The NA62 Rare Kaon Decay Experiment
Photon Veto System

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Outline

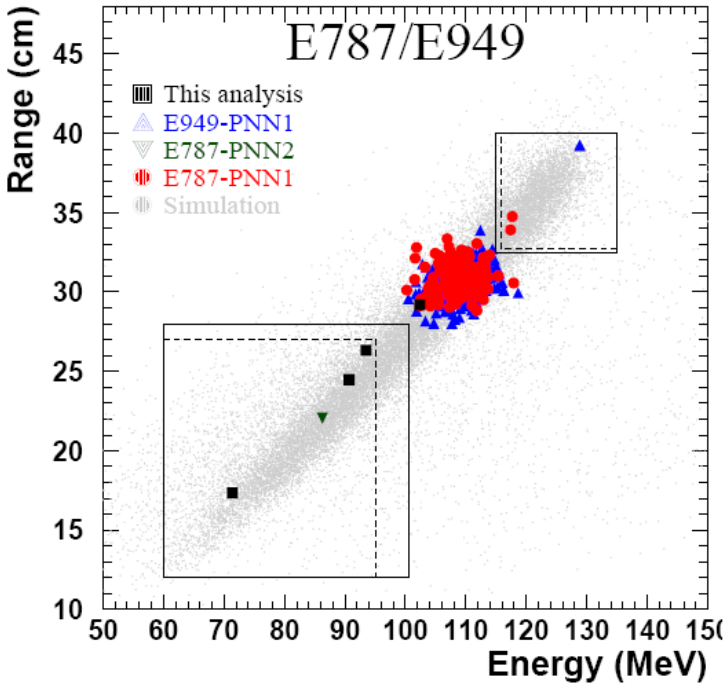
- The NA62 experiment at CERN
  - Large Angle Veto (LAV) requirements
- Photon veto technologies
  - Photon veto prototypes performance
  - Results of the test at the DAFNE BTF
- October prototype test CERN
- Blocks characterization
- Readout electronics concept
- Conclusions

The decay $K^+ \to \pi^+ \nu\nu$

Allow independent determination of the CKM matrix

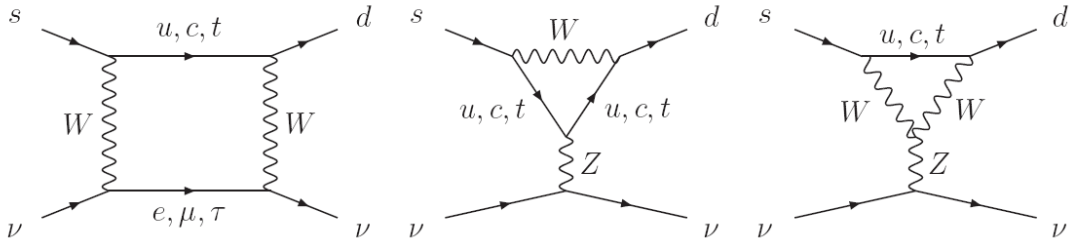
Very sensitive to new physics

Allow precise SM test



See T. Numao's talk

Contribution dominated by top quark



Standard Model prediction:

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (8.22 \pm 0.84) \cdot 10^{-11}$$

Error dominated by CKM element knowledge

non parametric error ~ 5%

Present experimental status:

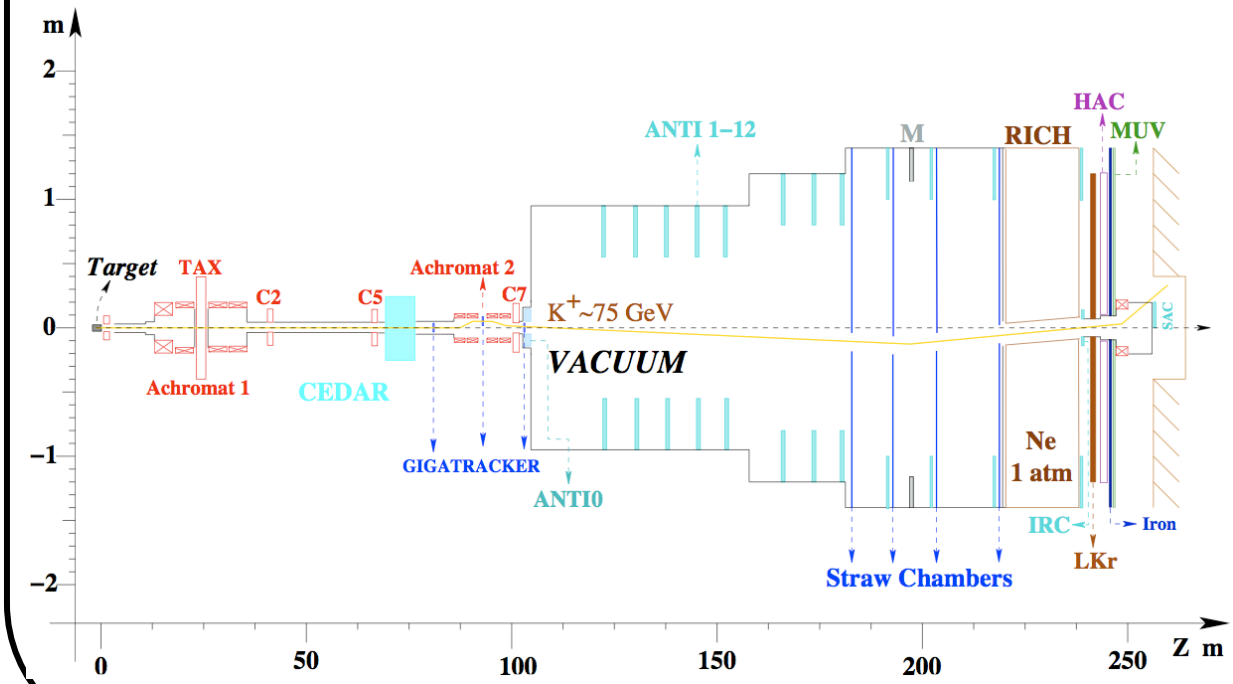
7 events observed by E787+E949:

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$$

NA62 aims to O(100) evt 10% BG during two years of data taking

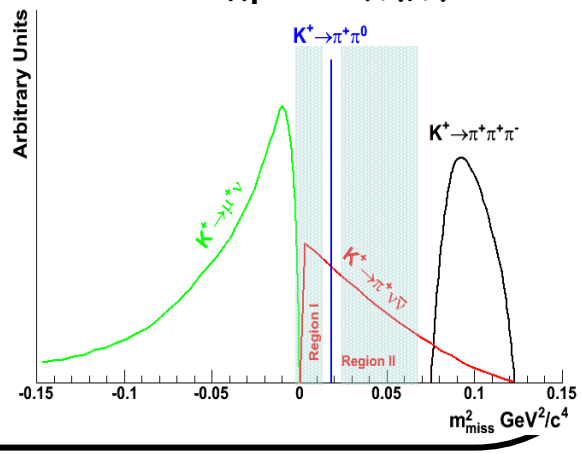
NA62: The detector

- BR($K^+ \to \mu^+ \nu$) ~ 63%, BR($K^+ \to \pi^+ \pi^0$) ~ 21% need rejection factor 10^{-12}
  - Kinematical rejection based on GigaTraker and Straw tube spectrometer
  - PID (π/μ) with RICH and MUV
  - Veto rejection based on the detection of 2γ coming form π^0 decay
- See Evgueni Goudzovshi poster for more details

