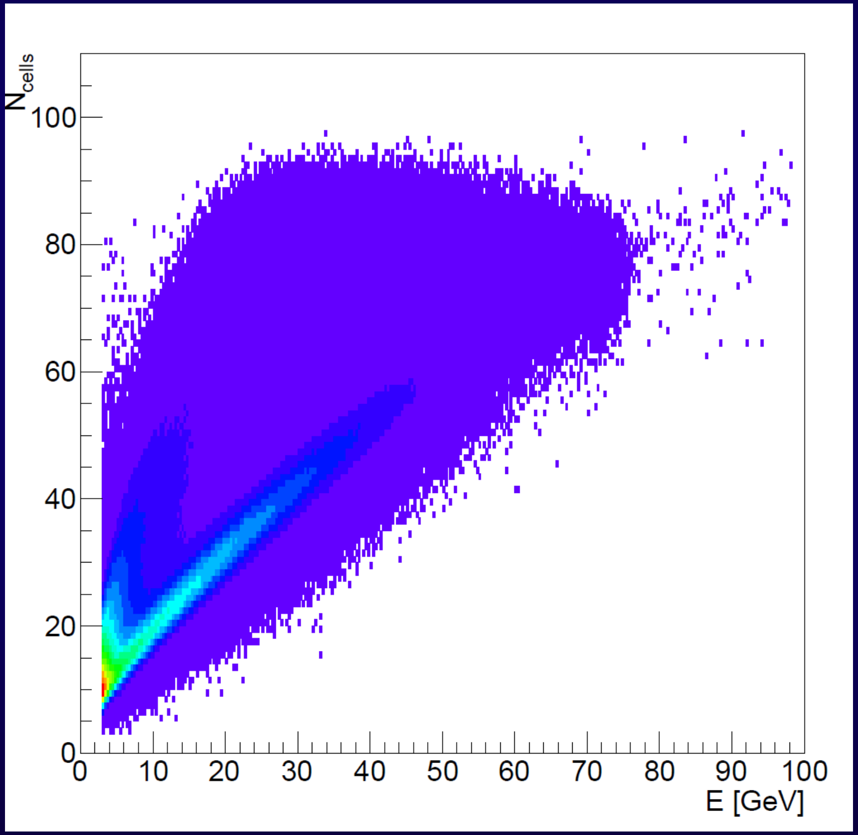
Analysis of the TR Data

- Selection of $K^+ \rightarrow \pi^+\pi^0$ events to:
  - Assess the performance of beam and detectors
  - Study of the timing correlation
- Trigger: Q1 * NHOD
  - Q1: coincidence of two quadrants of the CHOD
  - NHOD: signal from the Neutral Hodoscope embedded in the LKr (provides a signal proportional to the electromagnetic energy deposided in the LKr)
- Analysis selection:
  - Identification of at least two electromagnetic clusters in LKr
  - Reconstruction of the π^0 four-momentum imposing the π^0 mass
  - Reconstruct the π^+ using the π^0 four-momentum and the K^+ four-momentum defined by the beam constraint
- As a result, $K^+ \rightarrow \pi^+\pi^0$ events exhibit a peak in the missing mass:

