The Large-Angle Photon Veto System

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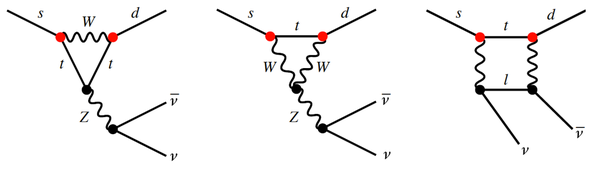
Why study $K^+ \to \pi^+ \nu\bar{\nu}$?

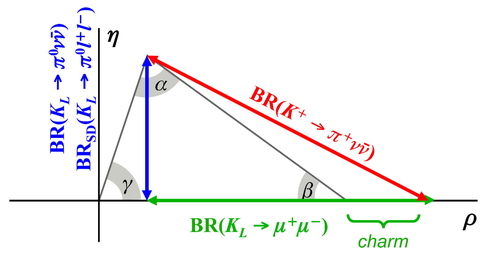


FCNC processes with loops dominated by top
No long-distance contributions from intermediate γs
Hadronic matrix element from BR(K_{e3})

Theory: BR = $(8.22 \pm 0.69_{par} \pm 0.29_{th}) \times 10^{-11}$
10% measurement offers NP sensitivity

Experiment: BR = $(17.3^{+11.5}_{-10.5}) \times 10^{-11}$
BNL 787/949 – Stopped K^+, 7 candidates

Clean measurement of unitarity triangle to compare with B physics



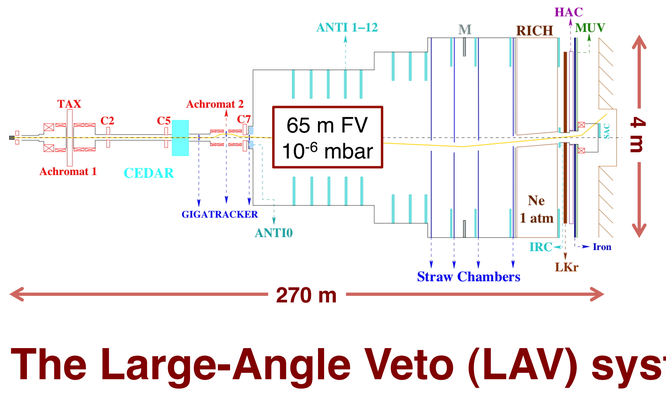
NA62 goal:

~100 $K^+ \to \pi^+ \nu\bar{\nu}$ decays w/ S/B ~ 10

Need 10^{-12} rejection for abundant channels: $K^+ \to \pi^+\pi^0$, $K^+ \to \mu\nu$

The NA62 experiment at the CERN SPS

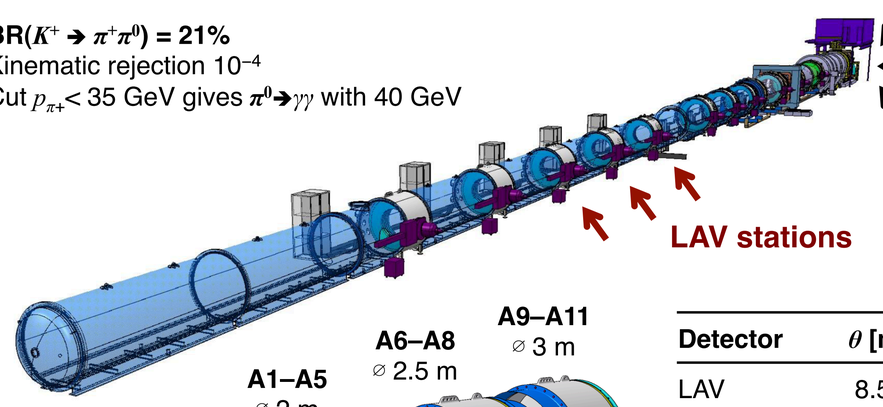
75-GeV unseparated beam
800 MHz into decay volume
5 MHz of K^+ decays in FV



K beam definition	**CEDAR** (diff. Cerenkov)
Beam tracking	**Gigatracker** (Si pixel)
Decay tracking	Magnetic spectrometer **4 straw chambers** in vacuum
Decay PID	**RICH, MUV** (μ veto)
Photon vetoes	**LAV** (**ANTI**) – large angle **LKr** calorimeter **IRC+SAC** – small angle

Rejection of channels with photons

BR($K^+ \to \pi^+\pi^0$) = 21%
Kinematic rejection 10^{-4}
Cut $p_{\pi^+} < 35$ GeV gives $\pi^0 \to \gamma\gamma$ with 40 GeV



A1-A11 in vacuum:
3 different sizes

A12 not in vacuum

Detector	θ [mrad]	Max. 1 – ε
LAV	8.5 - 50	10^{-4} at 200 MeV
LKr	1 - 8.5	10^{-3} at 1 GeV 10^{-5} at 10 GeV
IRC + SAC	< 1	10^{-5}