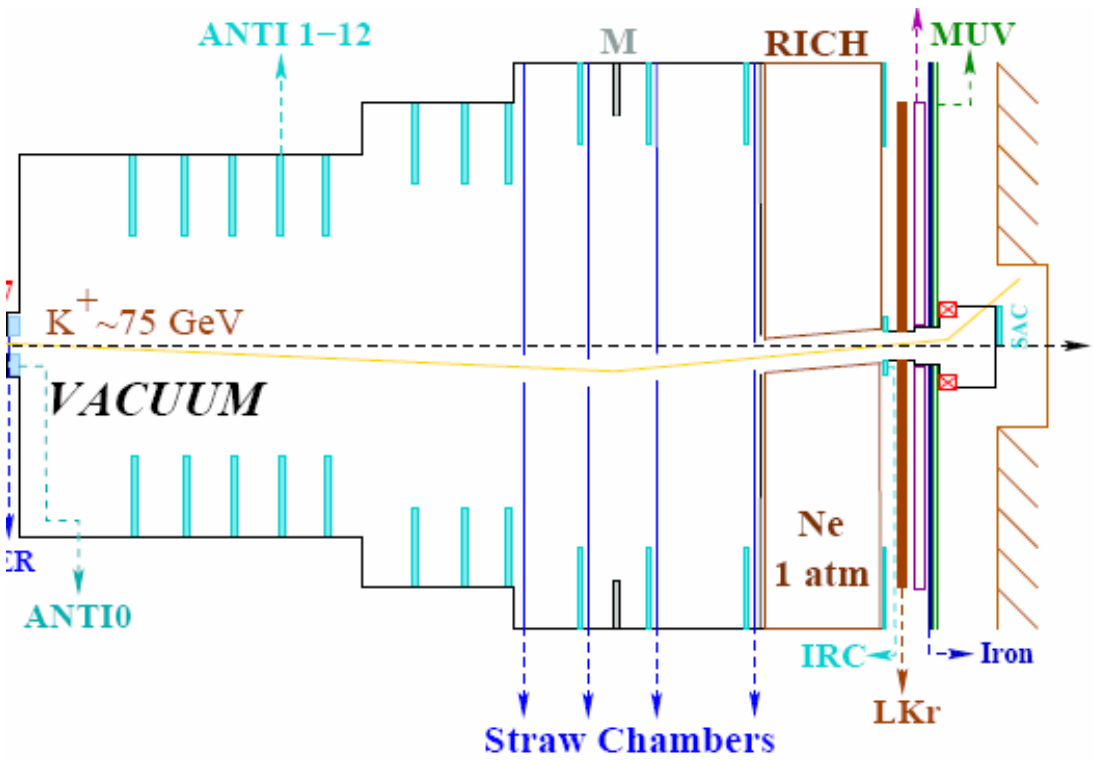


Kinematic

Measure K momentum
Measure π momentum
Compute MM^2



Large Angle Veto requirements



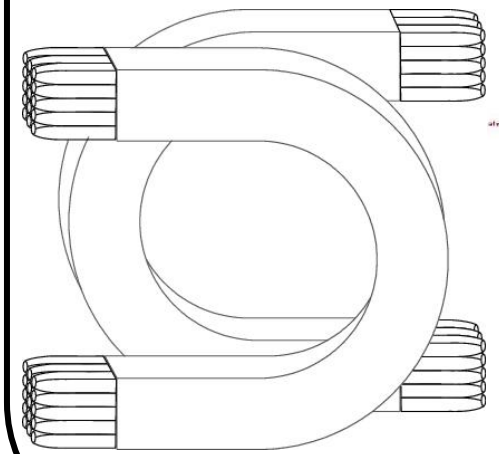
13 rings along >120 m decay region

- >20 X_0 to ensure shower containment
- Very low detection inefficiency for γ: $O(10^{-4})$ down to 50-100 MeV
- Time resolution better than 1 ns
- Energy resolution 10% at 1 GeV
- Operation in high vacuum region: $O(10^{-6})$ mbar

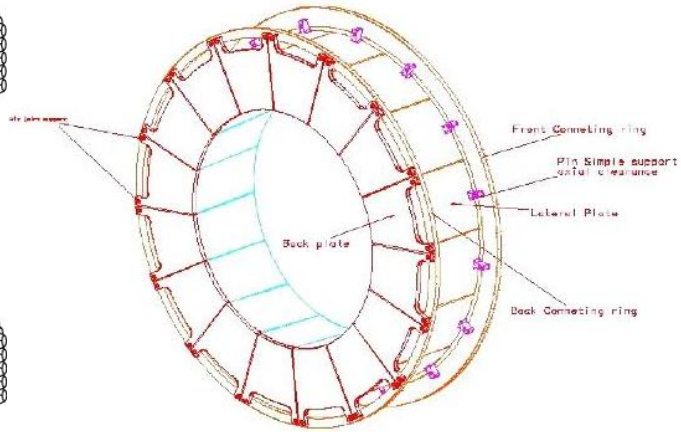
Possible technology choices

- Lead + Fiber (constructed @ LNF)
- Lead + Scintillator Tile (loan form CKM)
- Lead glass crystals (OPAL)

