

Status Reports of NA48 and NA48/1

Augusto Ceccucci/CERN
for the NA48 Collaboration

NA48 (Epsilon'/Epsilon)

- New Epsilon'/Epsilon Result
- Rebuilding of the Drift Chambers
- Data Taking in 2001
- Conclusions

NA48/1 (Rare K_S and neutral hyperon decays)

- Brief Review
- Preparations for 2002
- Conclusions and Outlook



NA48 Phys. Motivation: Direct CP Violation

$$\eta_{00} = A(K_L \rightarrow \pi^0\pi^0) / A(K_S \rightarrow \pi^0\pi^0)$$

$$\eta_{+-} = A(K_L \rightarrow \pi^+\pi^-) / A(K_S \rightarrow \pi^+\pi^-)$$

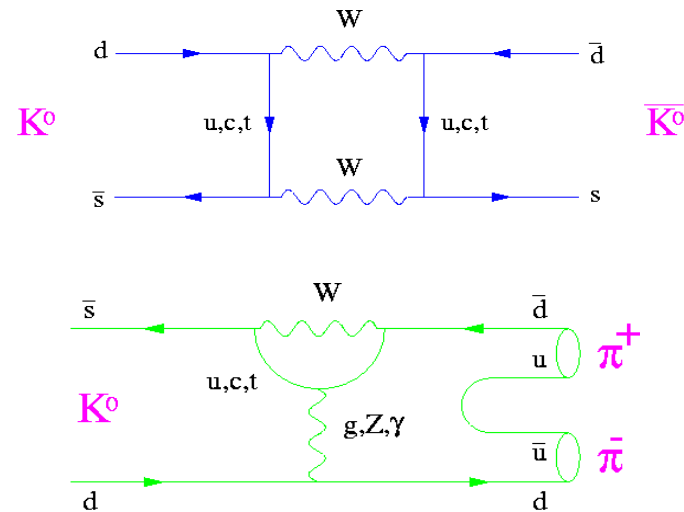
$$\eta_{+-} = \varepsilon + \varepsilon'$$

$$\eta_{00} = \varepsilon - 2\varepsilon'$$

$$6 \operatorname{Re}(\varepsilon'/\varepsilon) \cong 1 - |\eta_{00}|^2 / |\eta_{+-}|^2 = 1 - R$$