The Large-Angle Veto (LAV) system

System requirements

Efficiency 10^{-4} for $E_\gamma > 200$ MeV
Operation in vacuum 10^{-6} mbar
Dynamic range 10 MeV - 10 GeV
Energy resolution ~10% at 1GeV
Time resolution ~ 1ns

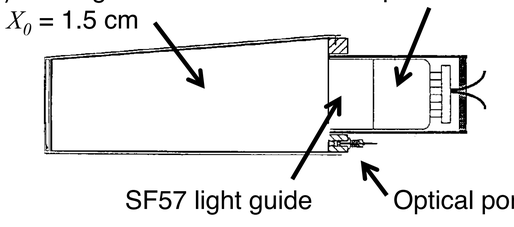
Technologies compared

Lead/scintillating fiber calorimeter (e.g. KLOE)
Lead/scintillating tile calorimeter (e.g. CKM)
Lead-glass blocks from OPAL

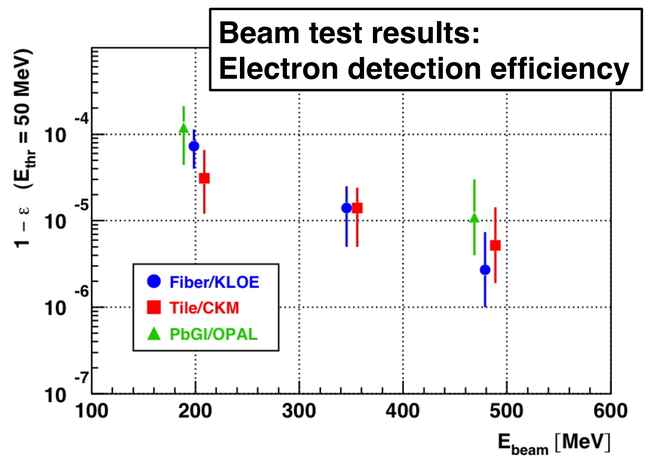
Lead glass blocks from OPAL

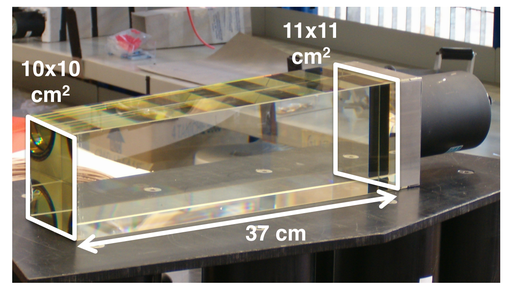
SF57 lead glass
ρ = 5.6 g/cm^3 n = 1.85
X_0 = 1.5 cm

R2238 PMT in μ-metal case



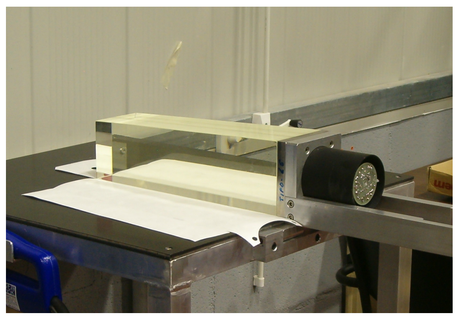
Beam test results:
Electron detection efficiency



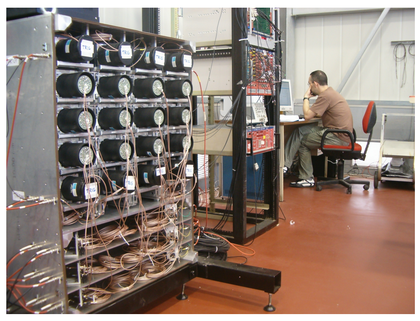


LAV construction

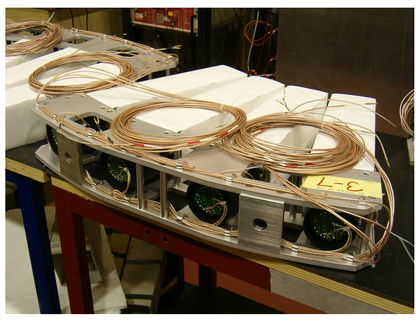
Reinforcement of glass blocks with steel plates



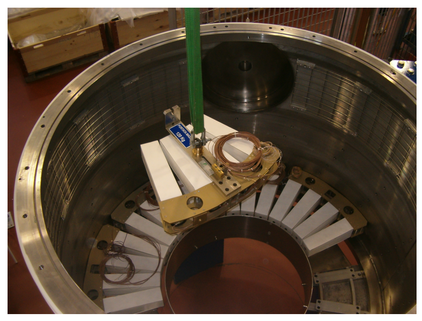
Cleaning of blocks; wrapping with white Tyvek