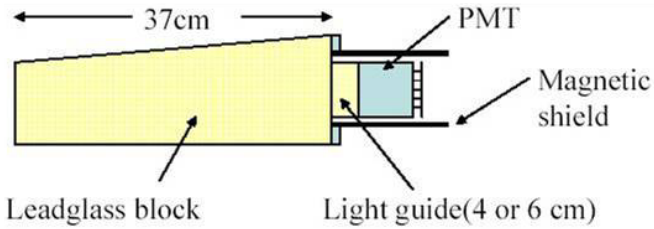
Lead + Fiber

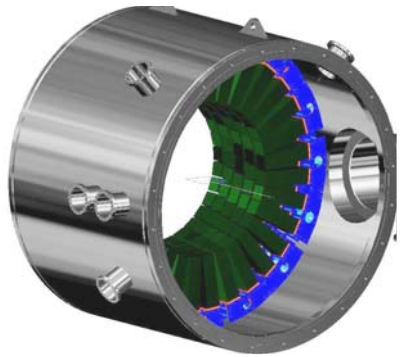


Lead + Tile



Lead glass crystals

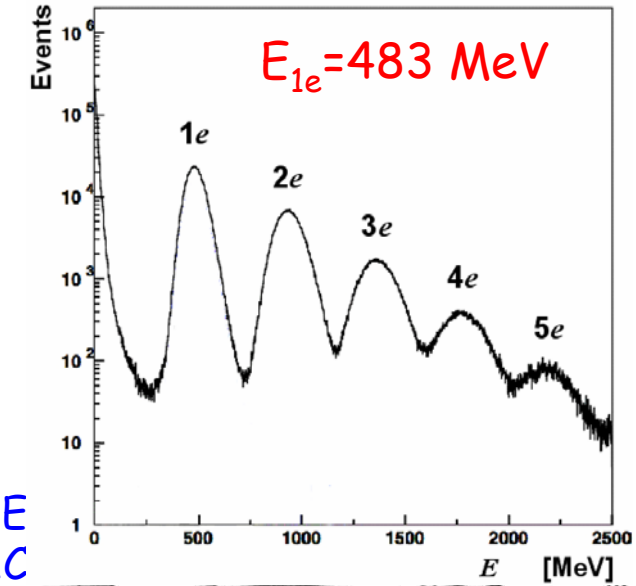




The Frascati Beam-Test Facility

Electron test beam parameters:

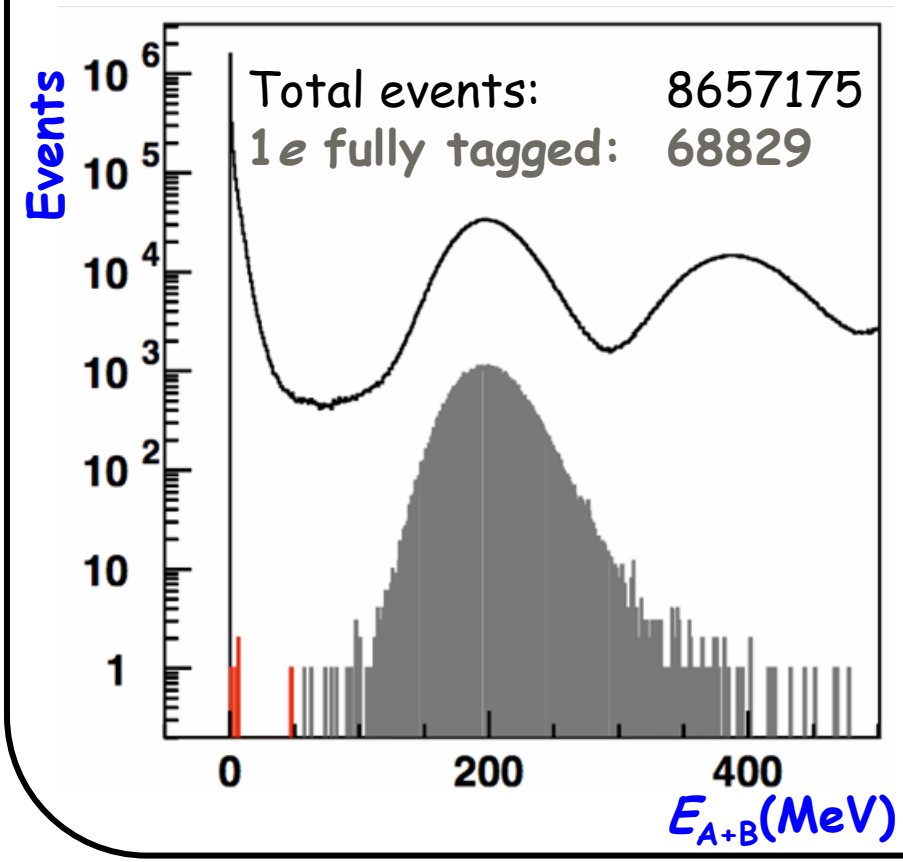
Energy range	100 to 750 MeV
Selection resolution	$\Delta E/E \sim 1\%$
Mean multiplicity	1 to 10^9
Bunch length	10 ns
Repetition rate	50 Hz

