

The NA62 RICH Detector

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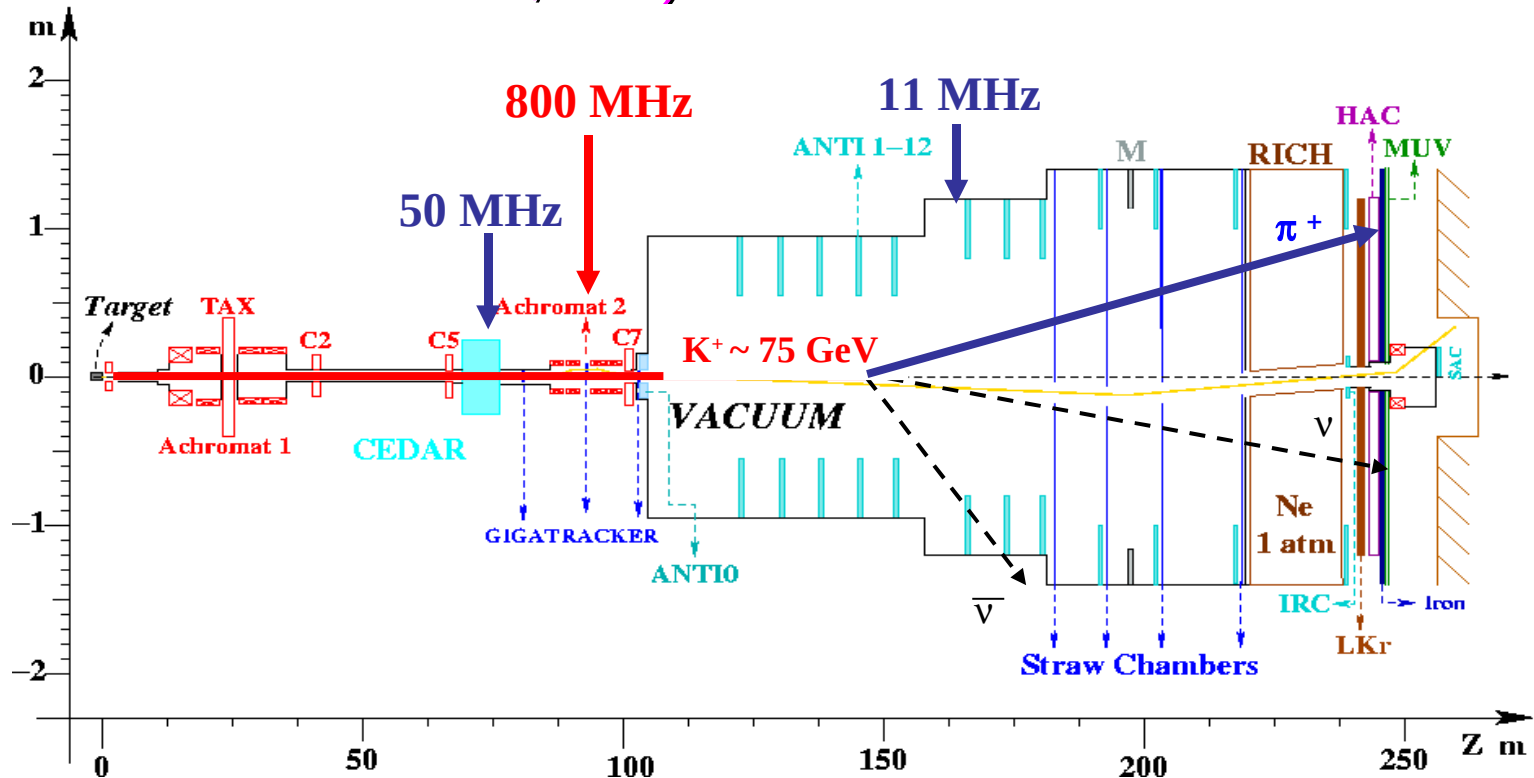
On behalf of
NA62 RICH Group

NA62

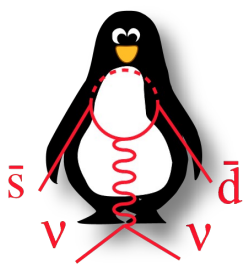


NA62: measurement of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

- Very clean theoretical prediction, sensitive to V_{td} , very sensitive to new physics (if measured at level of 10%: ~100 events)
- $BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (8.0 \pm 1.1) \times 10^{-11}$ SM @ NLO
- E787/949: $BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = 1.73_{-1.05}^{+1.15} \times 10^{-10}$ (7 events)
 (Phys.Rev.Lett.101:191802,2008)



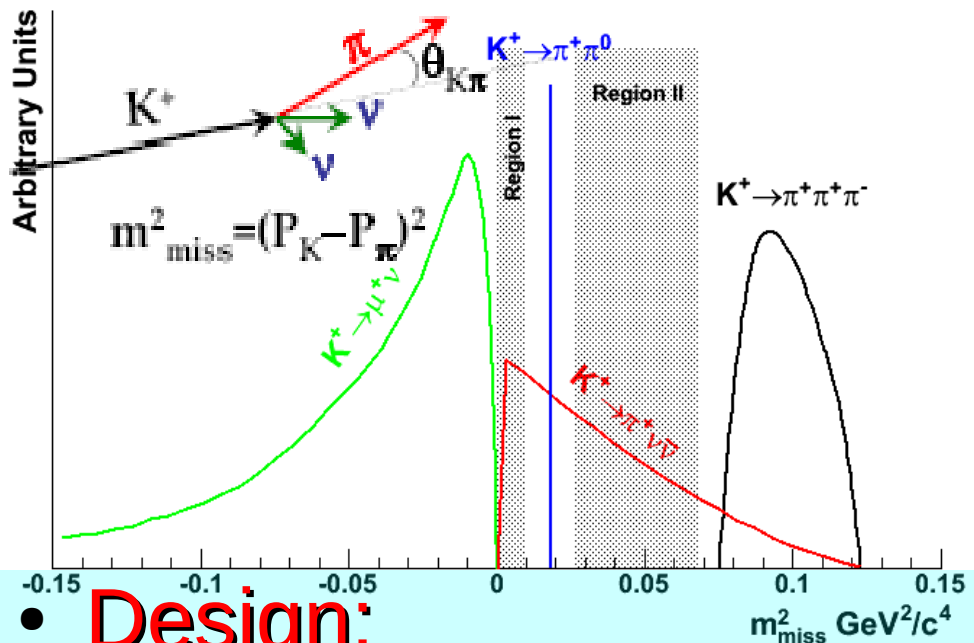
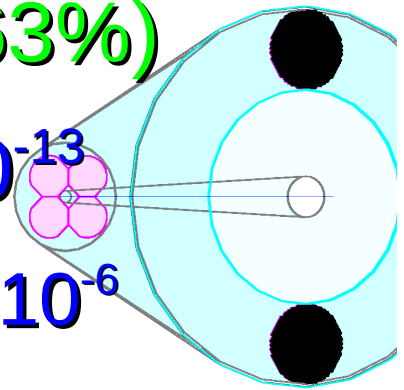
NA62



The RICH

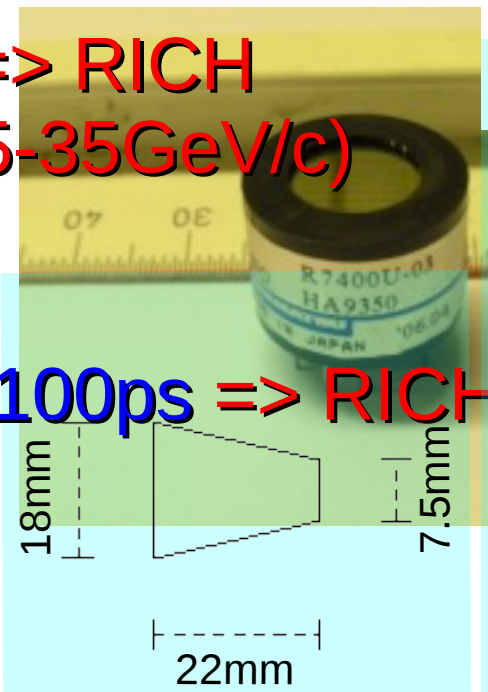
- Main background
 $K^+ \rightarrow \mu^+ \nu$ (BR ~ 63%)

- Rejection $\sim 4 \times 10^{-13}$
 - Kinematics $\sim 8 \times 10^{-6}$
 - Vetoes $\sim 10^{-5}$
 - PID $\sim 5 \cdot 10^{-3} \Rightarrow$ RICH
 $(\pi - \mu \text{ at } 3\sigma \text{ } 15\text{-}35 \text{ GeV}/c)$



- Time K- π
 - Resolution $\sim 100 \text{ ps} \Rightarrow$ RICH

- Design:
 - Focal length $f \sim 17 \text{ m}$
 - Neon at 1 atm $\leftrightarrow P_\pi > 12 \text{ GeV}/c$
 - 2000 PM (Hamamatsu R7400U)
 - granularity 18mm



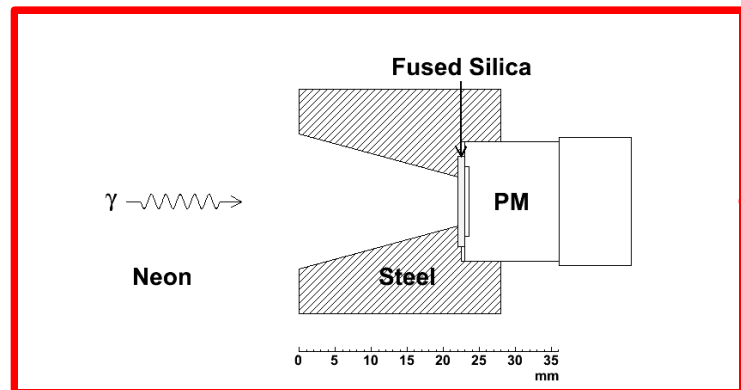
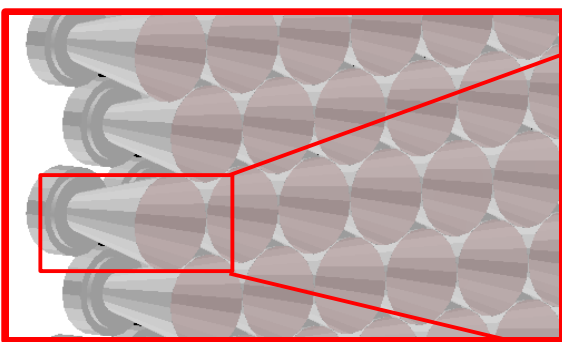
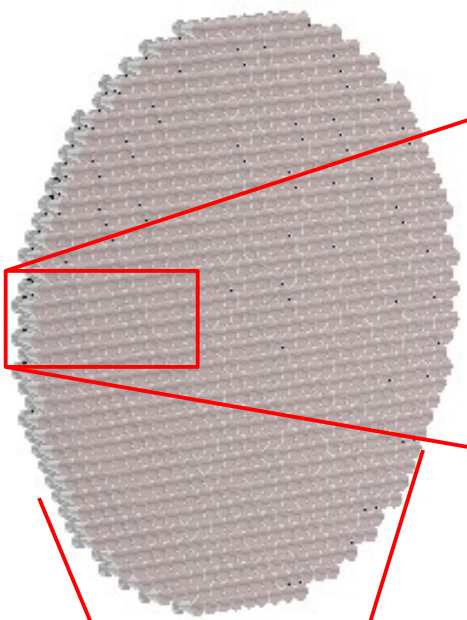
Winston's cone



2 x 1000 PM

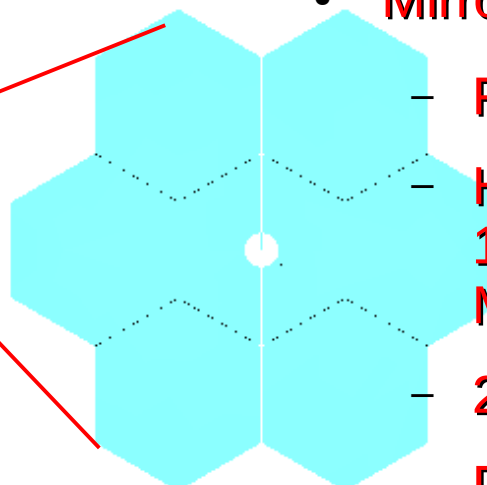
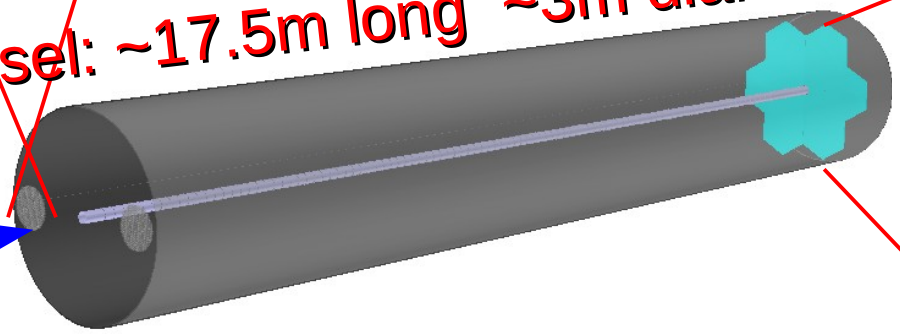
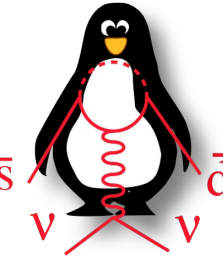
The RICH

(schematic view)