Measurement of photoelectron yields and tube gains using LED pulser and cosmic rays



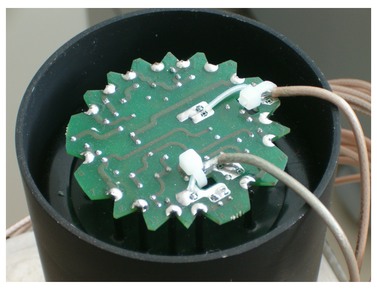
Assembly of four blocks in aluminum support structure ("banana")

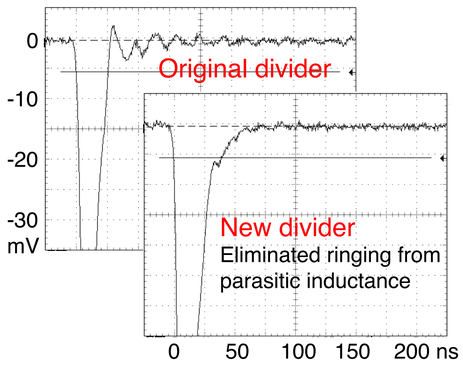


Installation in vacuum vessel

Complete LAV station at CERN, ready for installation

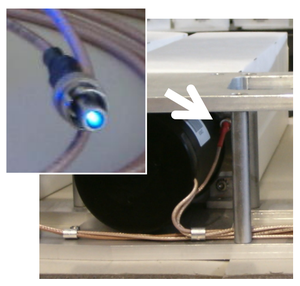
New HV dividers





Add resistors to final dynode and anode stages to damp parasitic inductance
Add storage capacitors to final dynode stages to improve linearity
Add decoupling resistor between HV and signal ground

Monitoring

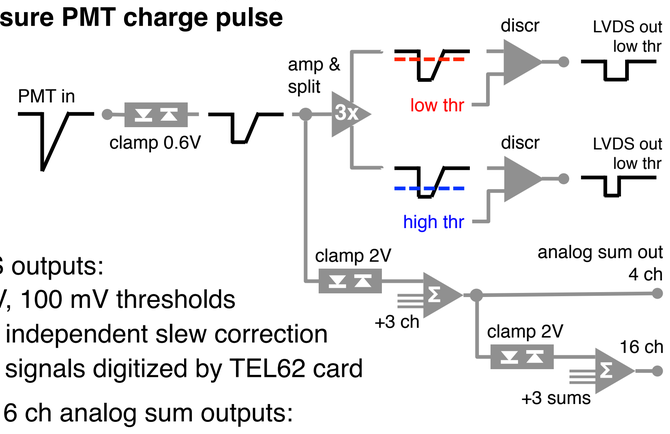


Blocks individually pulsed with blue LED

Front-end electronics

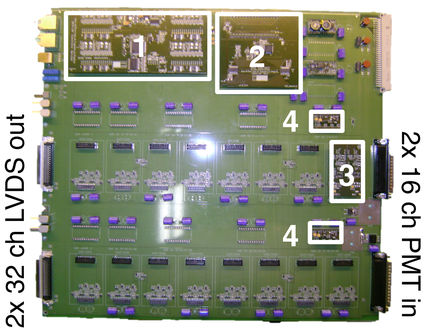
Dynamic range 10 MeV – 10 GeV ≈ 10 mV – 10 V

Use time-over-threshold (ToT) to measure PMT charge pulse



2 LVDS outputs:
~7 mV, 100 mV thresholds
Gives independent slew correction
LVDS signals digitized by TEL62 card

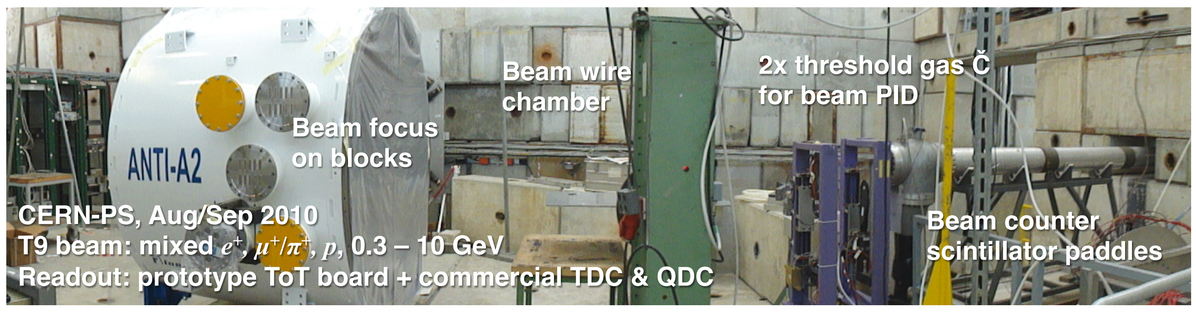
4 and 16 ch analog sum outputs:
Useful for diagnostics and calibration