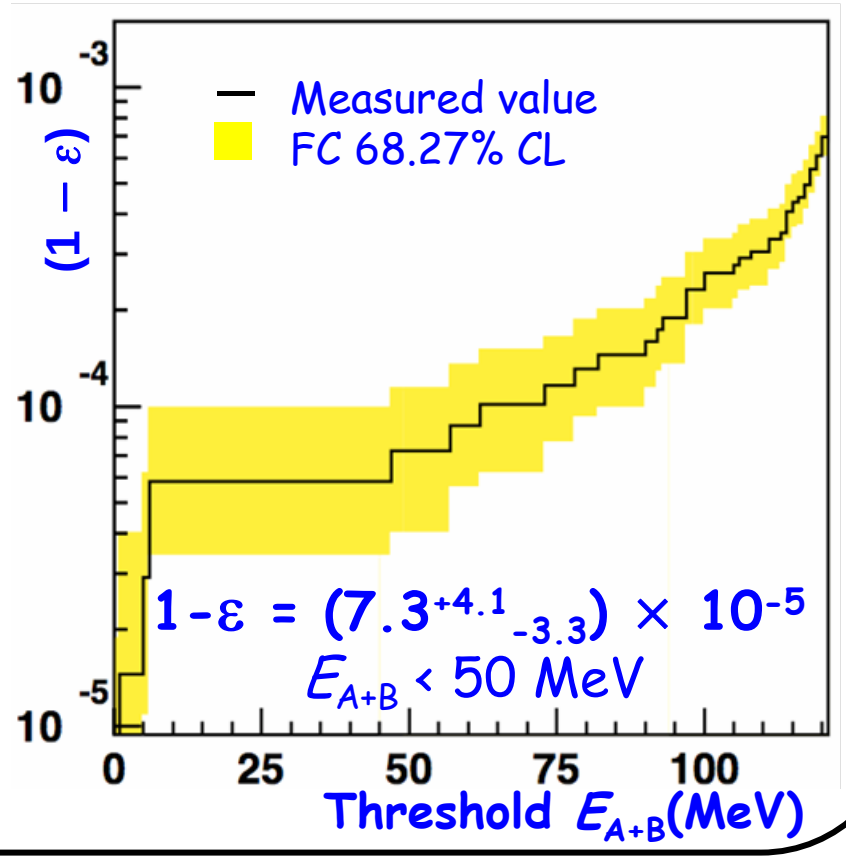


Typical single electron energy spectrum in e^- line

Analysis technique

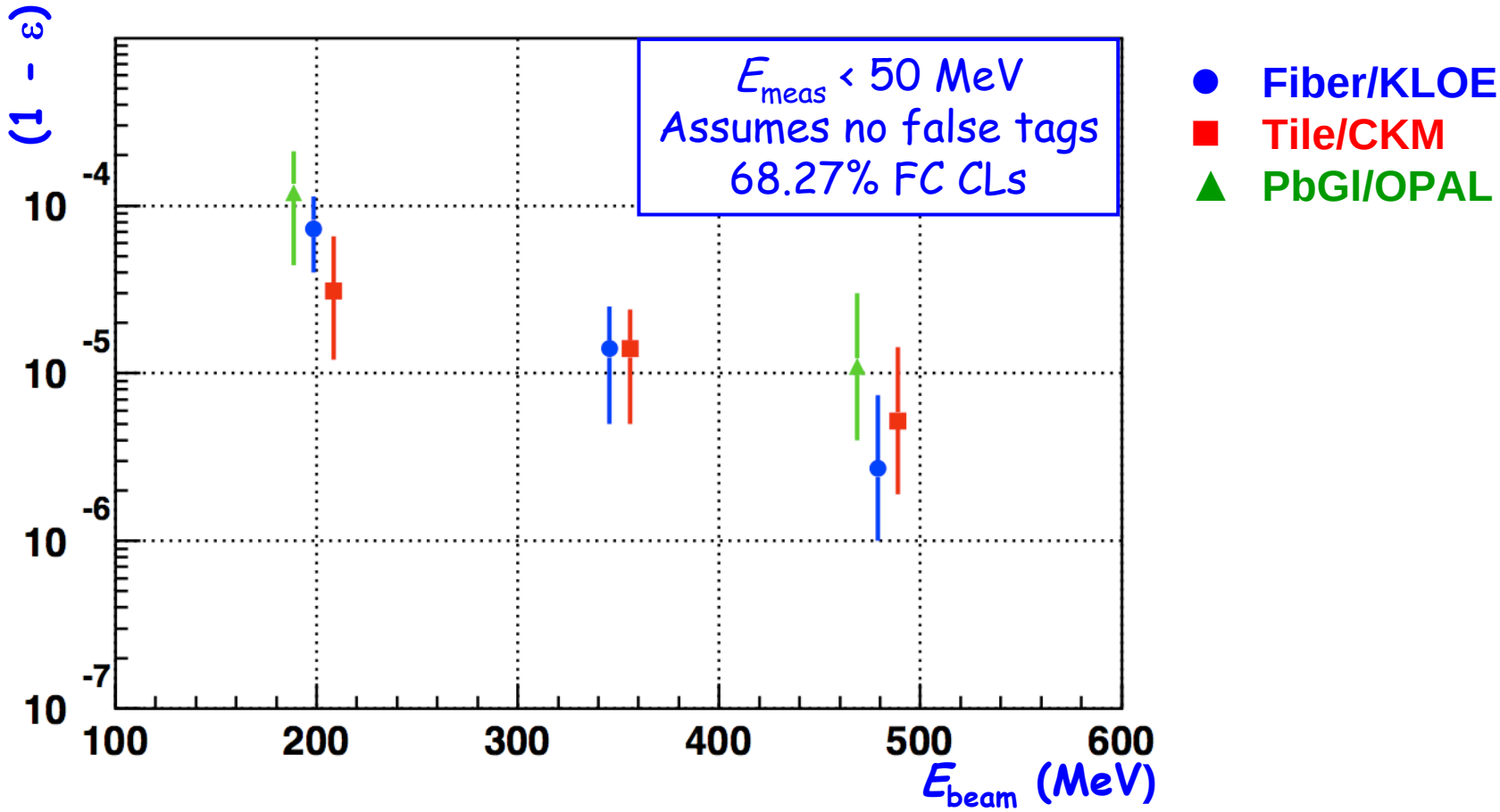
1. Calibrate the calorimeter and obtain raw energy distribution
2. Ask for full tag $F_1 \cdot F_2 \cdot \bar{H}_1 \cdot \bar{H}_2$ and count events with <50 MeV
3. Apply Feldman and Cousin recipe to evaluate efficiency limit vs Thr





Summer '07 results comparison

Tile (CKM) and lead glass (OPAL) results are preliminary



Efficiencies for electron detection similar for all 3 technologies

2nd lead glass test in February '08

Preliminary not all the available data analyzed already

Beam Energy (MeV)	*Tagged Events*	*Event with E<50 MeV*	*1-ε (Inefficiency)*
Central 471	22703	1	$4.4^{+7.6}_{-2.8}\times10^{-5}$
On edge 471	9711	1	$1.^{+1.75}_{-0.65}\times10^{-4}$

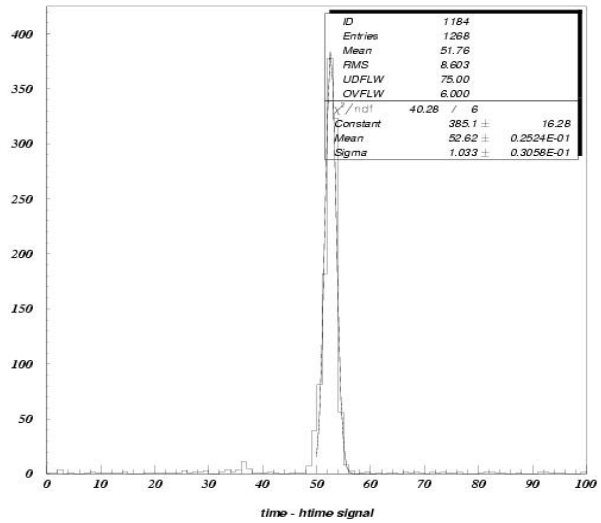
- Blocks assembled in a way similar to the final one
- 25 block in 5 rows of five blocks each
- Different impinging point tested:
  - Central : on the center of block 33
  - On edge: on the edge of block 33

Roadmap to the final detector

- Sector prototype test in October @ CERN
  - 5x4 crystal prototype with the final mechanics and vacuum solution has been constructed
  - Test in the NA62 decay region in vacuum
- We decided to use lead glass as baseline solution
  - Lead glass crystal quality test procedure established
  - Validation of in vacuum electronic heating
  - Measurement of blocks outgassing rates
  - Mechanical design of vacuum tight ring completed
- Entire ring prototype (160 crystals)
  - To be completed at LNF before end of 2008