Vessel: ~17.5m long ~3m diameter

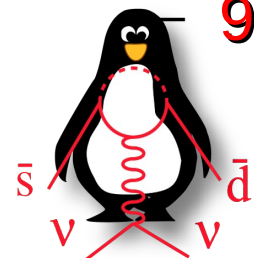
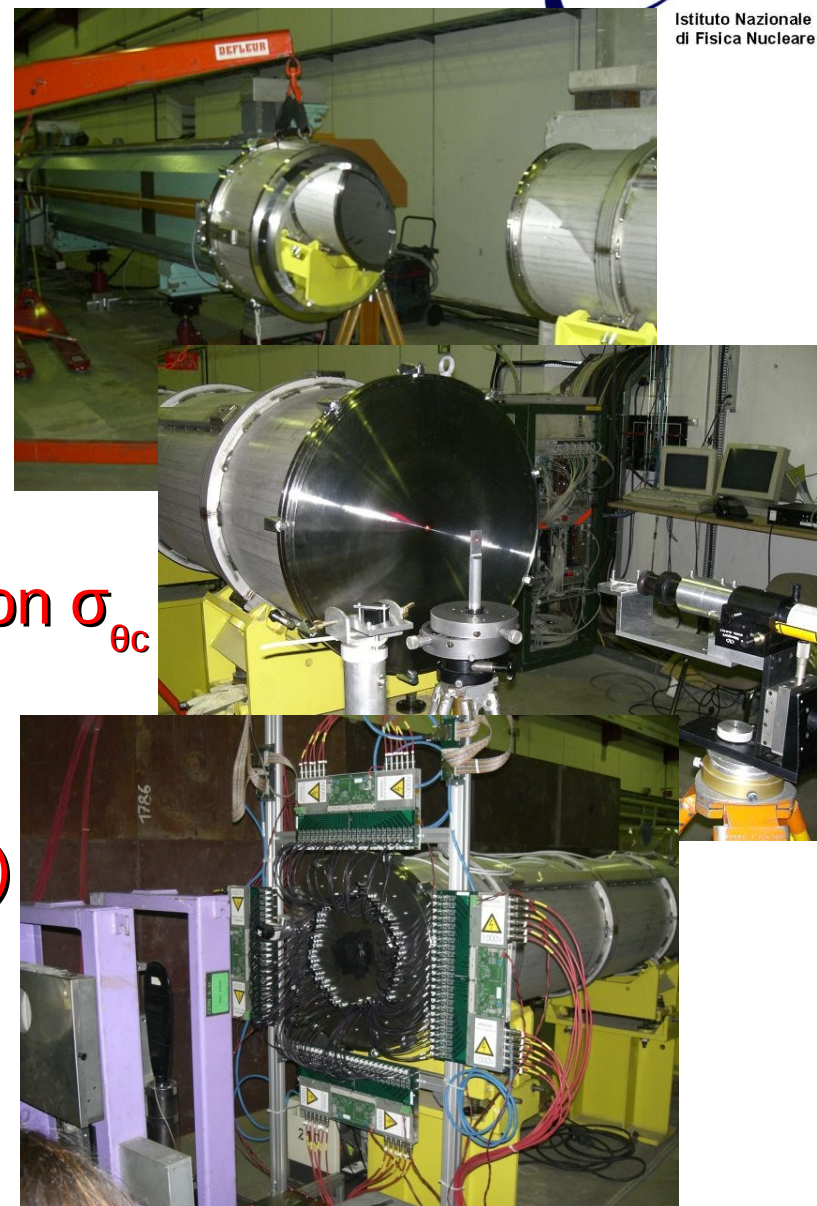
Beam
NA62



- Mirror:
 - Focal length $f \sim 17\text{m}$
 - Hexagonal segments 1m diameter by MARCON
 - 2cm thick glass
 - $D_0 < 4\text{mm}$
 - MgF_2 coated Al

• Aim: Prototype 100 (Fall 2007)

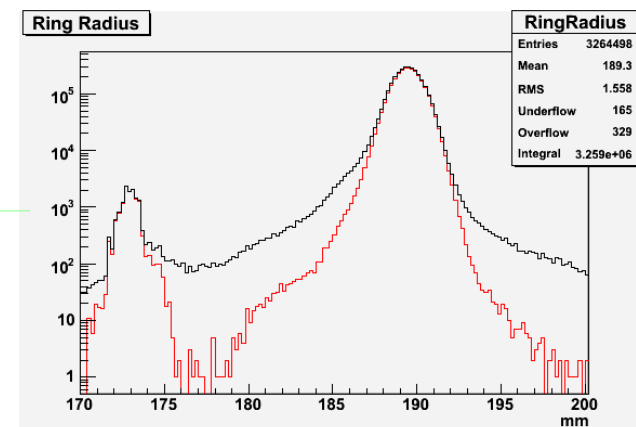
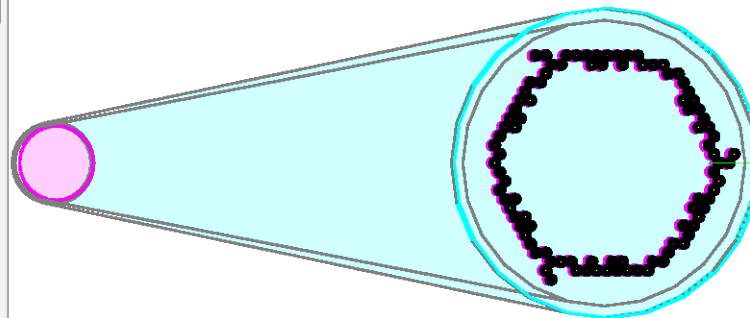
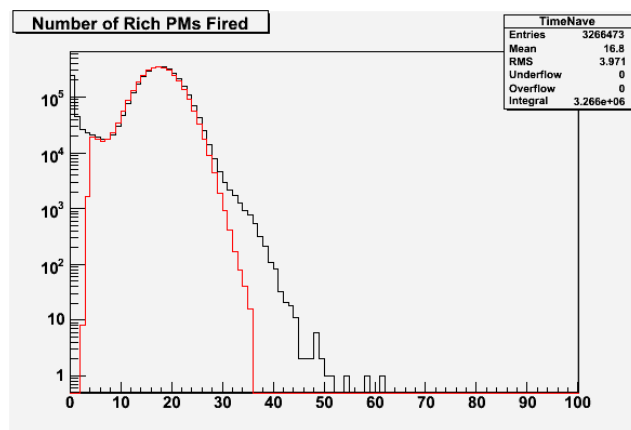
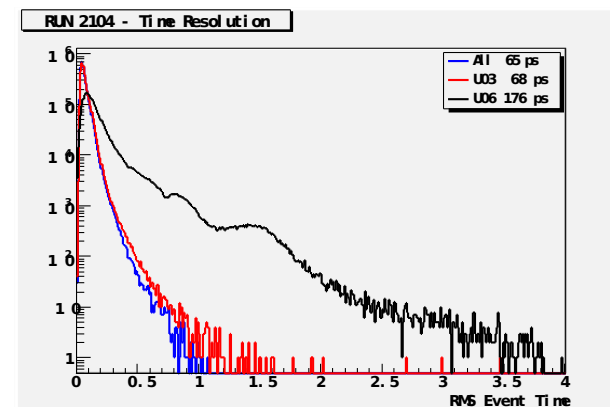
- Time resolution
- Hits multiplicity
- Features:
 - Mirror: $\Phi=50\text{cm}$, thickness=2.5cm, $f=17.01\text{m}$
 - 96 PM (Hamamatsu R-7400) \Rightarrow Bias on σ_{θ_c}
- Detector setup:
 - Test PM and Front-End (NINO based)
- Beam:
 - NA62
 - 96.2% π , 3.0% K, 0.8% p @200GeV



Test Beam Results

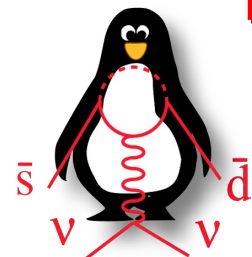
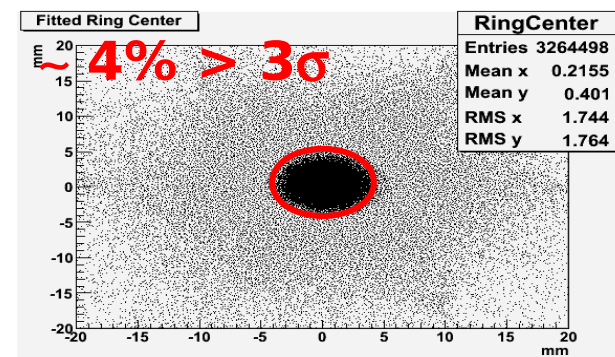
NIM A 593(2008) 314-318

- **Performance:**
 - Time resolution $\sim 65\text{ps}$
 - $\sigma_{\theta_c} \sim 50\mu\text{rad}$ (bias)



- Track Angular resolution $\sim 100\mu\text{rad}$

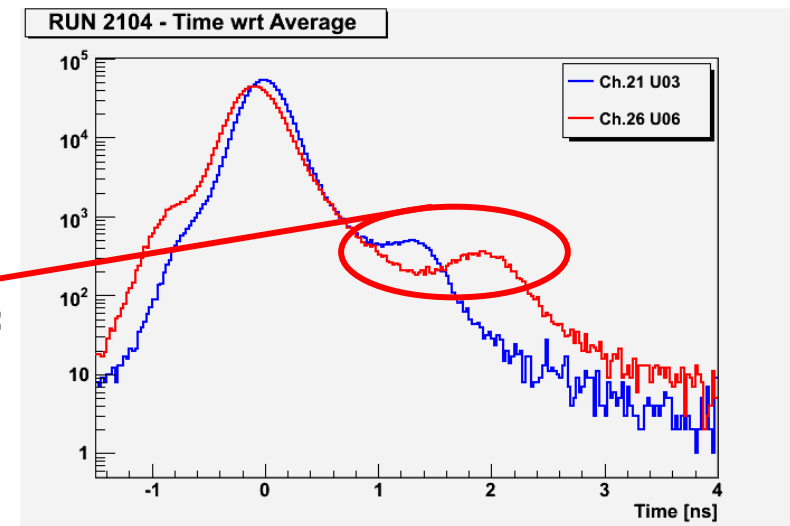
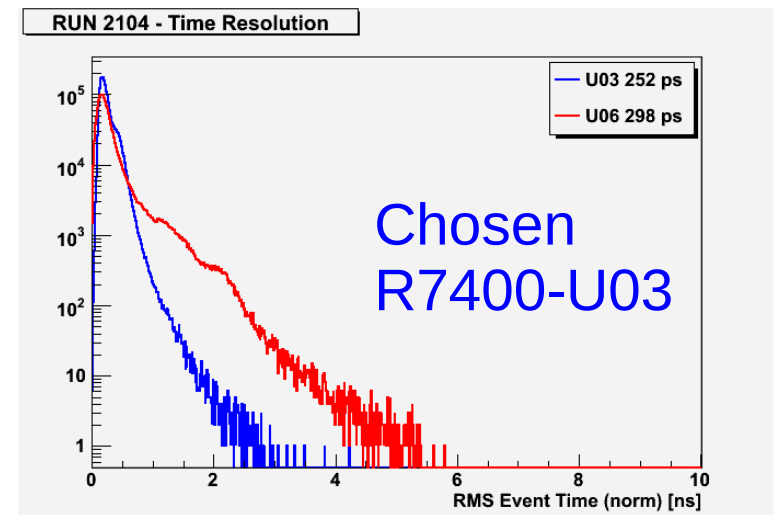
NA62 Hit PM multiplicity ~ 17



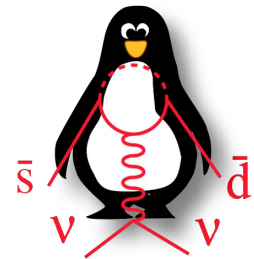
Test Beam Results

(details)

- Comparison between PMs:
R7400-U03/R7400-U06
- Single PM time resolution
- Robustness tests:
 - Neon contamination up to 1%
 - Temperature variations
 - No relevant effect



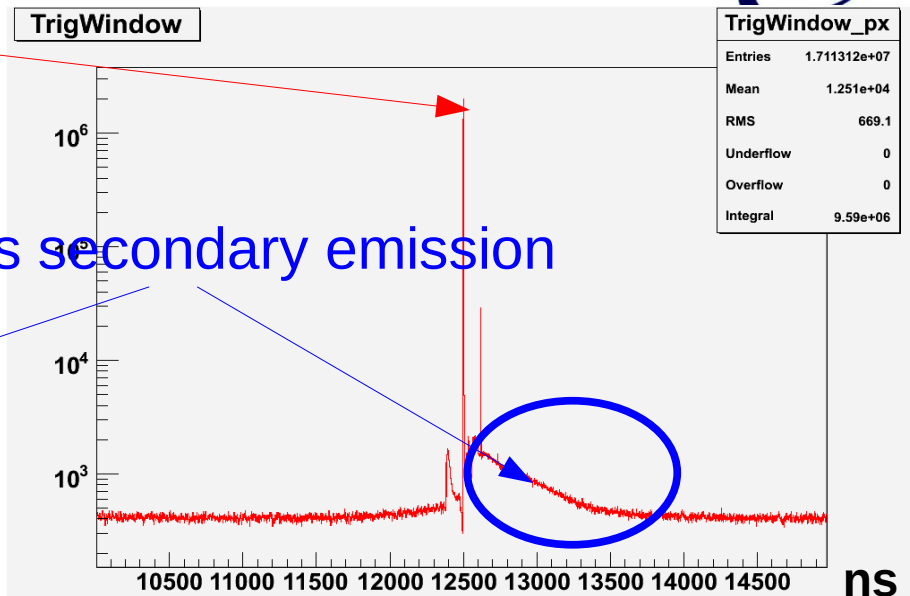
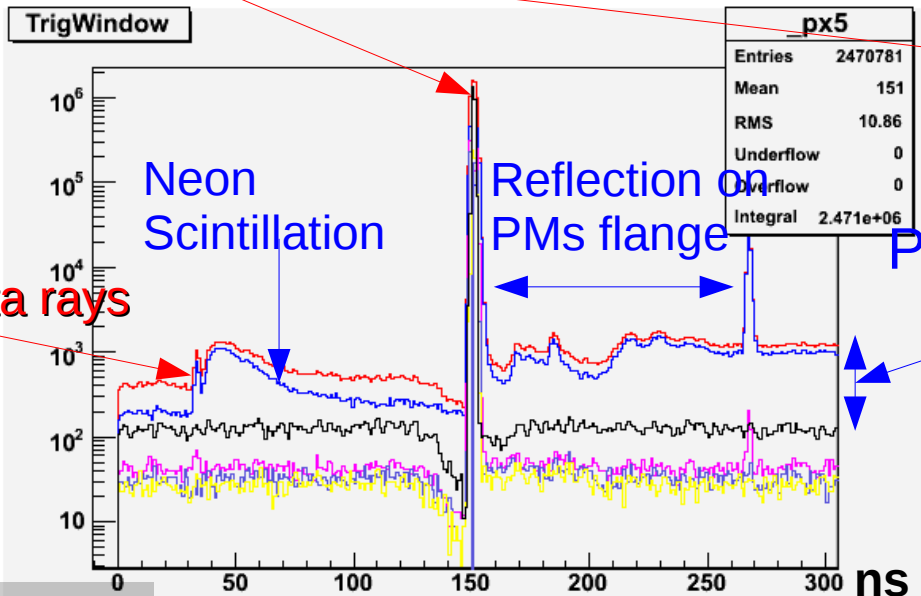
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Time of the event
(arbitrary offset)