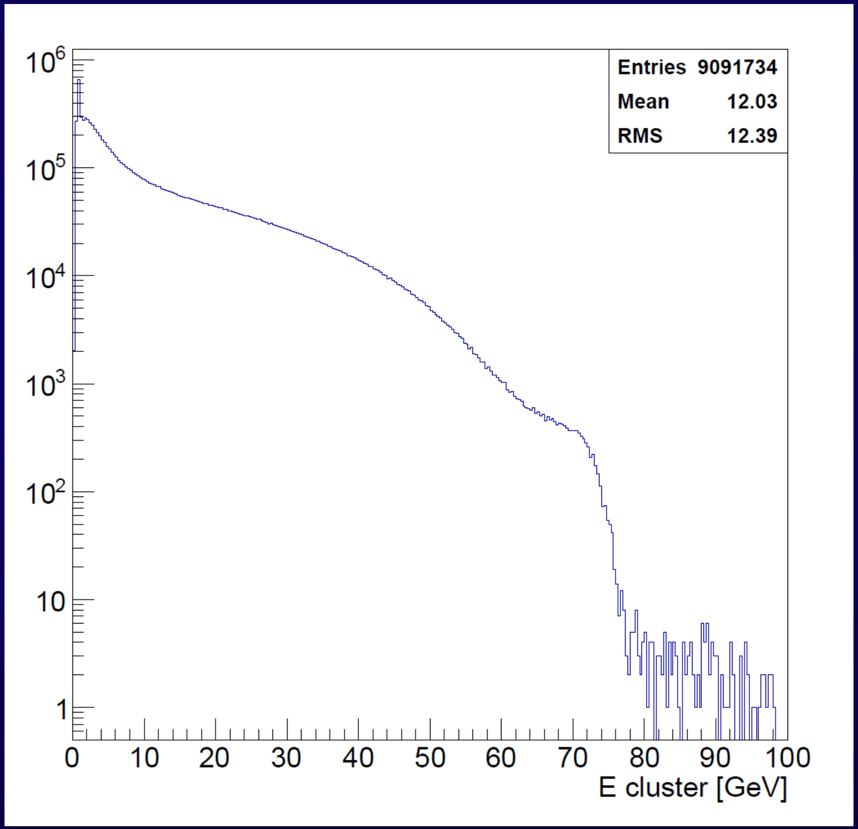
$$m^2_{miss} = (P_K - P_{\pi^0})^2$$

Identification of EM clusters in LKr

N_{cells} vs. Energy

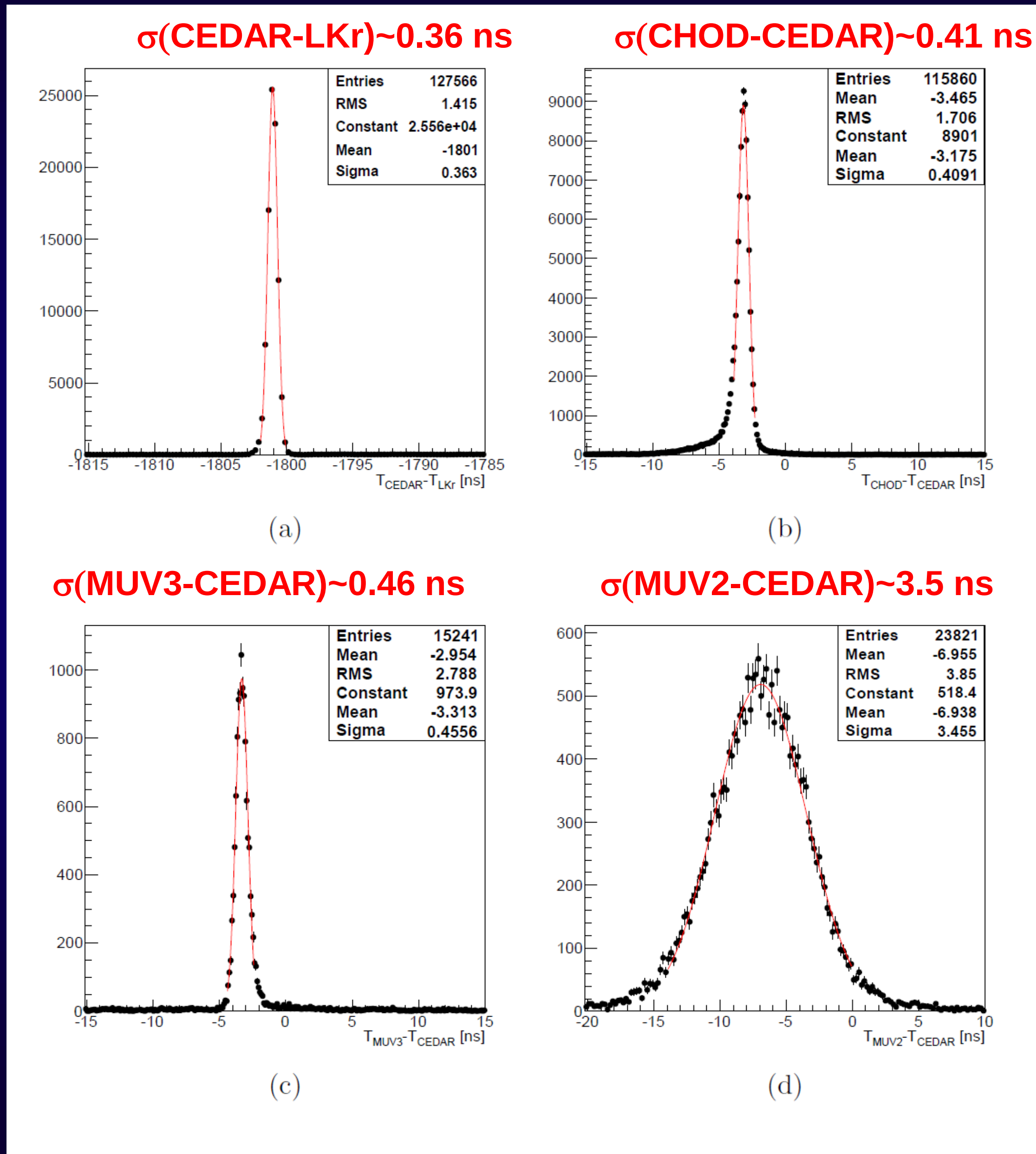