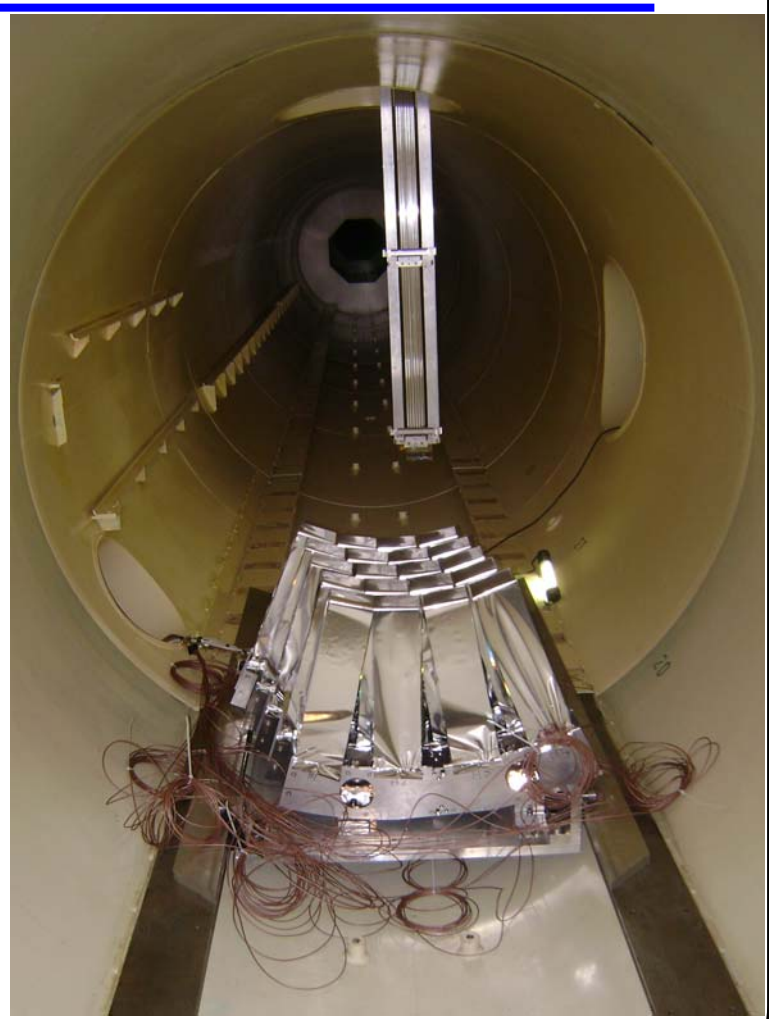
October test in NA62 @ CERN

- 4x5 blocks prototype detector successfully assembled inside blue tube (1/8 of a full ring)
- HV and signal feedthroughs tested as well
- Response to muons and γ studied
- Readout with old NA48 ADC and TDC

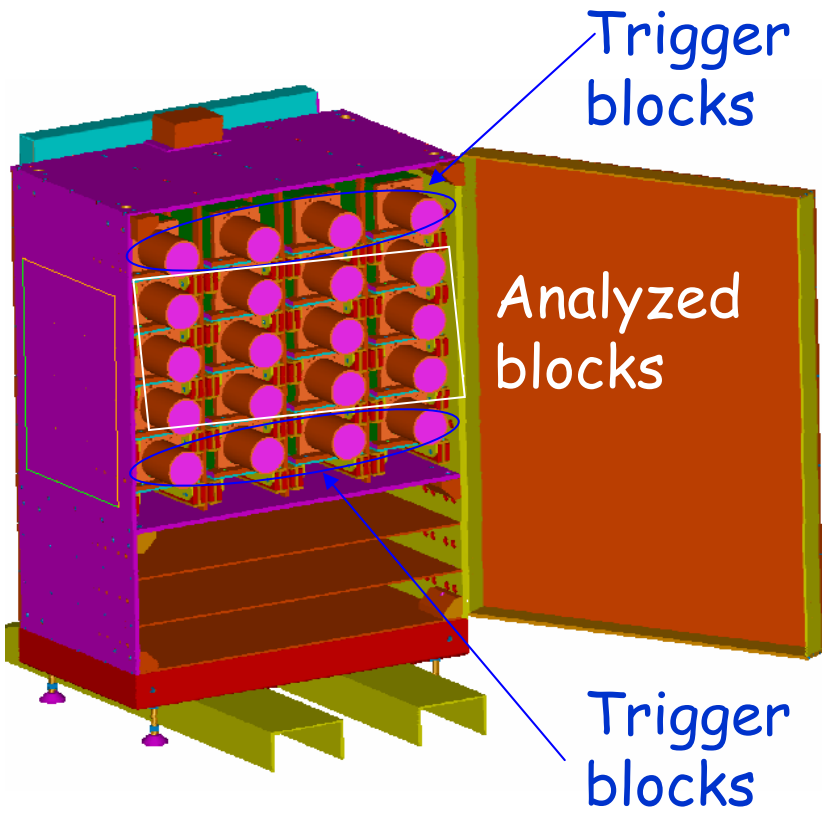


Preliminary time resolution with Kaons

$\sigma_t \sim 1$ ns



Lead glass test station



More than 2K blocks from OPAL to be characterized

- Blocks can be moved in/out using drawers
- One LED distributes light to all modules
- Trigger modules allow self triggered cosmic rays test
- All software, including analysis and fits done in LabView in an integrated framework
- 12 blocks tested in few hours. Can test up to 24 blocks in 1 day if needed.

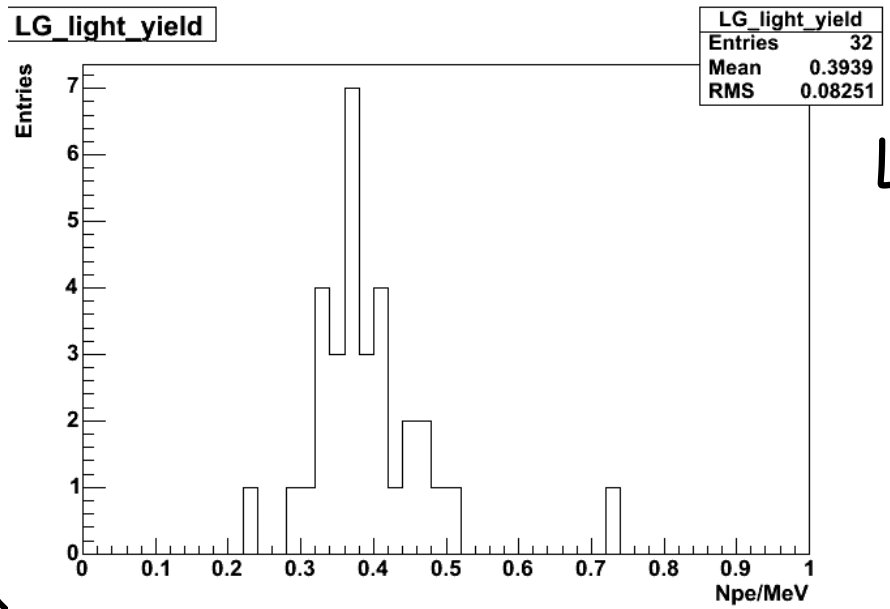
Characterization procedure

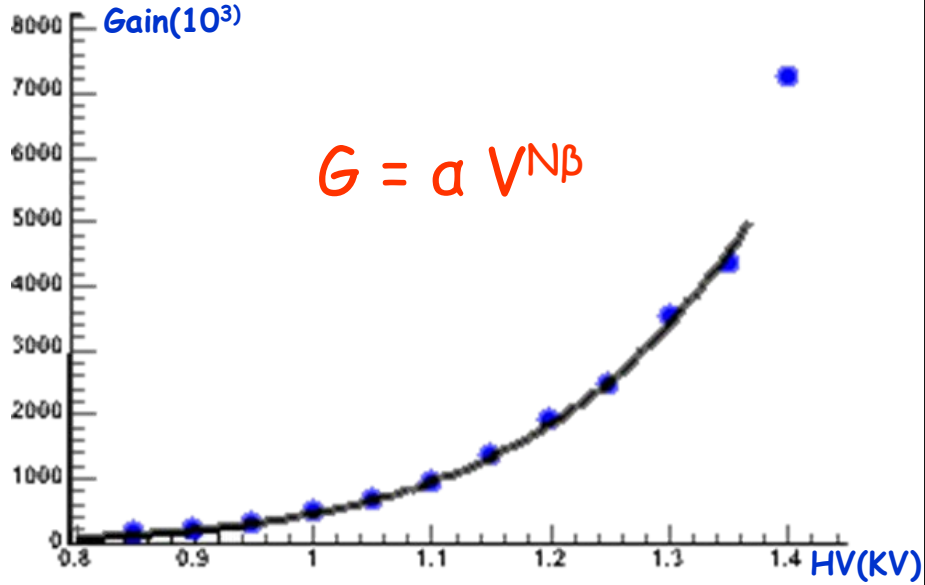
Fully automatic procedure perform following steps:

1. Pedestal run
2. Check for light tightness (pedestal run with PMT @ HV)
3. Measure gain vs HV values using LED pulses
4. Fix the individual block HV, equalize all blocks to same gain
5. Acquire cosmic to measure the Light Yield (LY)
6. Using LY set individual voltage to equalize in response
7. Check achieved equalization with a second cosmic run

Characterization results

Stable light source provided by a LED





$G = \alpha V^{N\beta}$

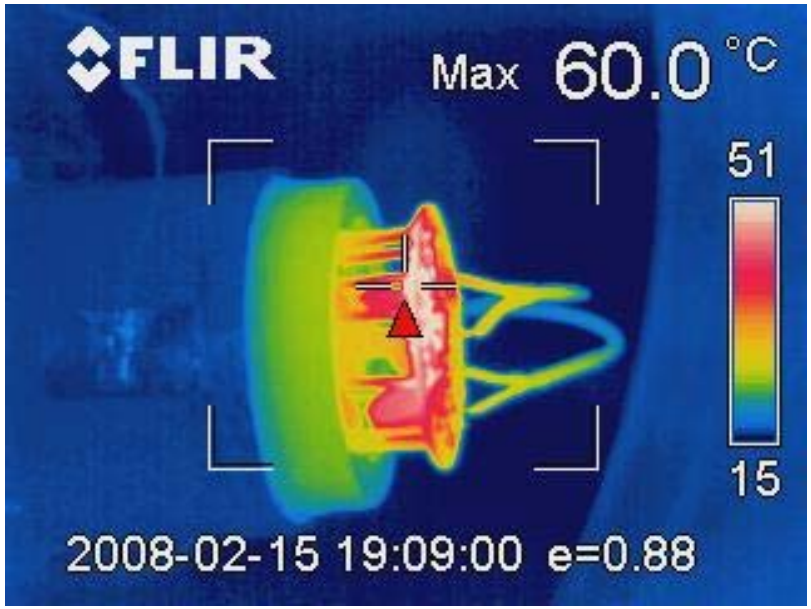
Light Yield seems quite stable

$LY = N_{pe}/\langle E_{mip}\rangle$

$N_{pe} = Q/(G\, q_e)$

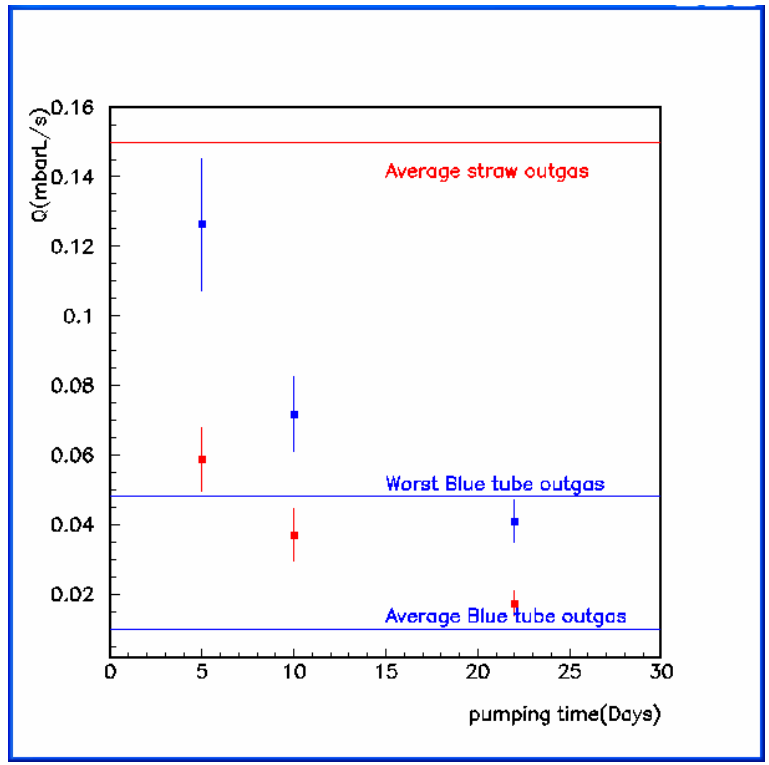
$\langle E_{mip}\rangle = 77\text{MeV}$

Validation in vacuum



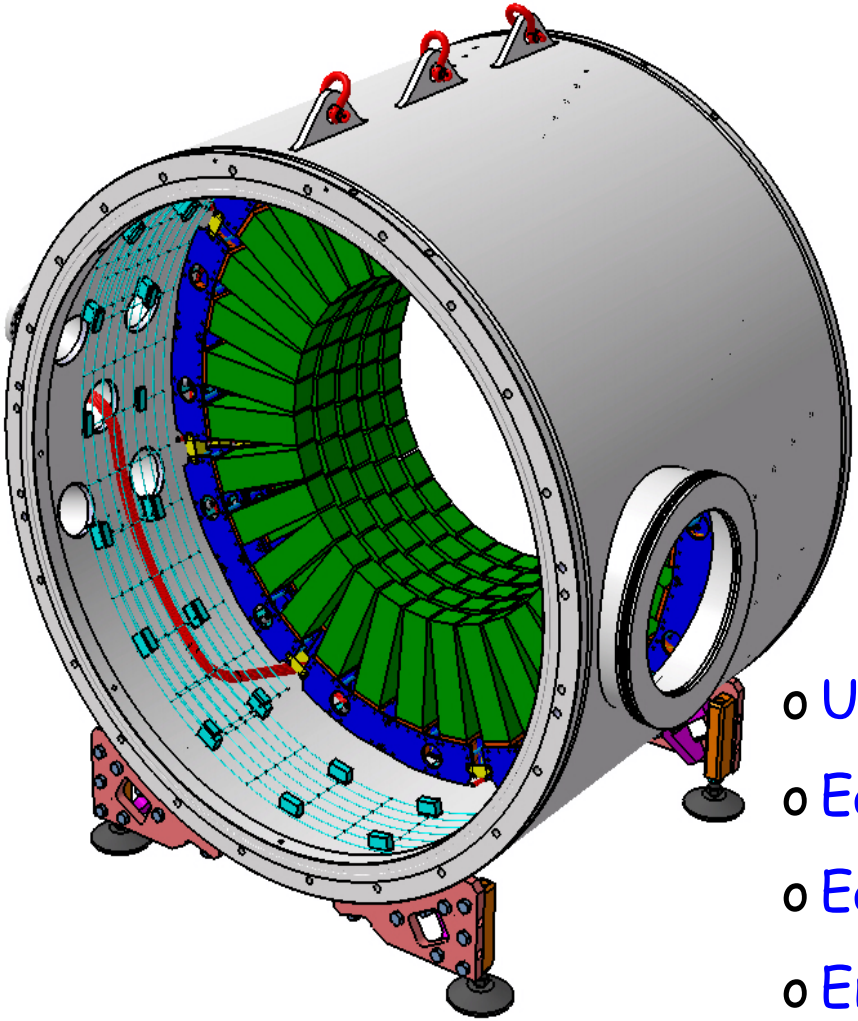
Electronic's heating under control max T=60° after several hours @ 2000 V