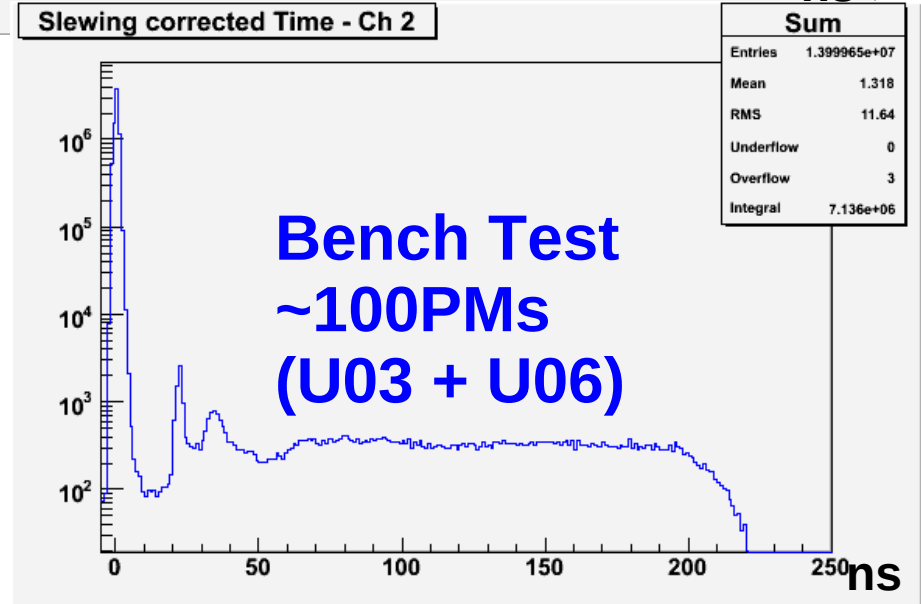
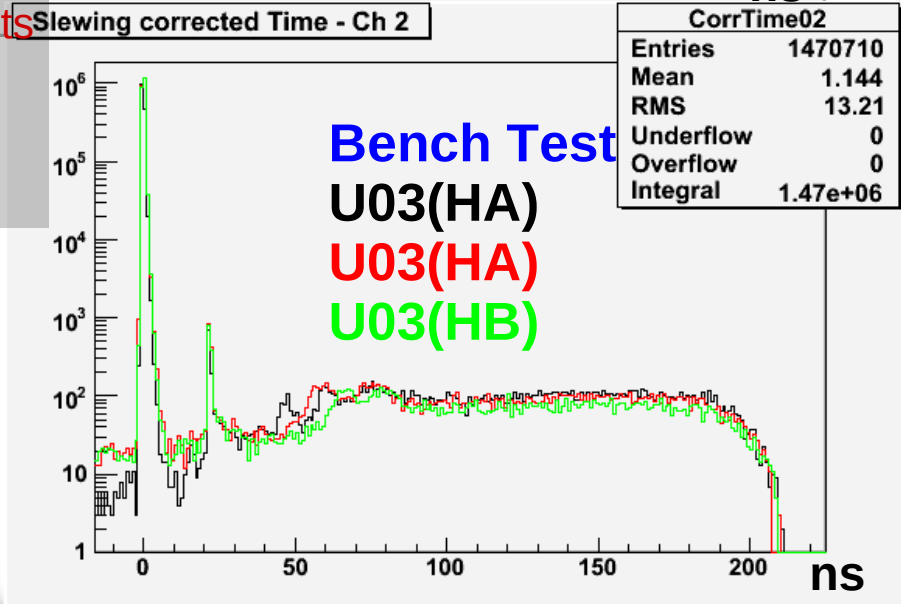
Test Beam Results

(further details: IEEE TNS vol. 56 no. 3, June 2009)

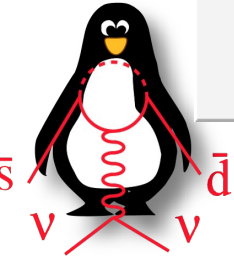


Delta rays

- all events
- 1 PM
- 2 PMs
- 3 PMs
- ≥4 PMs

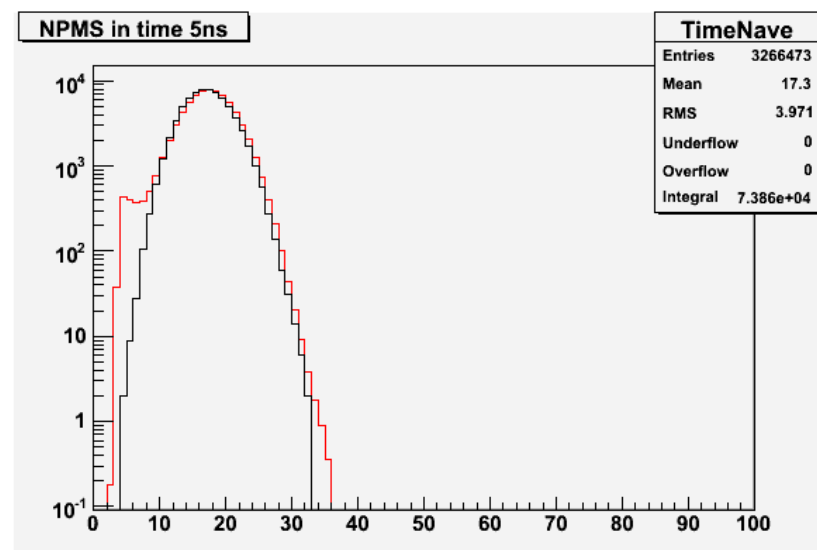
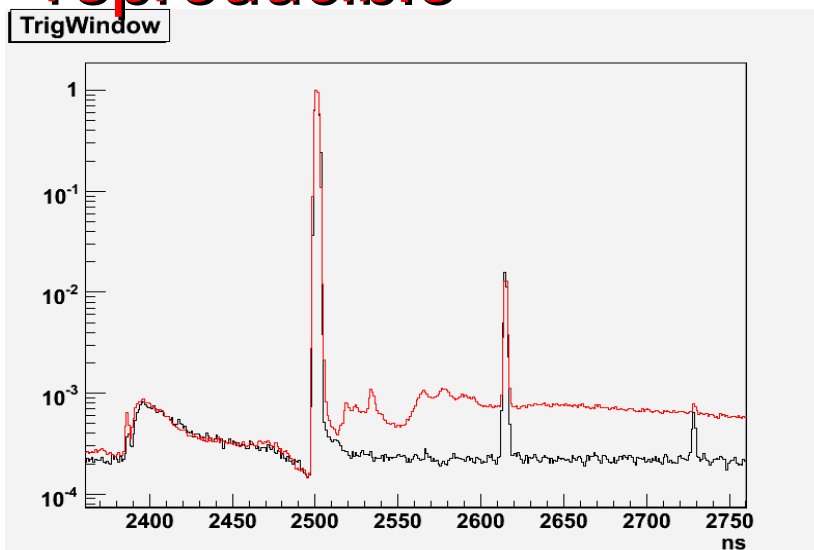
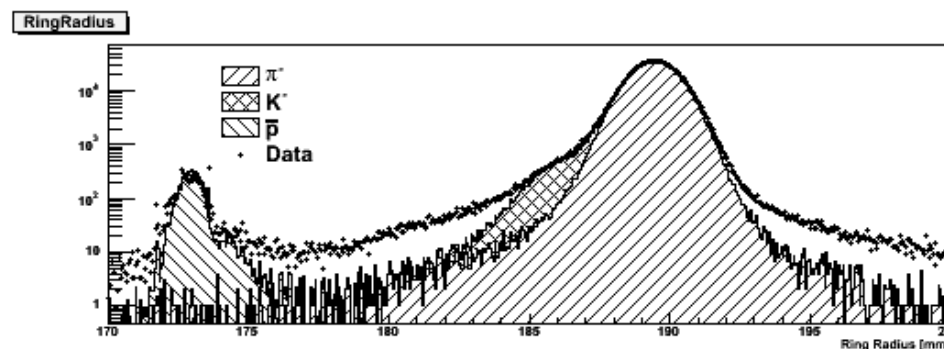
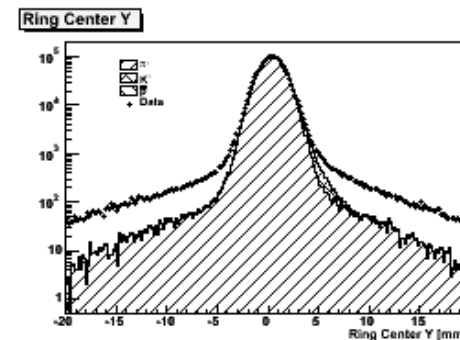
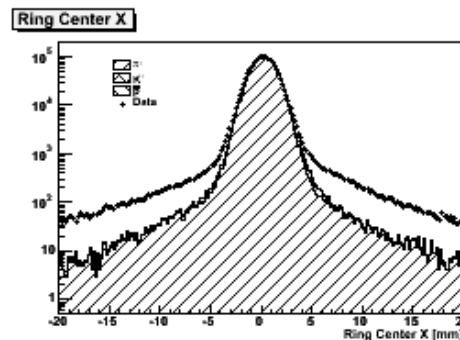


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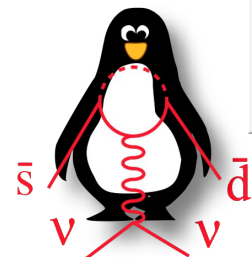


MonteCarlo

- Cherenkov related performance reproduced
- Higher order effects:
 - could be tuned better
 - PM's secondary emission not reproducible



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Prototype 400

- **Aim:**

- π - μ separation at 15-35 GeV/c
- Improvement of cooling and mechanical structure

- Test DAQ and Trigger by TELL1 (HPTDC)

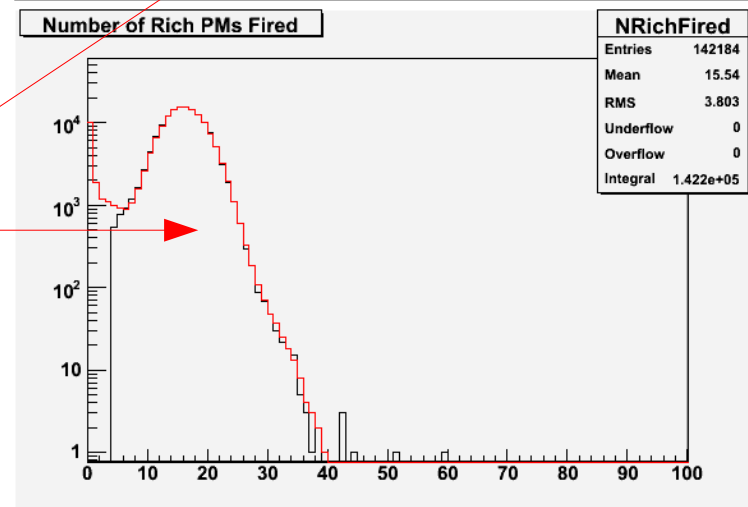
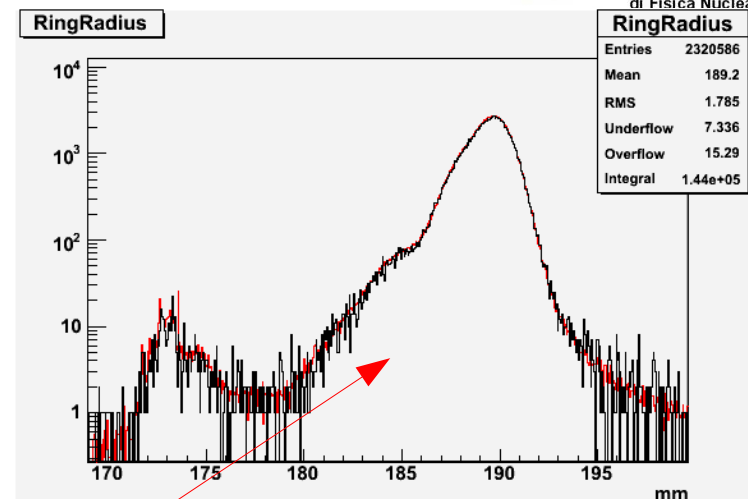
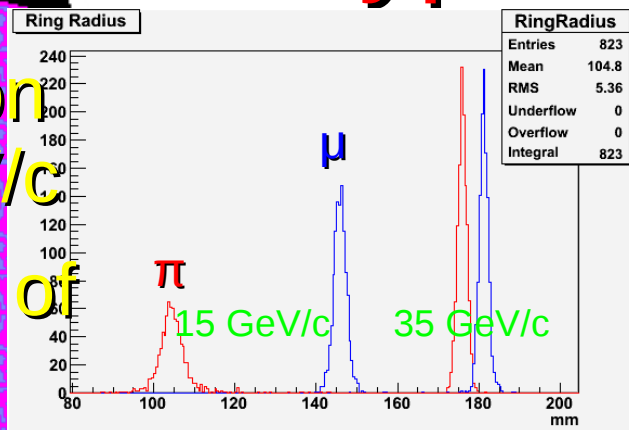
- **Features:**