ε : CPV in $K^0 - \bar{K}^0$ mixing
Indirect CPV

ε' : CPV in decay amplitude
Direct CPV

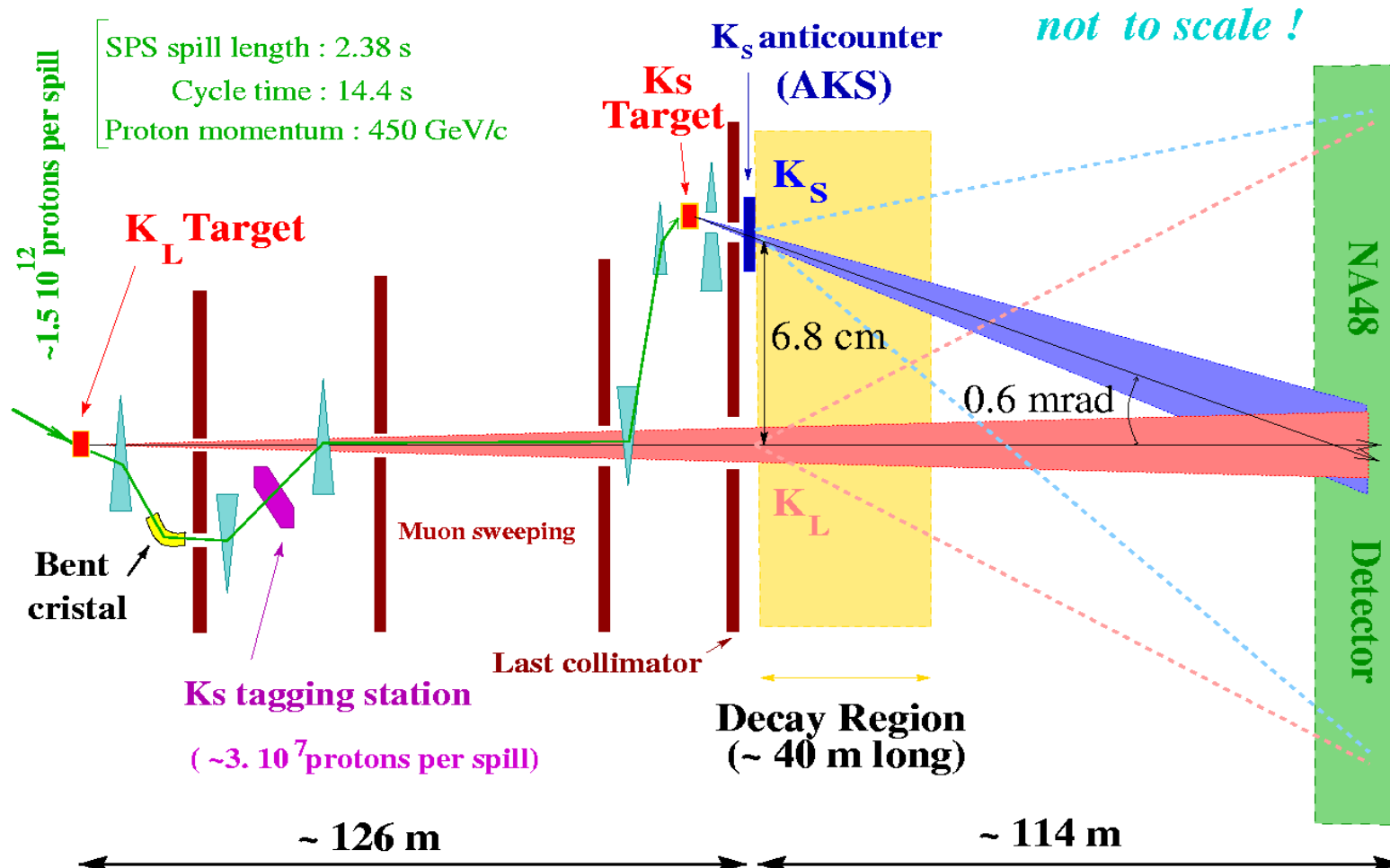


NA48 technique (reminder)

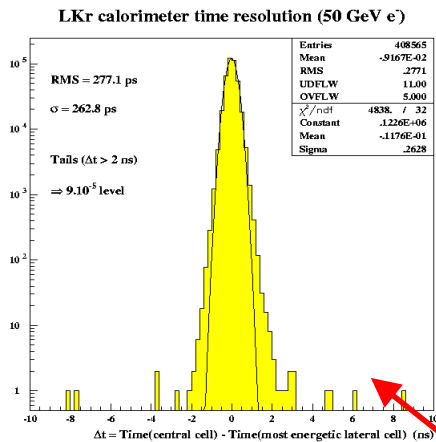
- Employ two almost collinear neutral beams
- Collect the four decay modes simultaneously, in the same detector and from the same decay region
- Keep the acceptance correction small by weighting the K_L events according to the ratio of K_S/K_L decay intensities as a function of proper time
- Distinguish K_S and K_L events by tagging the protons upstream of the K_S target
- Use precise and stable liquid krypton (LKr) calorimetry to control the relative momentum scale



NA48 Beams (1999)