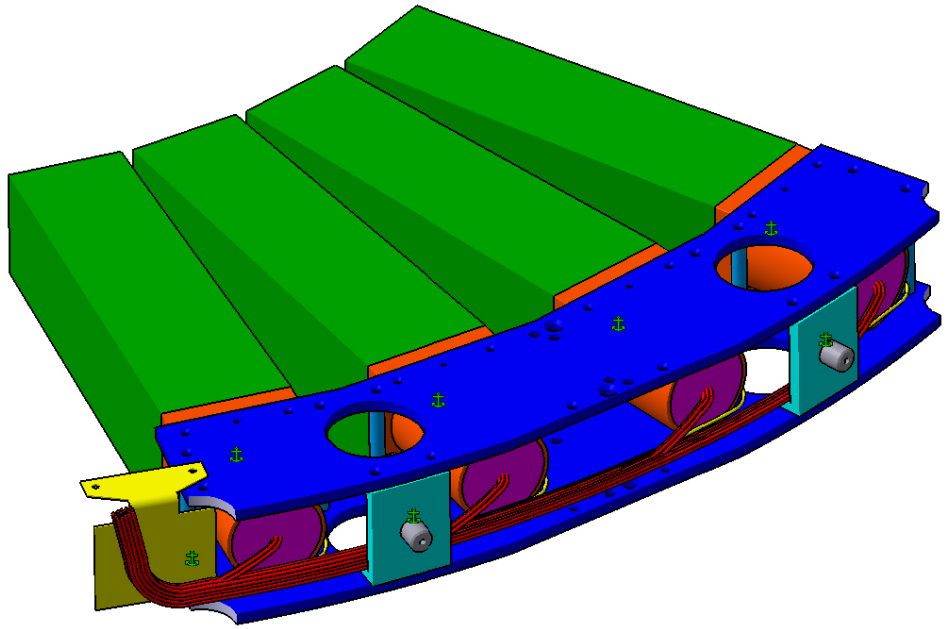
Full 13 rings outgassing rate



Outgassing rate compatible with other experiment's components

Final ring prototype





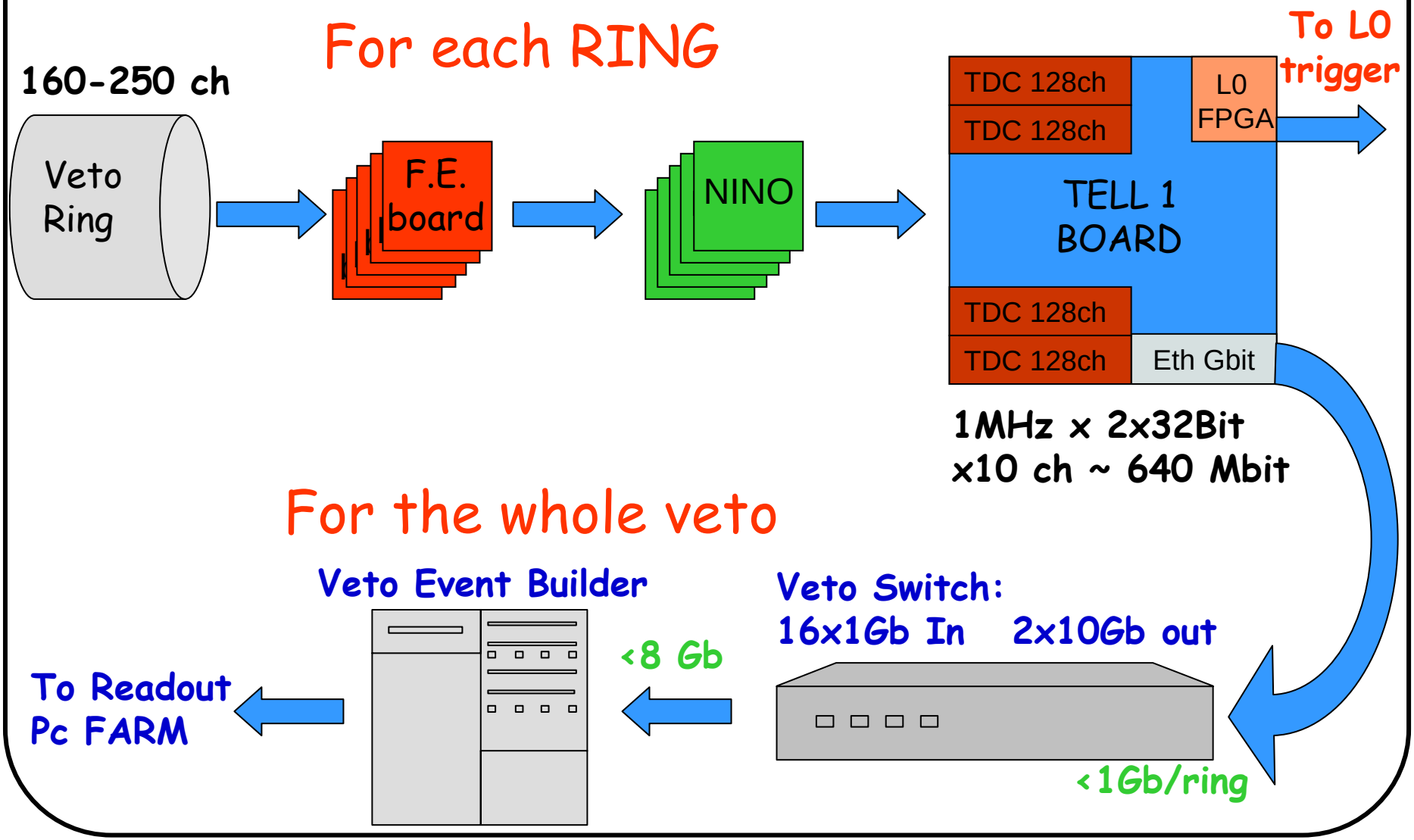
- Unit element made by 4 blocks
- Each circle made by 8 units of 4 blocks
- Each circle is rotated by 1/5 block
- Entire ring made by 5 circles (160 blocks)