Cluster Energy

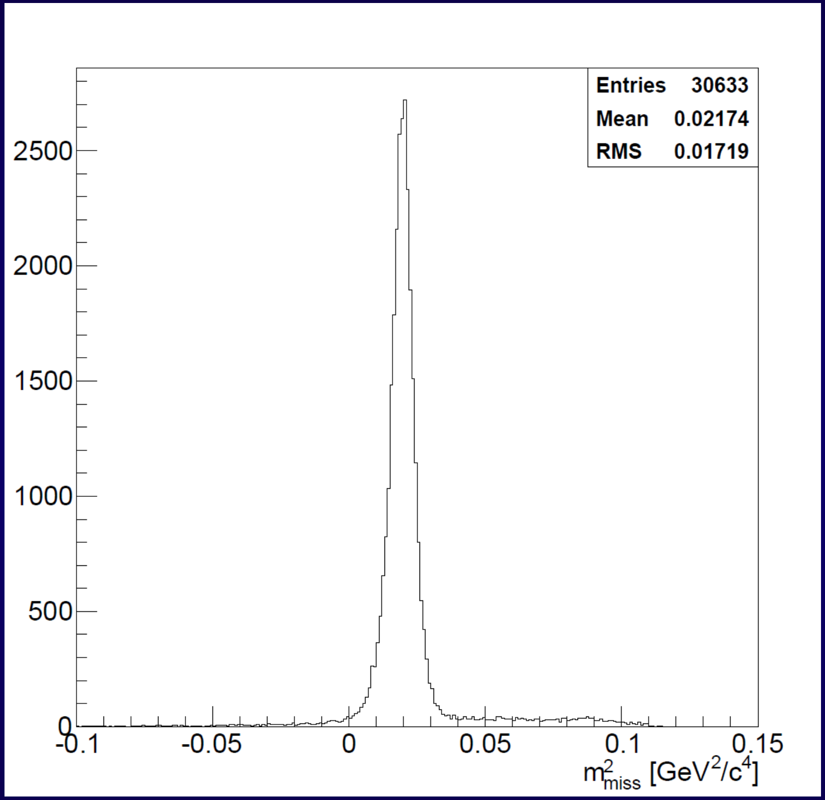


Notice the sharp edge in E cluster distribution due to the well defined *K* momentum (75 GeV/c)