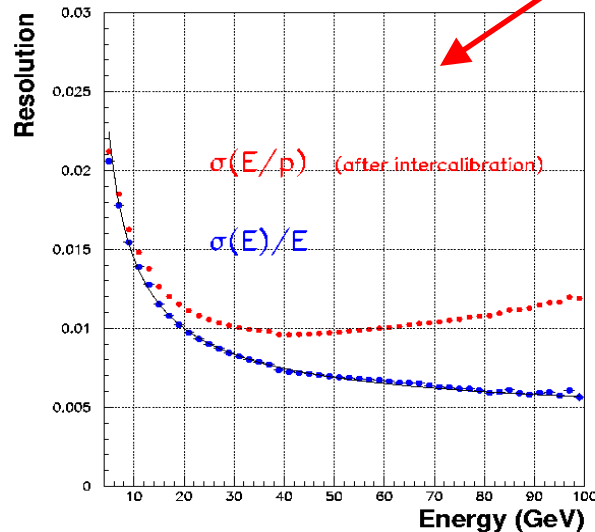
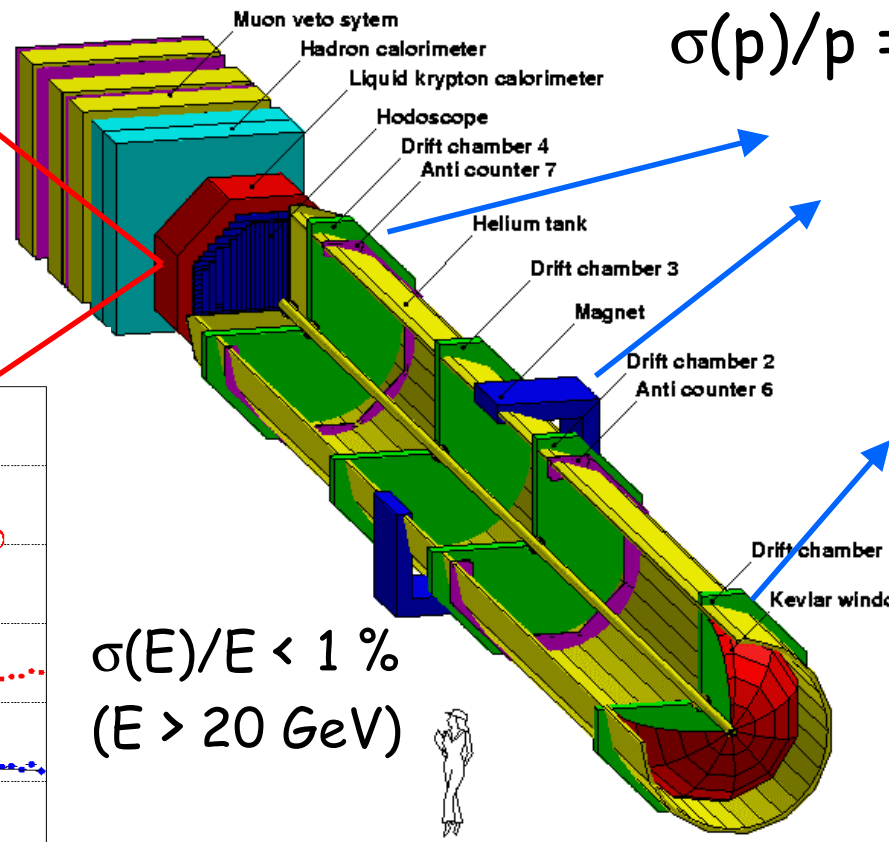


NA48 Detectors

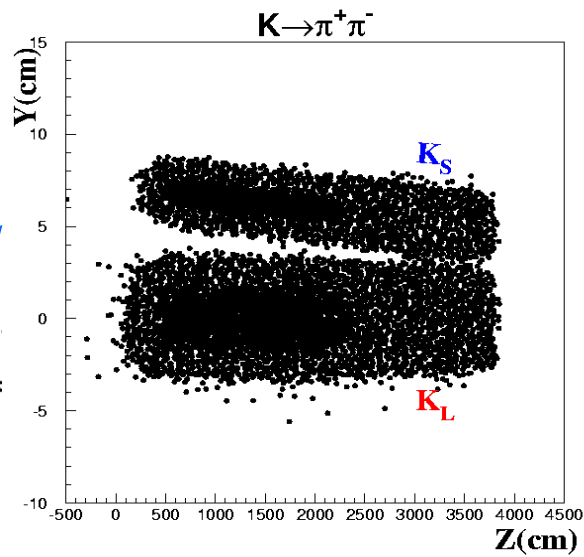


$\sigma_t = 230 \text{ ps}$

$\sigma(p)/p = 0.48\% \oplus 0.009p\%$



$\sigma(E)/E < 1\%$
($E > 20 \text{ GeV}$)