Requirements of readout electronics

- Very High Dynamic range 50 MeV – 20 GeV
- Energy resolution O(10%/√E)
- Good time resolution <1 ns
- On board L0 logic

- Use Time Over Threshold and multi scale system to have high dynamic at reasonable cost
- As first attempt we will use NINO asic from ALICE TOF to have TOT

Readout electronics conceptual design

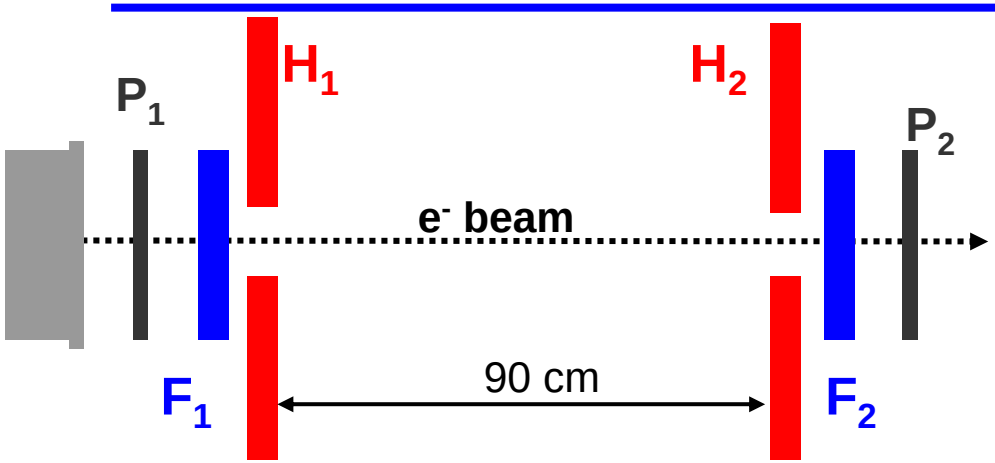


Conclusions

- Test beam have shown for all prototypes efficiencies for low energy electrons $<10^{-4}$
- The efficiencies are better than required ones
- The Lead Glass blocks have been chosen as baseline technology for the veto construction
- A fully automatic test stand has been built
  - Mass test of blocks already started
- A sector prototype has been tested NA48
  - Data analysis is ongoing
- Construction of the first full prototype ring starting soon in Frascati

Backup slides

The tagging system



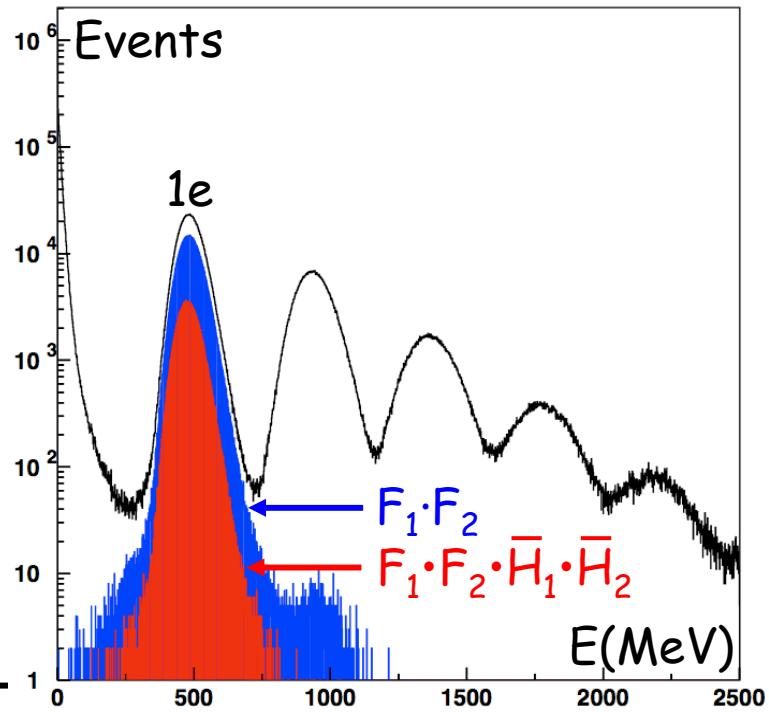
Finger counters (F_1, F_2) active

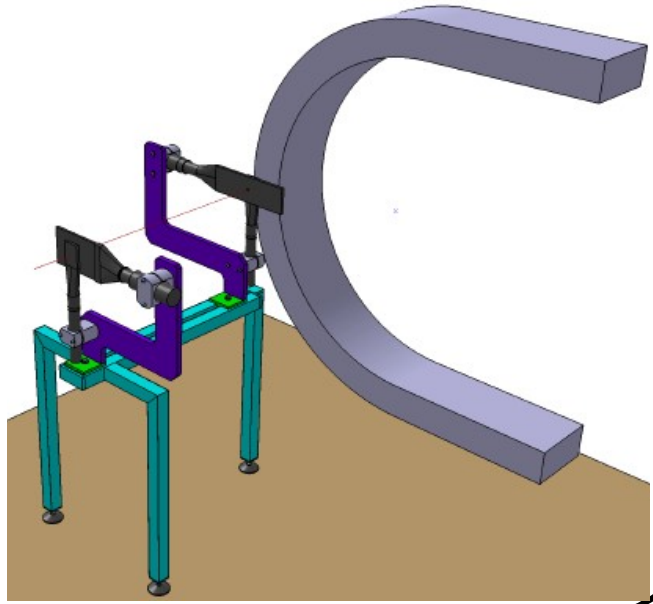
- 6x8.5x1 cm^3 scintillator paddles

Hole counters (H_1, H_2) veto

- 33x10x1 cm^3 (e.g. H_2) paddle with 1.4-cm hole in center

Beam profile meters (P_1, P_2)





Summary of summer 2007 data taking

	Energy (MeV)	$P(1e)$ (%)	$\varepsilon(\text{tag}\|1e)$ (%)	Tagged events
Analysis nearly complete	**Fiber (KLOE)**			
	203	31.3	2.5	70k
	350	33.0	9.2	210k
	483	33.3	14.4	370k
Analysis still preliminary	**Tile (CKM)**			
	203	29.5	3.7	65k
	350	31.8	8.8	220k
	483	29.0	17.6	370k
	Lead glass (OPAL)			
	203	30.2	3.9	25k
	483	26.0	17.1	90k

Gain measurement's technique

Use a fixed amplitude light source (LED), and measure the PMT response.

The functional relation between Response and Gain is:

$$\sigma_R^2 = R\,G' = L.Y. \cdot e \cdot G'$$

$G' = G(1 + \delta^2)$ and δ^2 is a correction due to the dinodes gain and is a function of Gain.

After gain estimation we can fit the gain curve for several values of PMT supply voltage values, with functional relation:

$$G = \alpha V^{N\beta}$$

The method has shown and accuracy of few %.