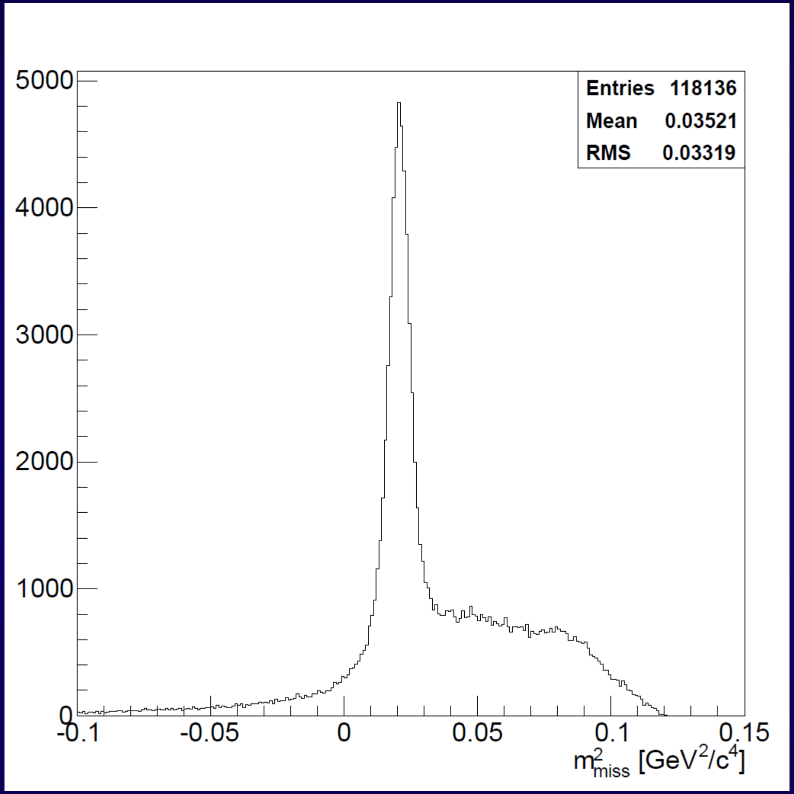
NA62 Timing in TR



Missing Mass



Missing mass for events with a cluster in LKR associated to the π^+



Missing mass for events without LKr cluster associated to the π^+

Missing mass after all cuts

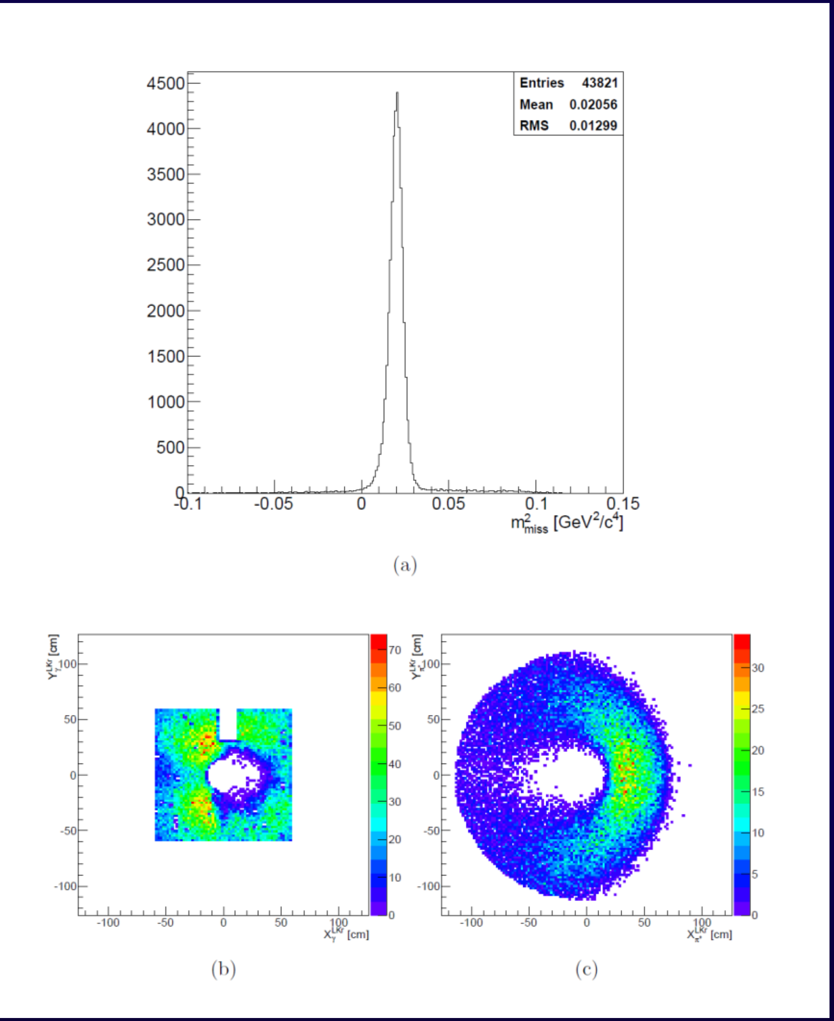
(a) Final selection:

- Kaon candidate
- No intime muon

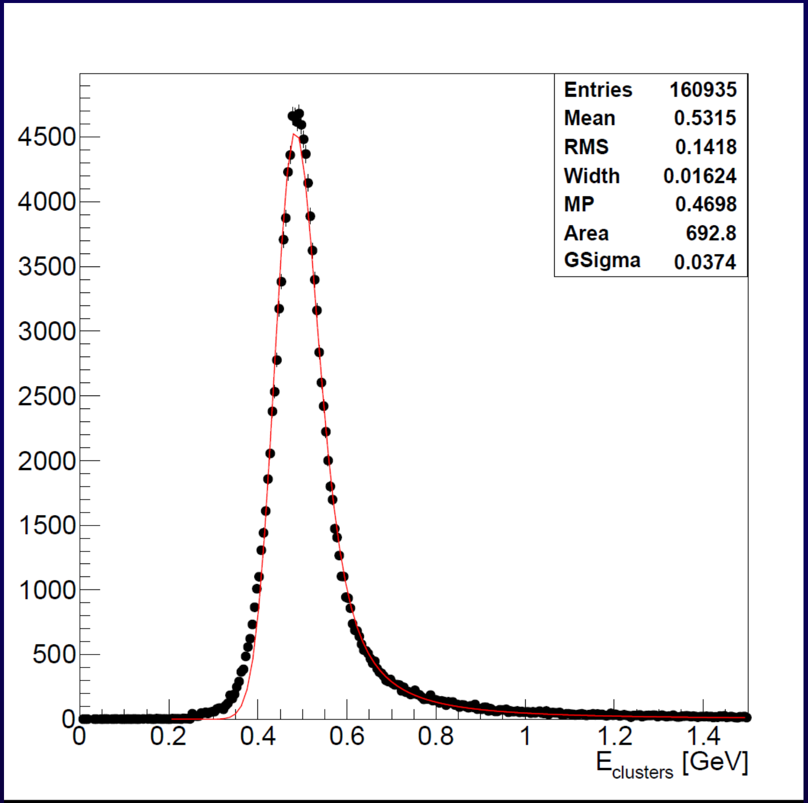
$$m^2_{miss} = 0.0198 \pm 0.0003 GeV^2/c^4$$
$$(PDG: 0.0195)$$

(b) Position of photon clusters

(c) Position of expected π^+ cluster



Bonus: MIPs in LKr



- (Re)discovered the capability to reconstruct minimum ionizing particles (MIP) in the LKr calorimeter
- Clusters have typically < 10 cells
- Landau convoluted with a Gaussian

  (37 MeV noise)

Publications and Analysis of older data

- **NA62**
  - **Precision Measurement of the Ratio of the Charged Kaon Leptonic Decay Rates, PLB 719 (2013)326 (February 2013)**
- **NA48/2**
  - **New measurement of the $K^{\pm} \rightarrow \pi^{+} \pi^{-} e^{\pm} \nu$ (Ke4) decay branching ratio and hadronic form factors, PLB 715 (2012), pages 105-115 (August 2012)**
- **NA48/1**
  - **Measurement of the branching ratio of the decay $\Xi^0 \rightarrow \Sigma^+ \mu^- \nu$, PLB 720 (2013) 105 (March 2013)**

Summary

- We have learned a lot from the experience of the Technical Run in 2012
- We have 18 very busy months in front of us to be ready for Physics data taking
- We are grateful for the strong support of the Funding Agencies
- The collaboration wishes to acknowledge the invaluable support provided by CERN and thanks in particular the Support, Technical and Administrative teams