- Added 318 PM

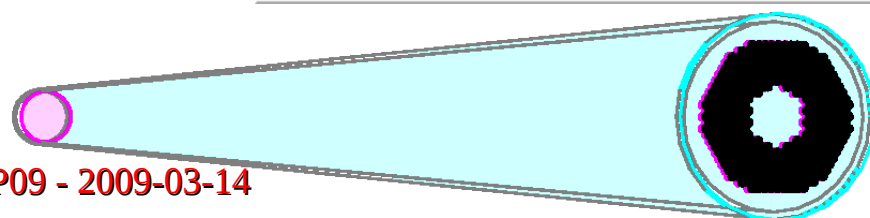
- **Status:**

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Design finalized,
ready for the beam



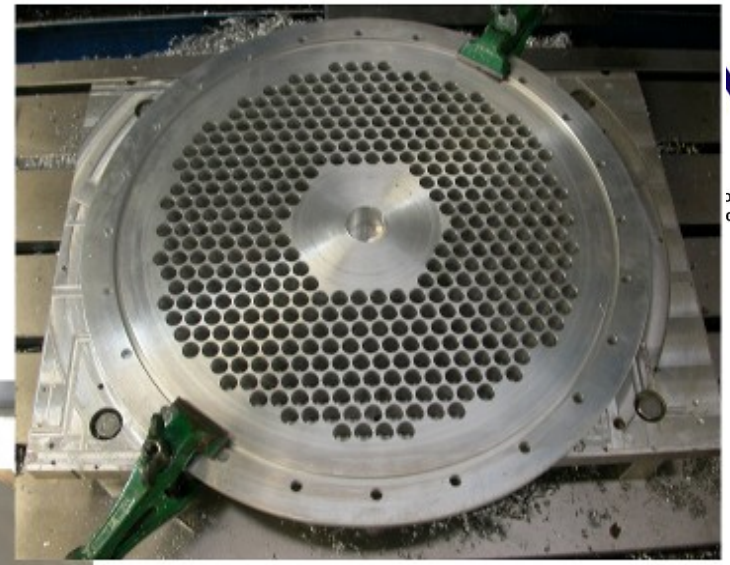
Offline application of
trigger algorithm to
data from TestBeam
2007



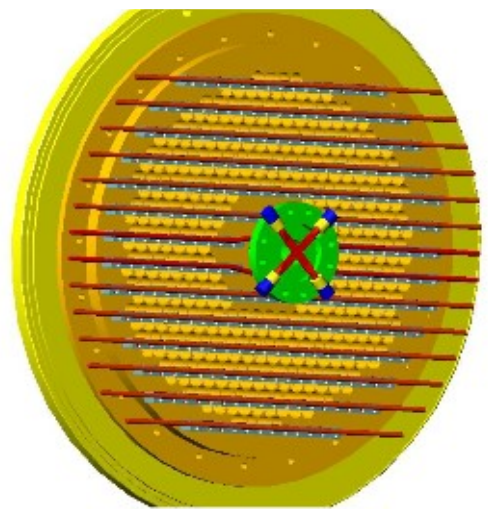
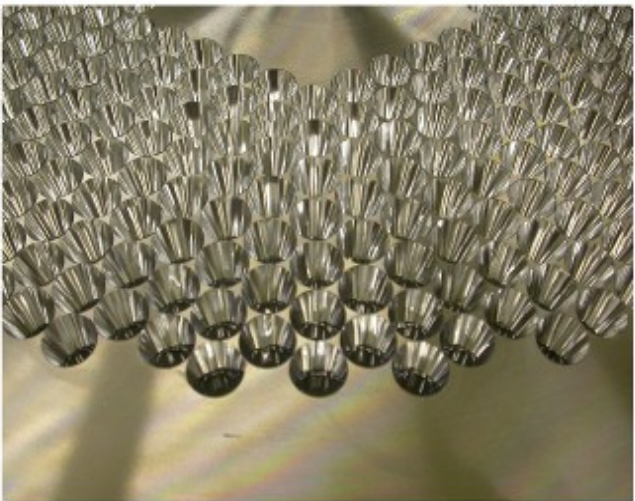


Prototype 400

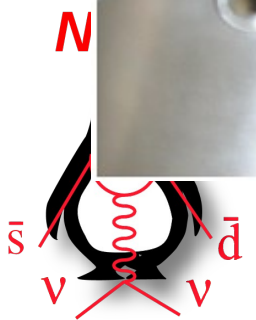
Test scheduled for October 2008
Postponed to May 2009 (LHC accident)



PM holder
Endcap (Cones)
Cooling



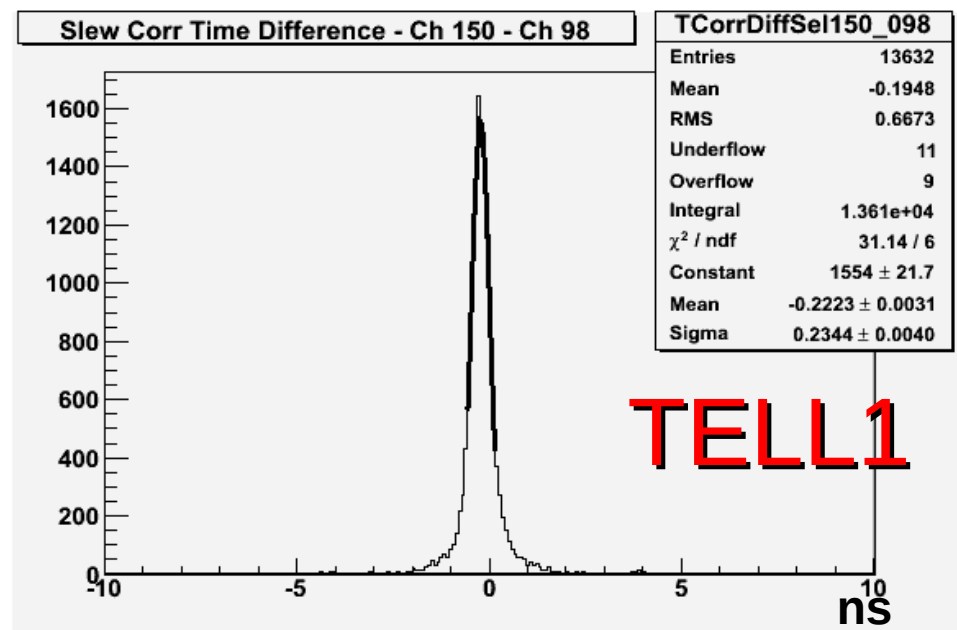
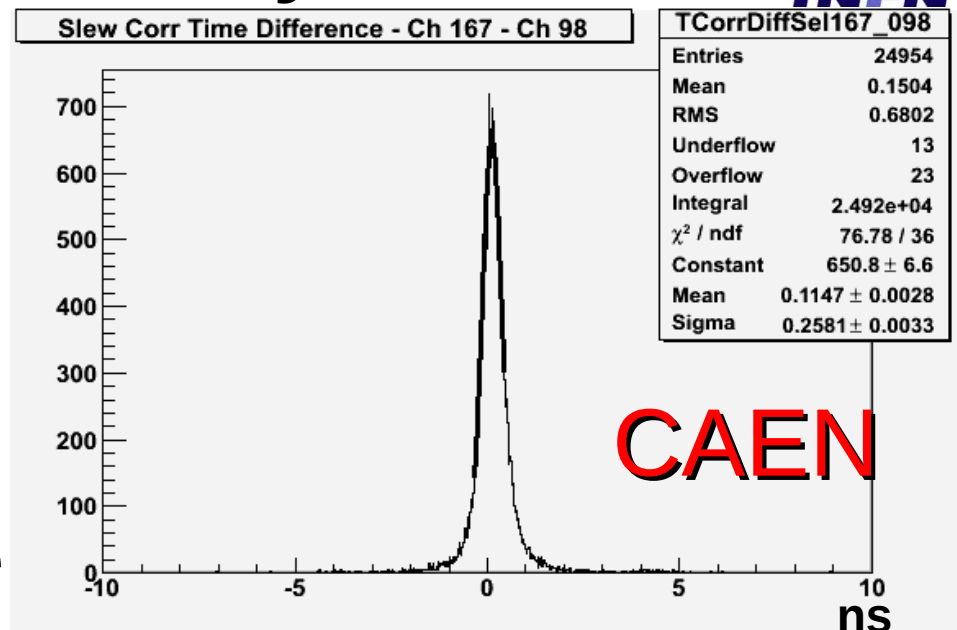
Antonino Sergi - TIPP09 - 2009-03-14



TELL1 preliminary test

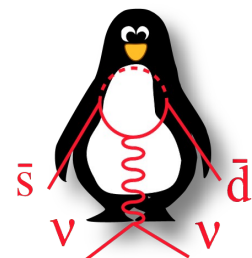


- ~400 PMs installed in the PM holder
- Full FE electronics assembly
- Laser arranged to pulse all the PMs at once
- Time resolution measurements using both CAEN TDCs (test 2007) and TELL1



NA62

See G. Lamanna talk



Summary

- NA62 demands a challenging RICH
- Test of the first prototype (96PM, Fall 2007):
 - Good results
 - Tool for MC validation
 - NIM and IEEE TNS papers
- Fall 2008: Preliminary test of TELL1 readout
- Spring 2009: test of the second prototype (414PM) for π - μ separation
- The final detector should be ready for 2011
NA62 commissioning run

NA62



SPARES

NA62



PMT Hamamatsu R7400U

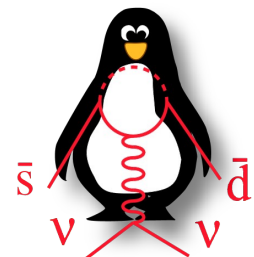
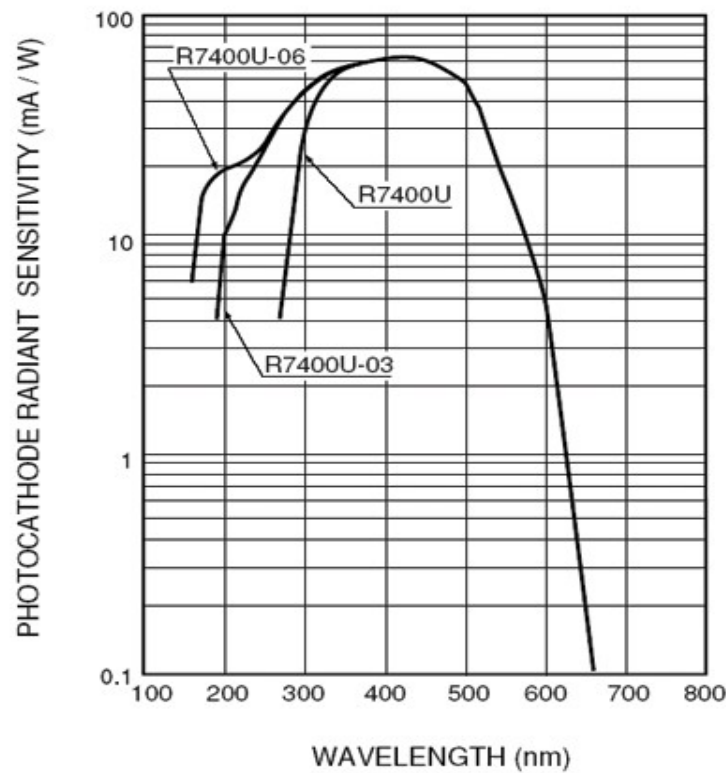
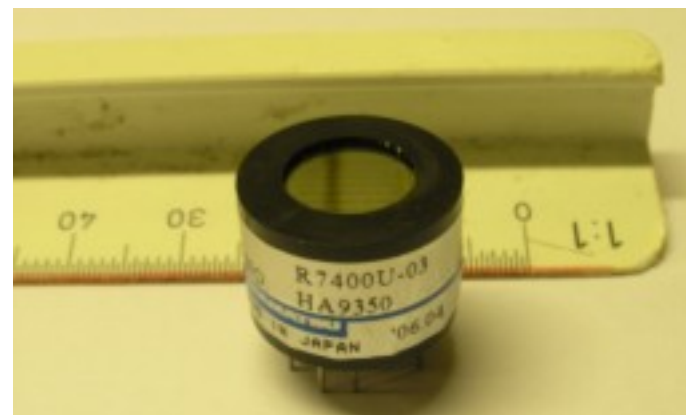
Hamamatsu R7400U PMT

- diameter 16 mm
- length 16 mm
- photocatode diameter 8 mm
- 8 stages
- Max HV 1000 V
- Gain@800V ~ $5-7 \times 10^6$
- λ peak ~ 420 nm
- t.t.s. 280 ps

Used:

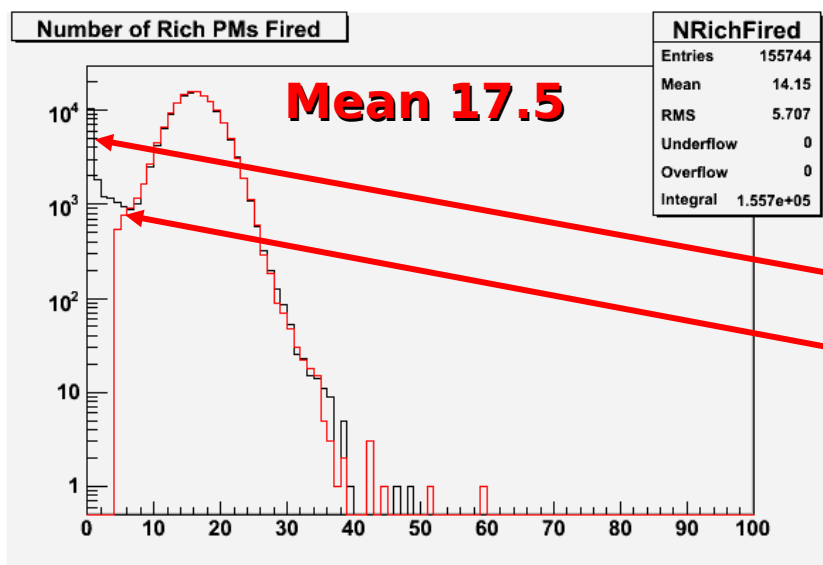
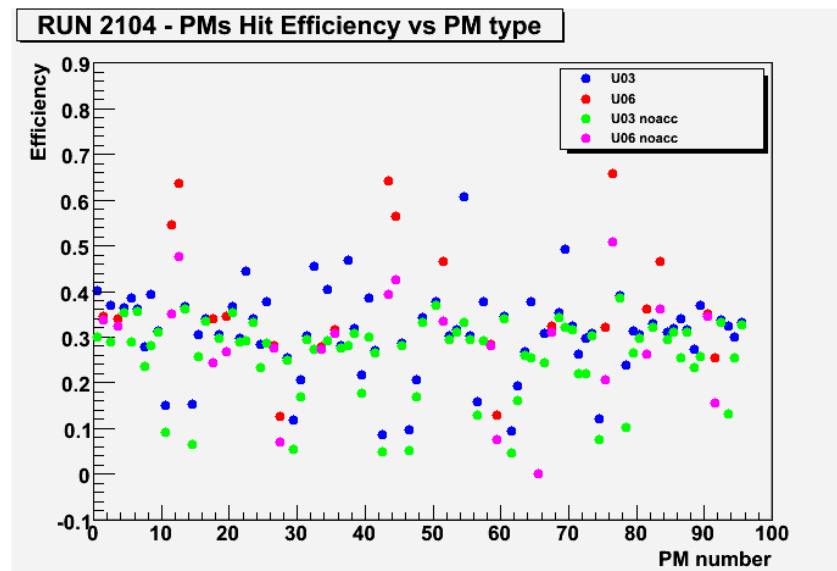
- R7400-U03: Bialkali, UV glass
- R7400-U06: Bialkali, quartz

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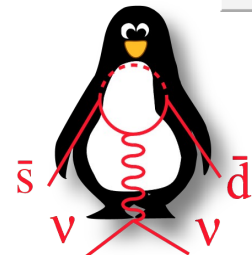
Efficiency

- PM “Efficiency” ~ 0.3 photoelectrons per PM
- Effect of Cuts
- $\lambda_1 \Rightarrow 0$ Hits (Prob $\sim 7\%$)

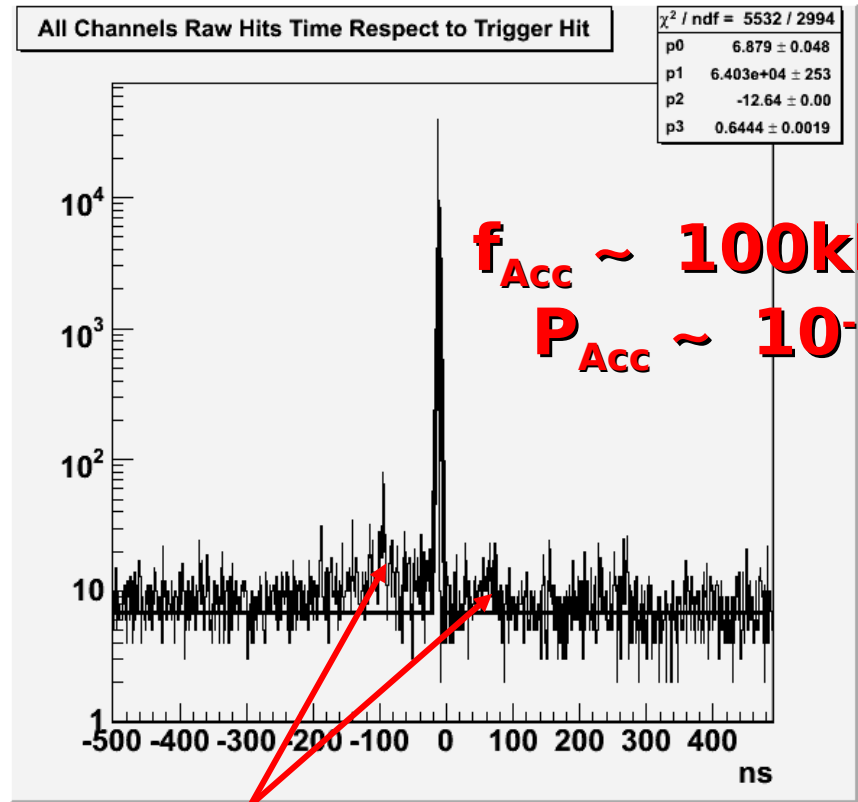
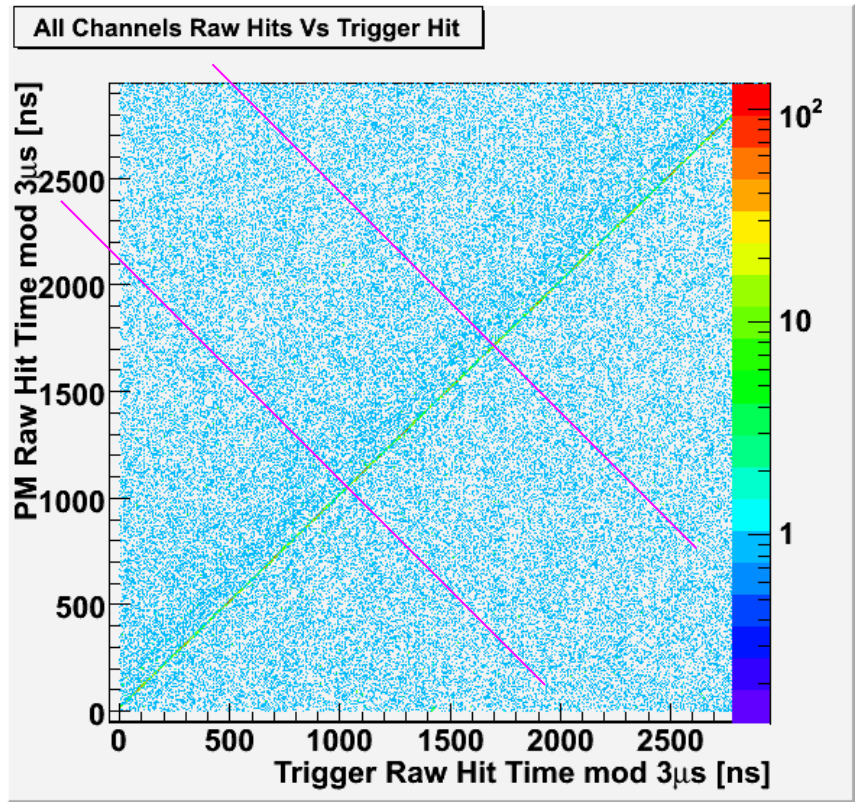
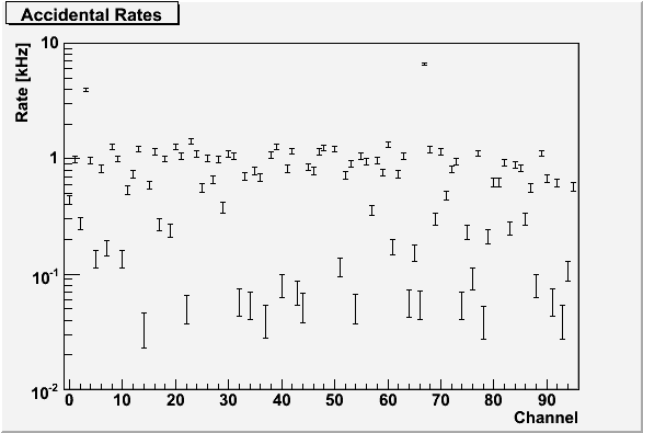


Cut / Run	Standard (2104)	Dx +500	Dx +100	Dy +500	Dy +1000
1 Trigger	.985	.985	.985	.984	.984
Trig Time Wind	.996	.996	.996	.996	.996
Nrich 2-35	.927	----	----	----	----
<Time> in 10ns	.996	.927	.884	.925	.885
≥ 4 PM in 1ns (Ring fit)	.984	.820	.259	.795	.255
Good fit	.999	.999	.988	.999	.986
Final	.891	.745	.222	.721	.218

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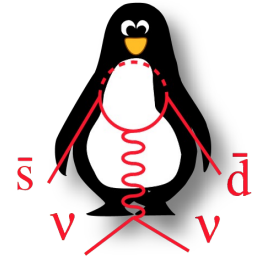
Accidentals



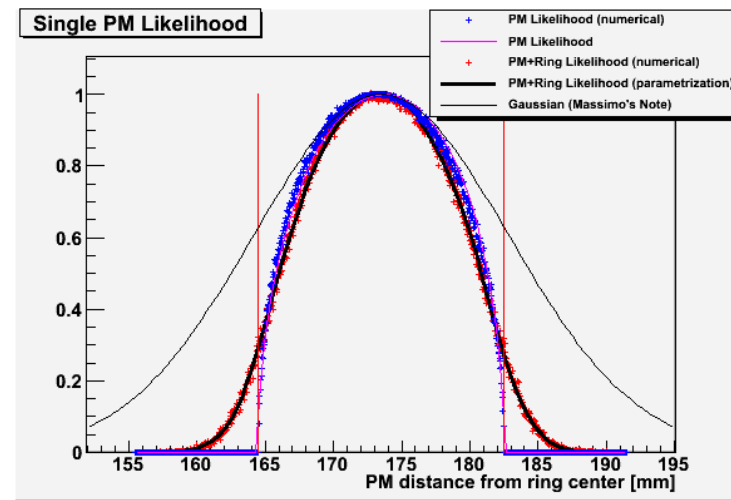
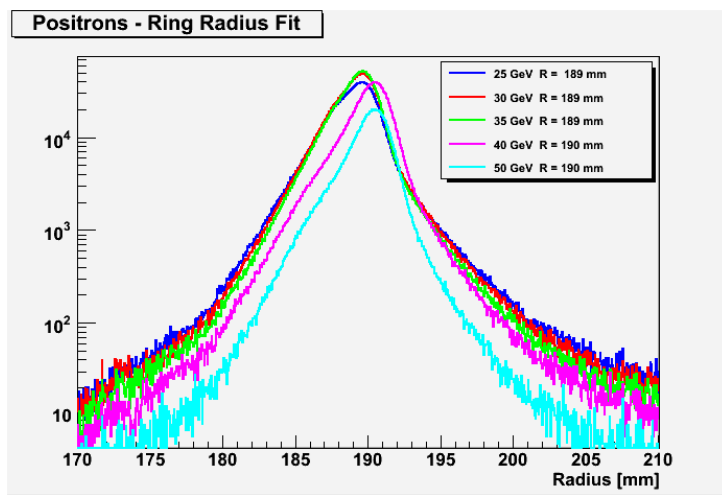
$f_{\text{Acc}} \sim 100\text{kHz}$
 $P_{\text{Acc}} \sim 10^{-3}$

Trigger (Low) Quality

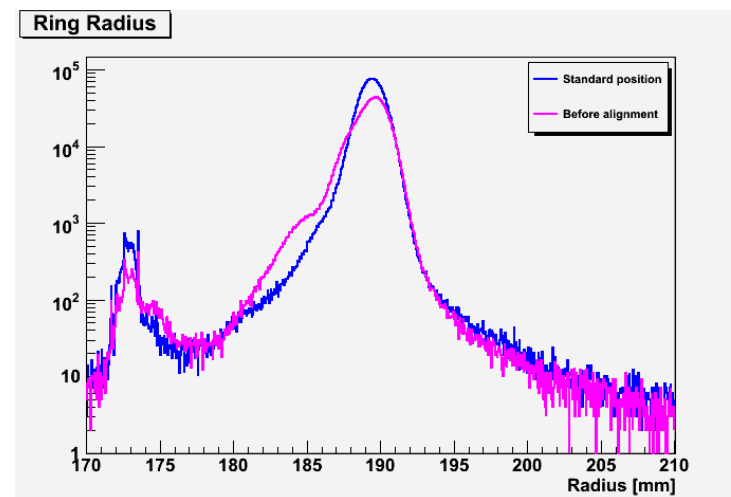
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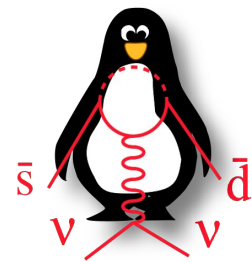
Ring Fit



- Positrons Run: Single Peak
- Bump in “Kaon Region” removed: Geometry/Fit artifact