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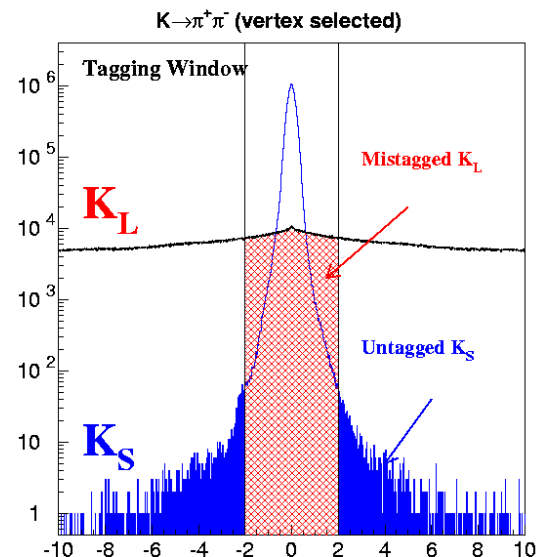
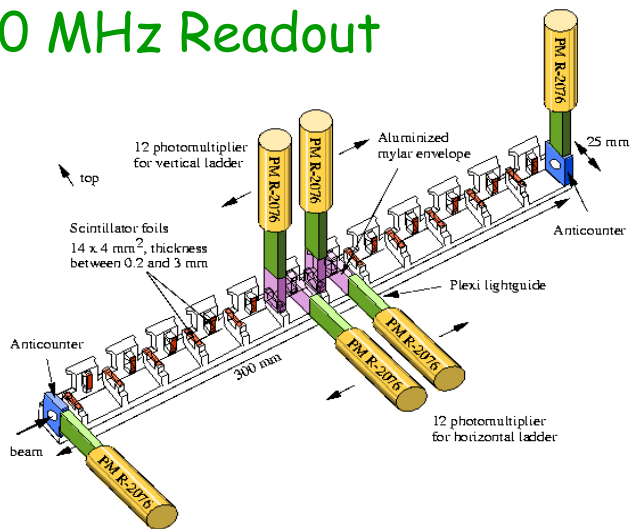
K_S Tagging

$\Delta\alpha_{SL}$ = difference in tagging efficiency between $\pi^+\pi^-$ and $\pi^0\pi^0$

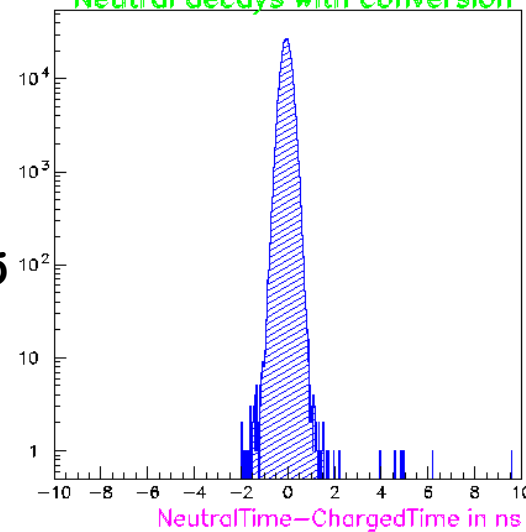
$\Delta\alpha_{LS}$ = difference in accidental tagging between $\pi^+\pi^-$ and $\pi^0\pi^0$