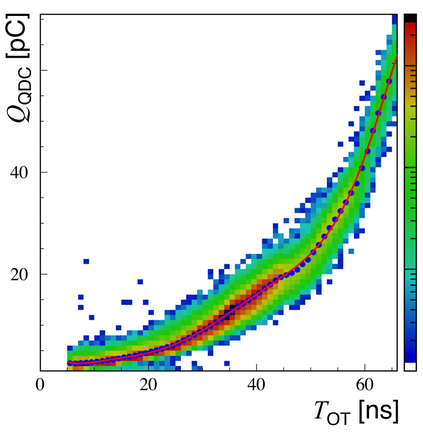
32 ch ToT discriminator board
Early production model

1 Board controller/CANOpen interface
2 Test pulse controller
3 ToT discriminator mezzanine (16)
4 Analog sum mezzanine (8 + 2)

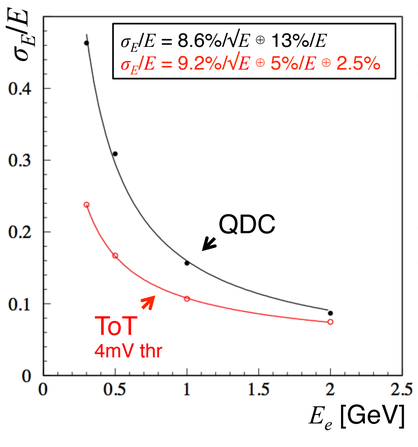
Test beam performance



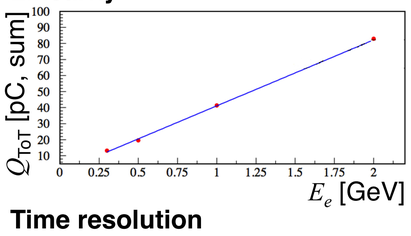
Charge reconstruction



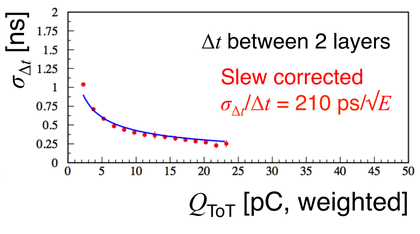
Energy resolution



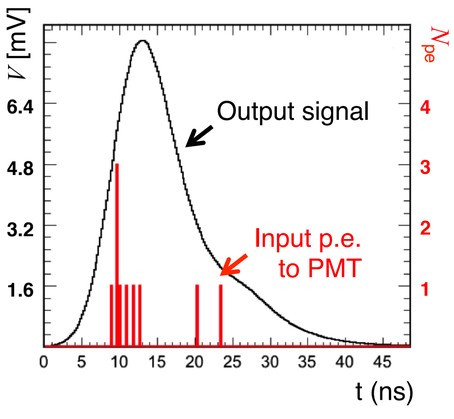
Linearity

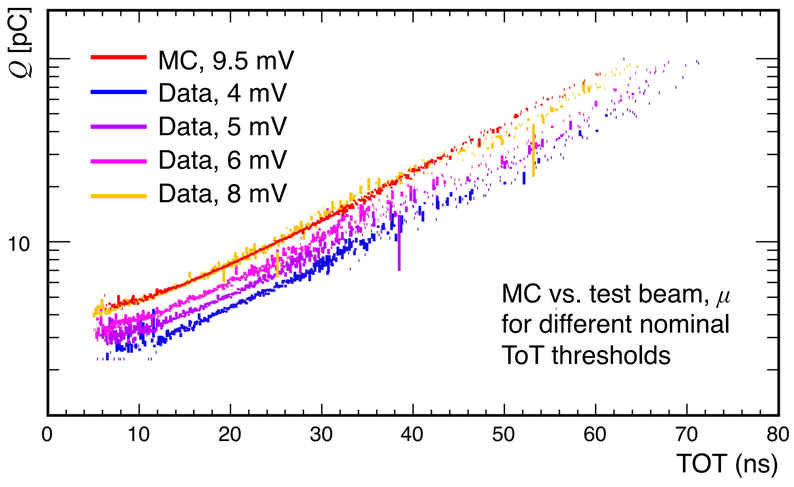


Time resolution



Simulation





Detailed simulation of signals from detector includes:

- Cerenkov photon emission and transport in glass
- Arrival times of single photoelectrons
- PMT gain and transit time fluctuations, PMT capacitance
- ToT circuit: threshold, comparator hysteresis, cable length

Simulation outputs:

- Complete PMT signal, charge integral and ToT response
- Good comparison between simulation and test beam data