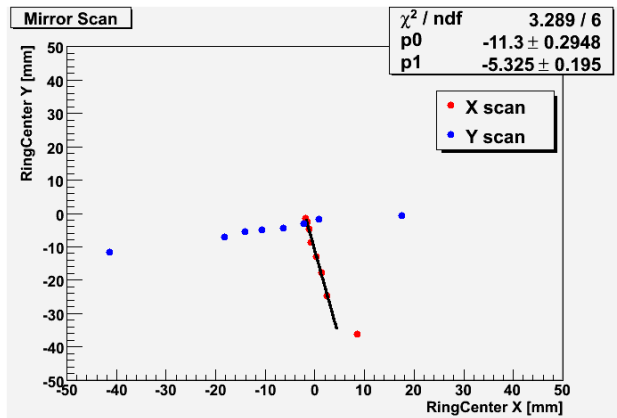


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Mirror Movements

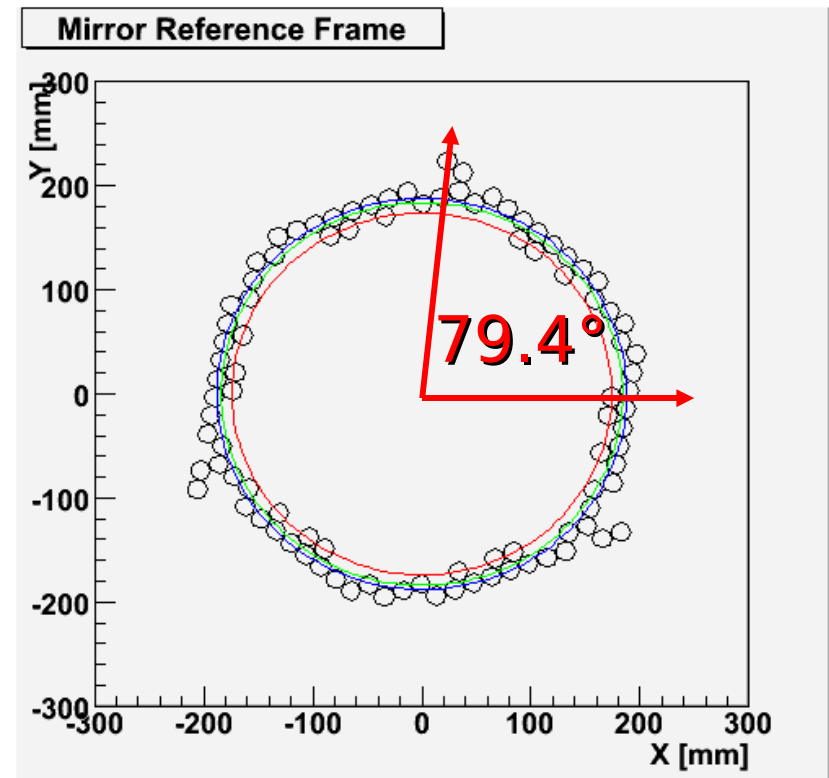
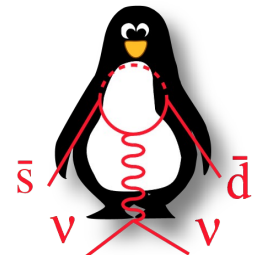
- Mirror orientation reproducibility



- Rotation angle between Mirror and PMs XY reference

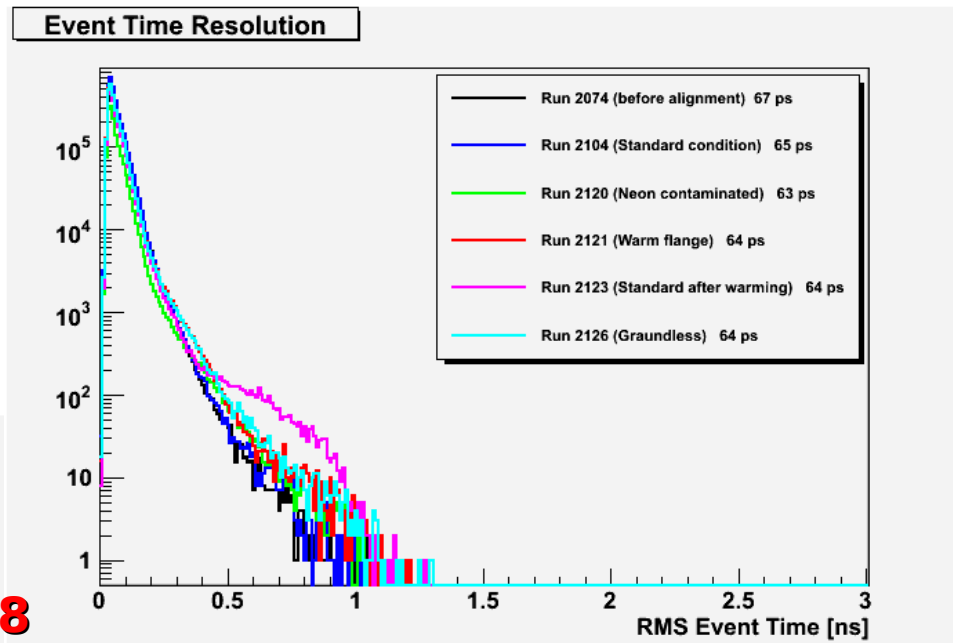
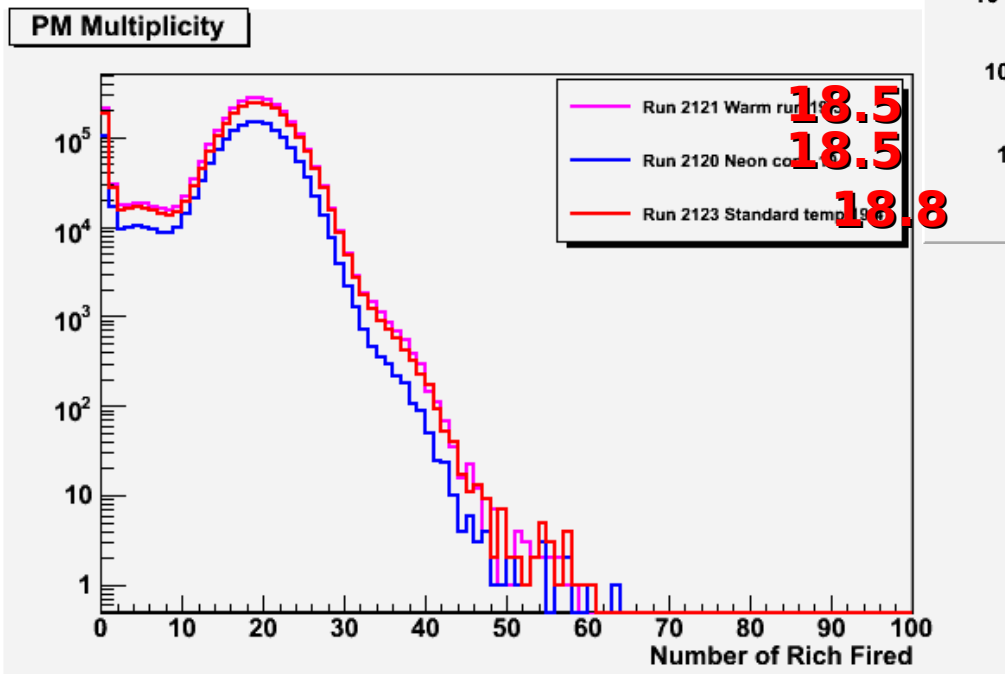
(~ 80°)

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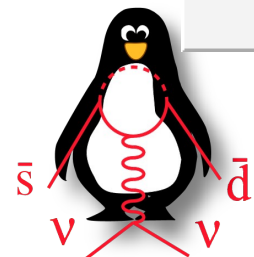
Robustness Tests

- Temperature
No visible effect on
“Cerenkov side”



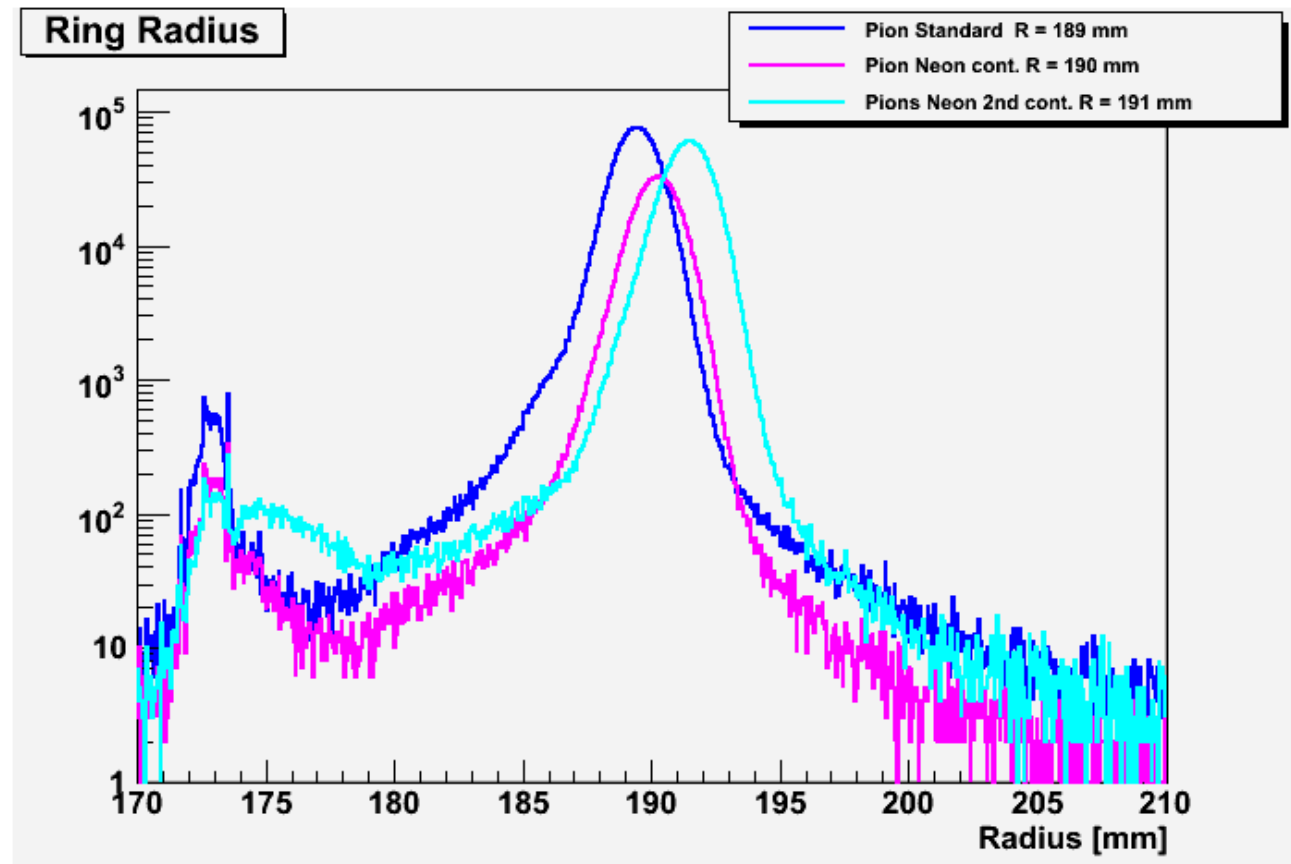
Neither on Time
Resolution

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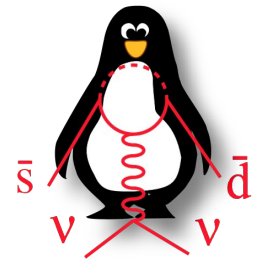


Robustness Tests (2)

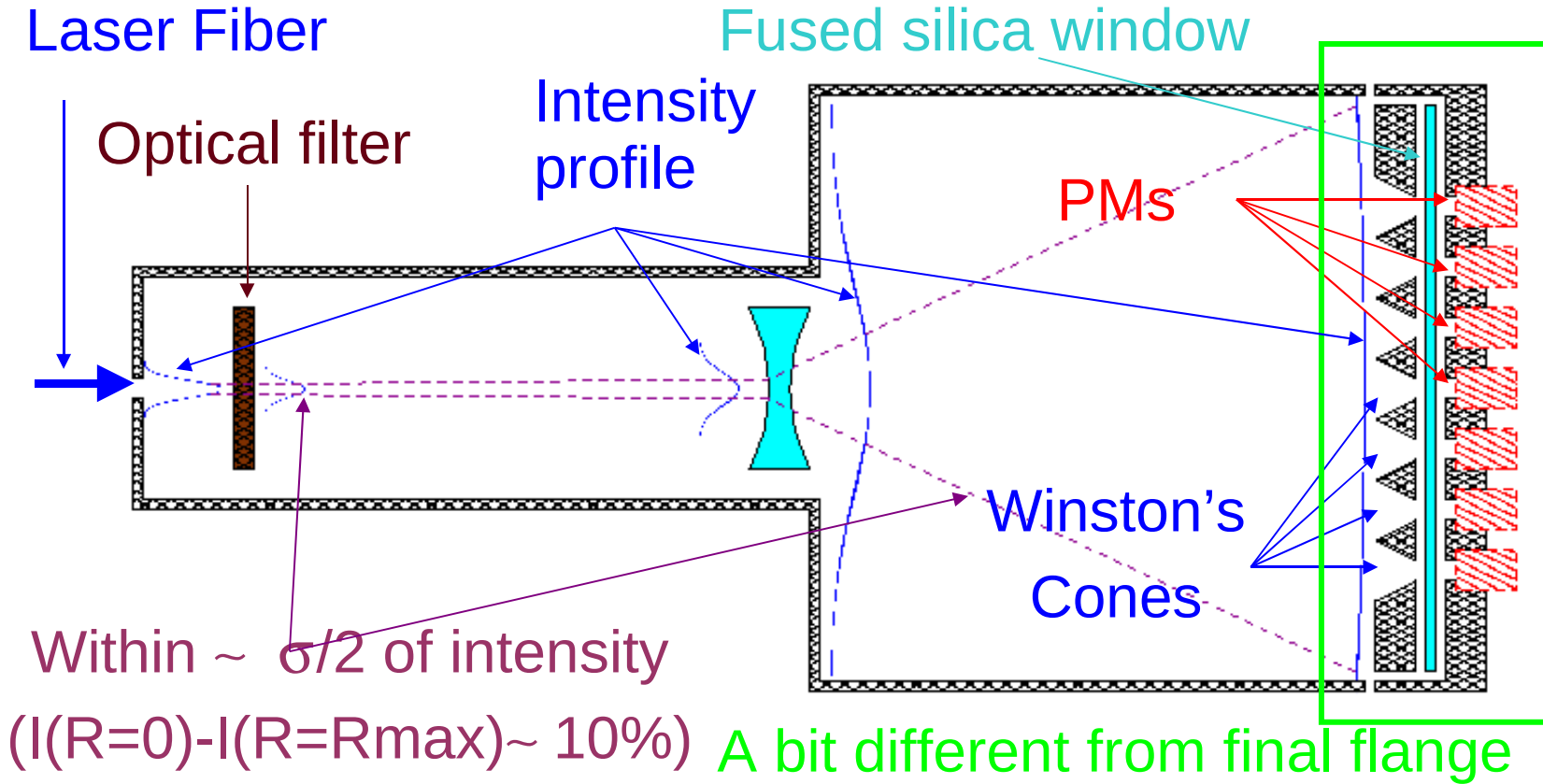
- Neon Contamination (N_2 0.5%+0.5%)



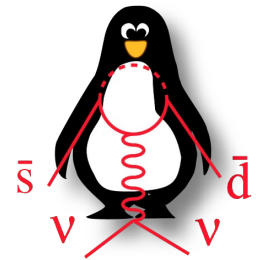
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Test Optics

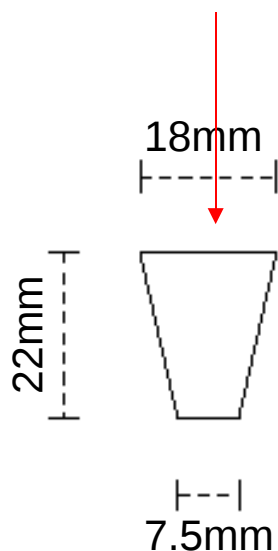


NA62



Flanges

Within $\sim 1^\circ$
 from axis
 max $\sim 3\text{mm}$ gap
 without loosing
 efficiency



Fused silica window(s)

PMS

Winston's
 Cones

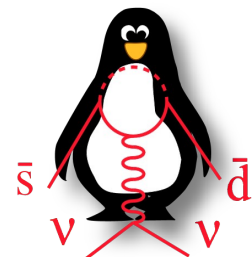
$\sim 7\text{mm}$ gap
 ($\sim 40\%$ loss)

$\sim 1.5\text{mm}$ gap

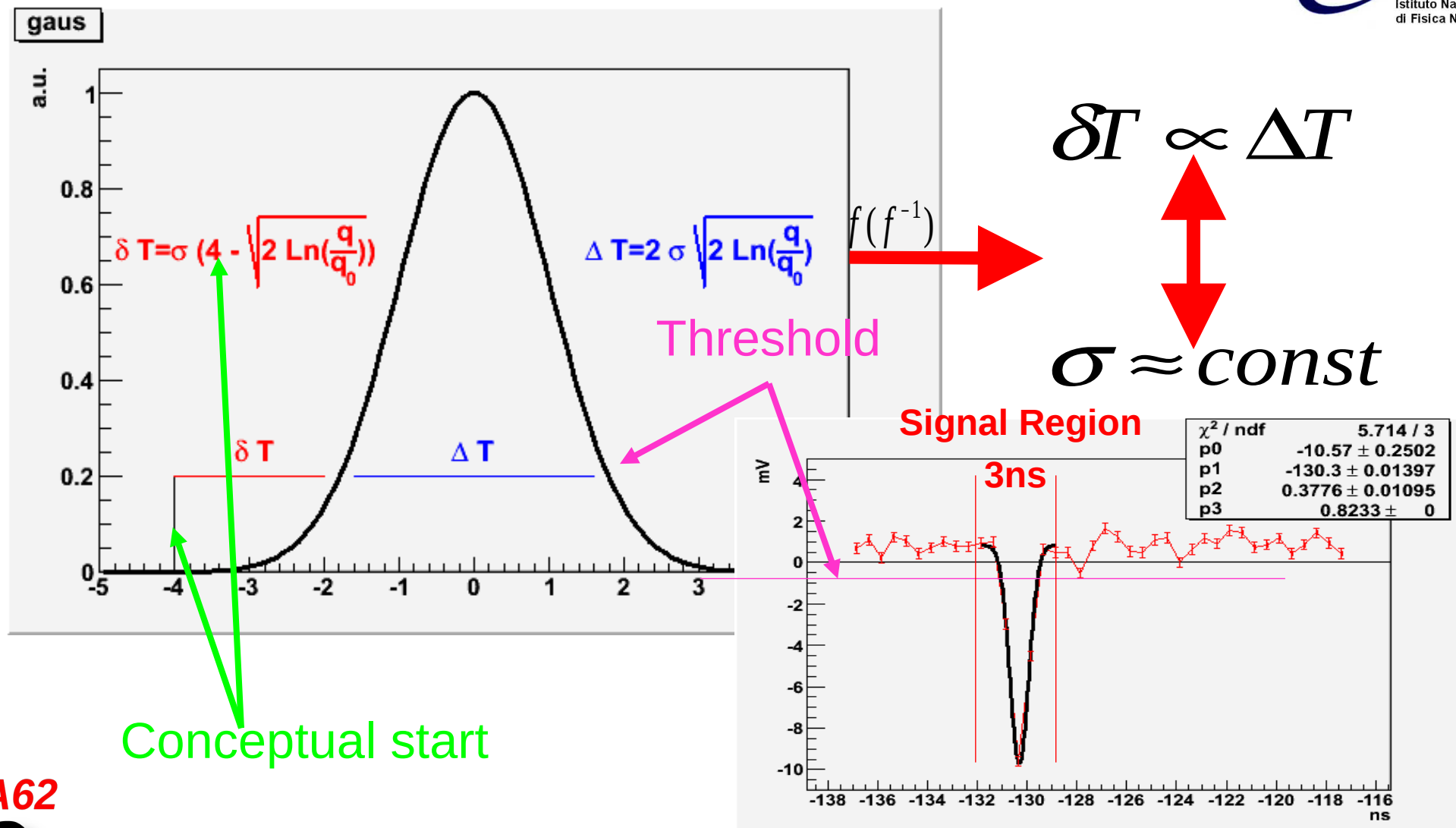
Perugia Lab

RICH TestBeam

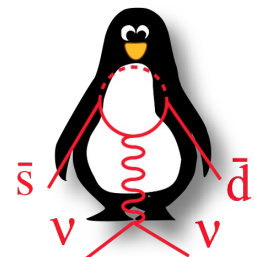
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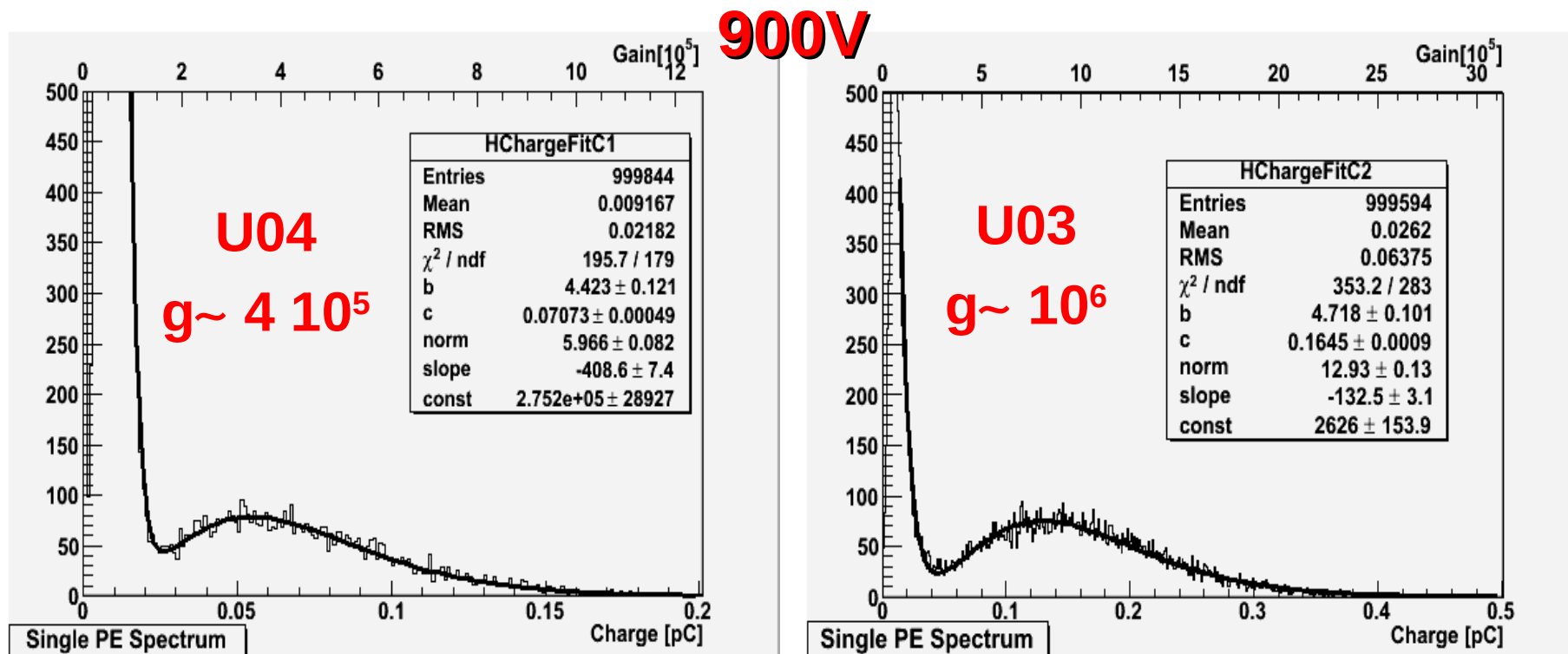
Analog signal parametrization



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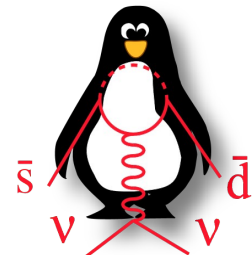


Single PE measurements



$$f(q) = \frac{\left(\frac{b}{c} - q\right)^b e^{-\frac{b}{c}q}}{x \Gamma(b)}$$

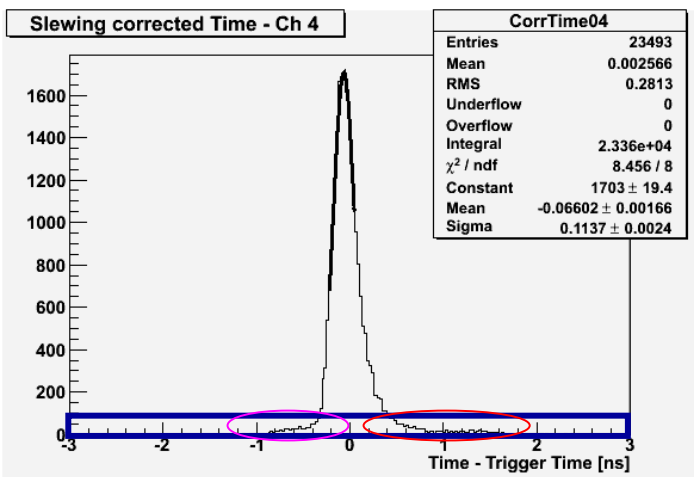
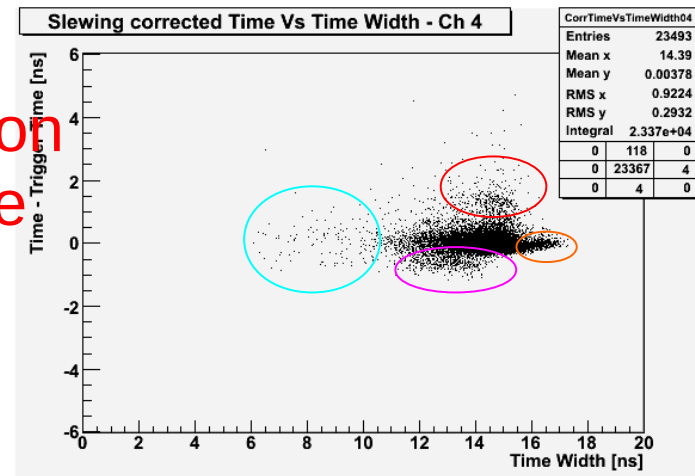
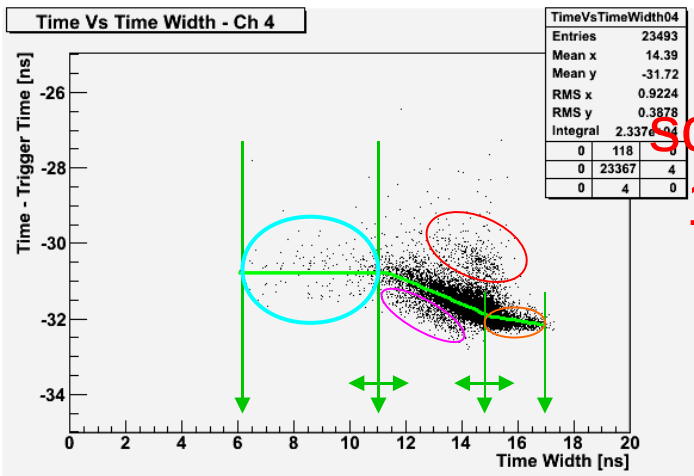
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Time resolution understandings

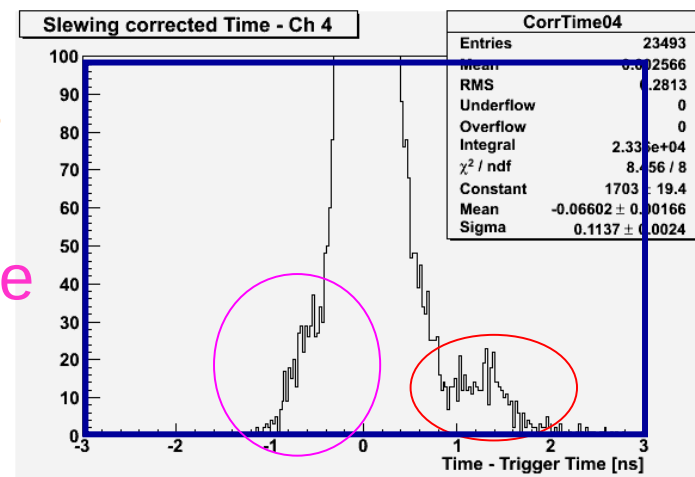
Laser specs + elastic scattering on 1st dynode

NINO stretch ineff

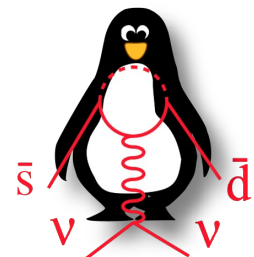


Restarts

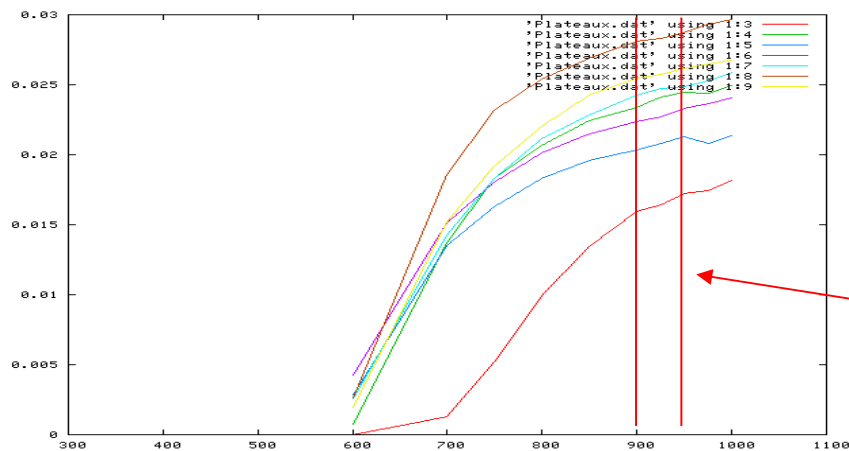
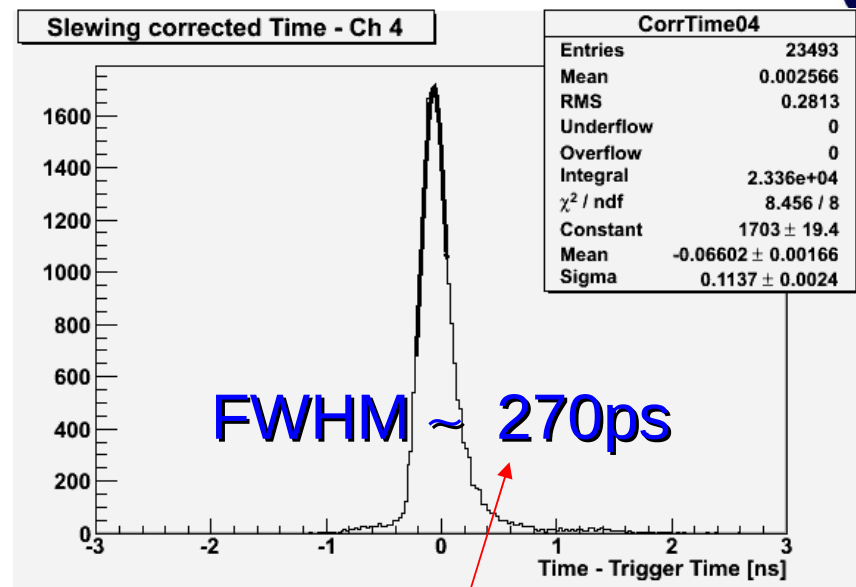
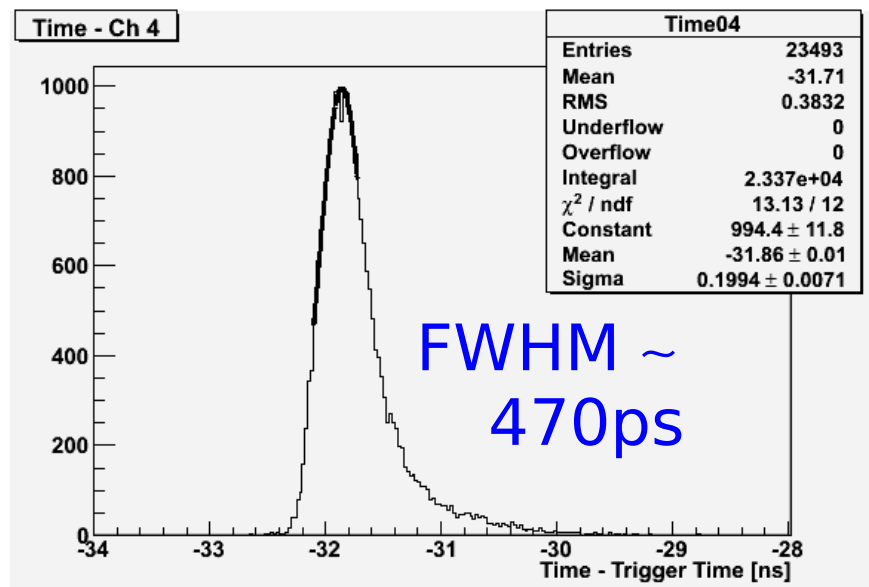
1st dynode PE



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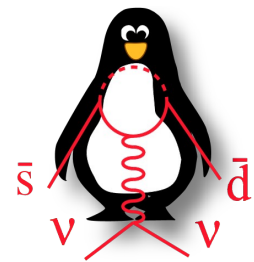


Time resolution for O(1-2) PE

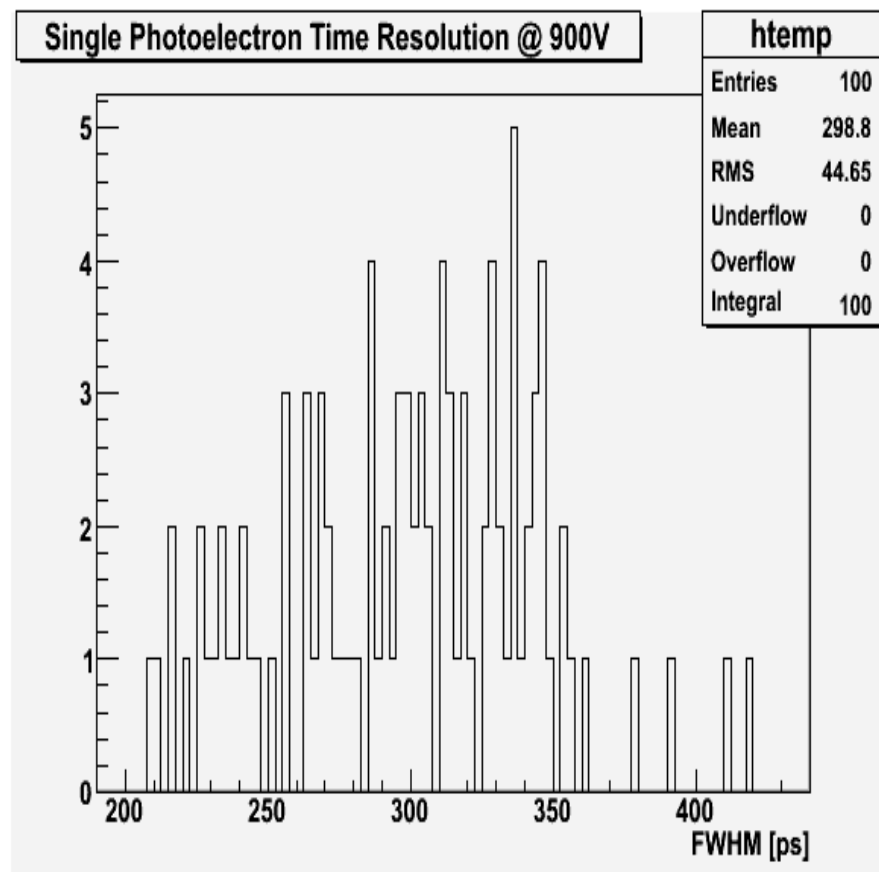
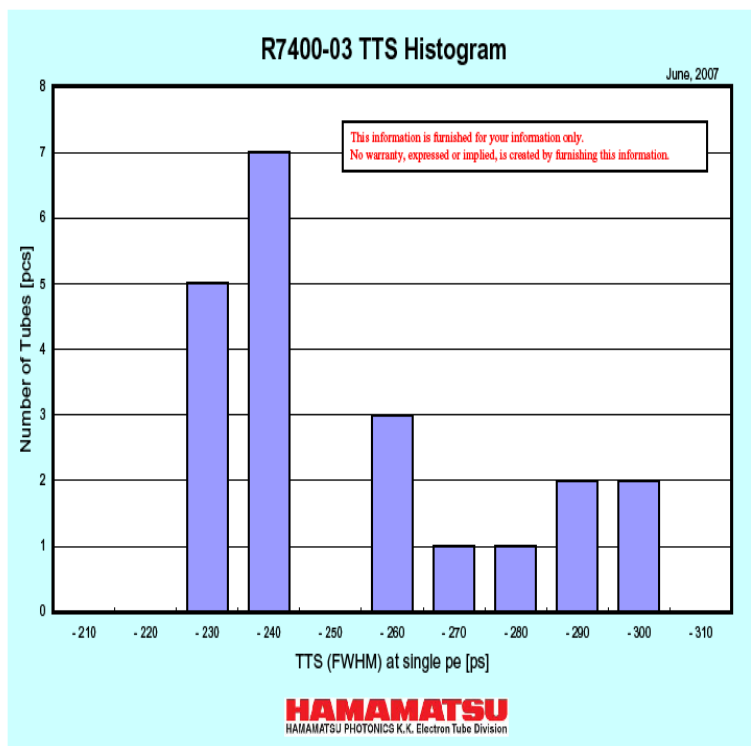


Electronics Contribution
~ 120ps

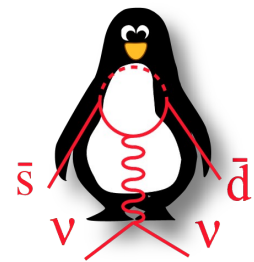
Suggested Working Voltage
900-950V



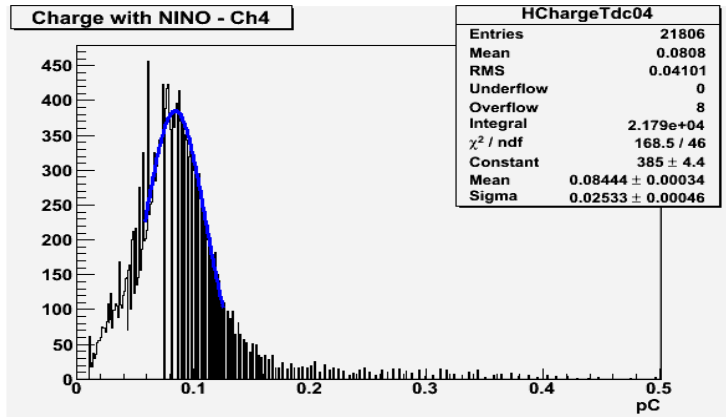
Time resolution for O(1-2) PE Results



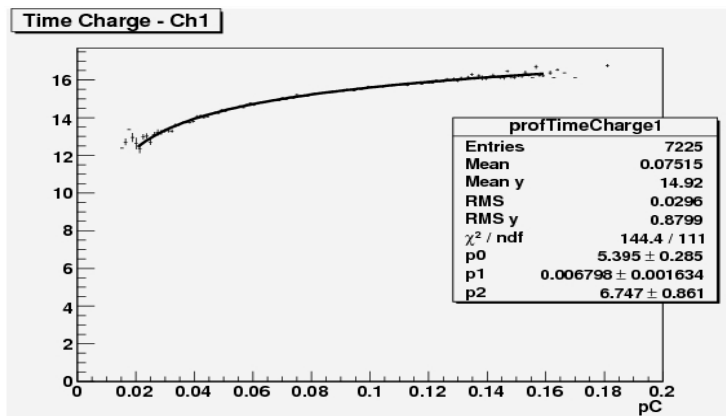
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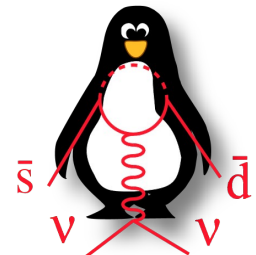
Charge Calibration Results



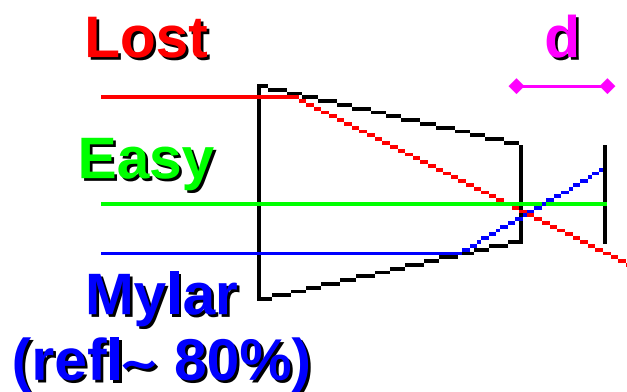
- Channel by channel
- Needs very clean input signal
- Gain estimate accuracy $\sim 10\%$
- Pulse height estimate without further electronics



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Winston's cones



- If $d < 3\text{mm} \Rightarrow 0\% \text{ Lost}$
- In tests $d = 7\text{mm} \Rightarrow 40\% \text{ Lost}$
- In the prototype $d < 2\text{mm}$
- Gain should be ~ 5
- Seen ~ 3 in tests (compatible with $40\% \text{ Lost}$)

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