• 12+12 counters

• 960 MHz Readout



Neutral decays with conversion



$< 2.5 \times 10^{-5}$



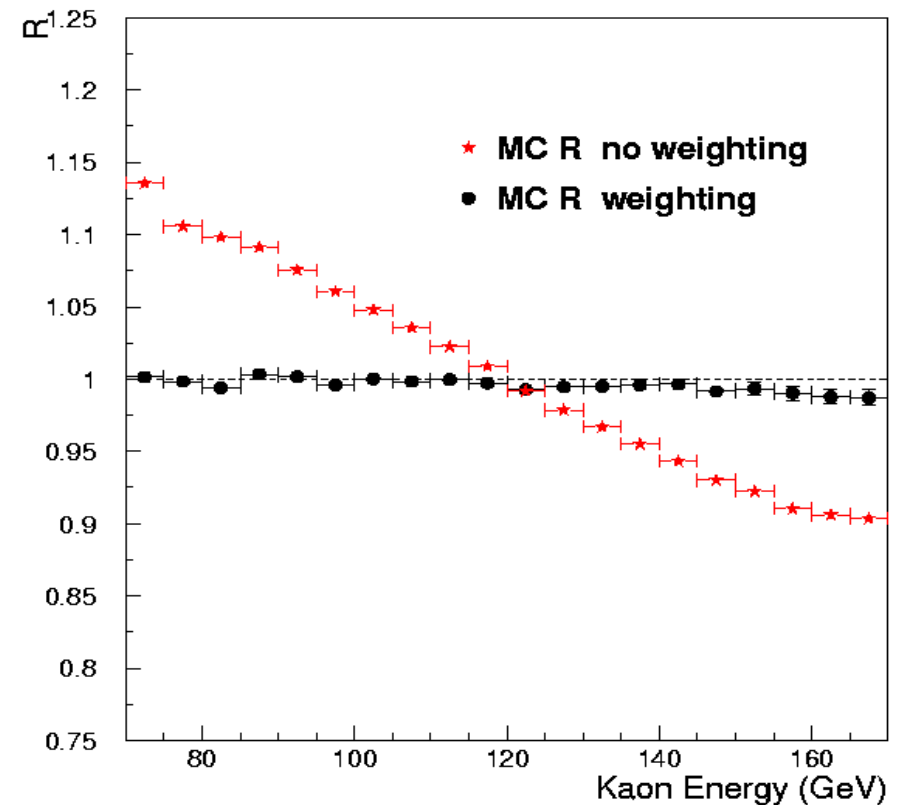
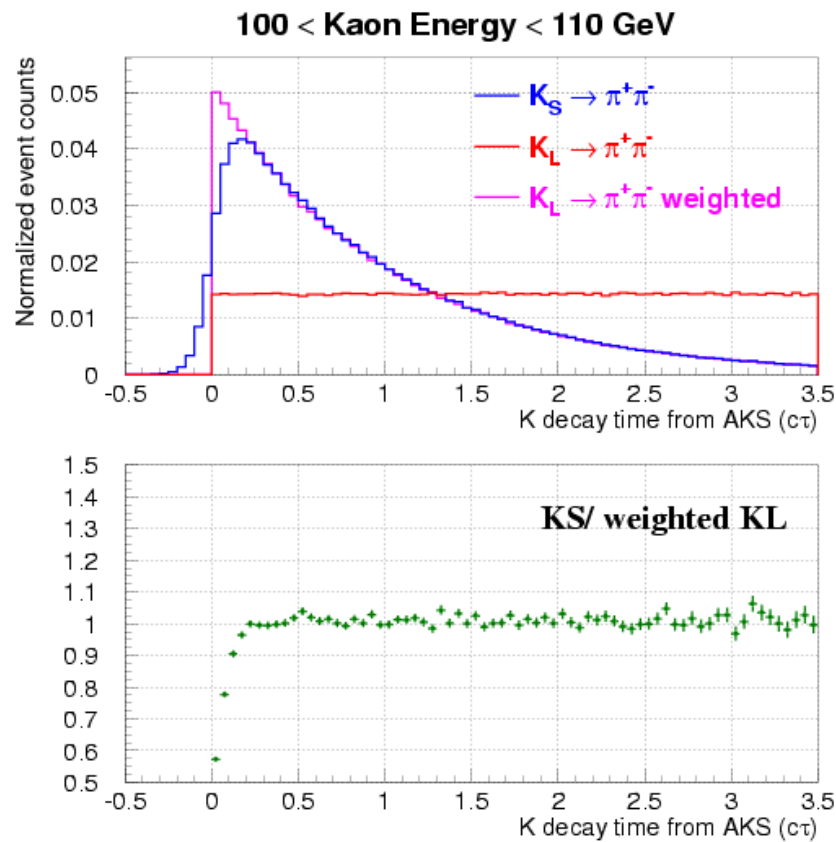
New Epsilon'/Epsilon Result

- The European Physical Journal C has accepted for publication the NA48 measurement based on the 1998-1999 data sample
- CERN-EP/2001-067
- $\text{Re}(\epsilon'/\epsilon) = (15.0 \pm 1.7 \text{ (stat)} \pm 2.1 \text{ (syst)}) 10^{-4}$
- $\text{Re}(\epsilon'/\epsilon) = (15.0 \pm 2.7) 10^{-4}$

Combining this result with the previously published NA48 result (1997 data) yields:

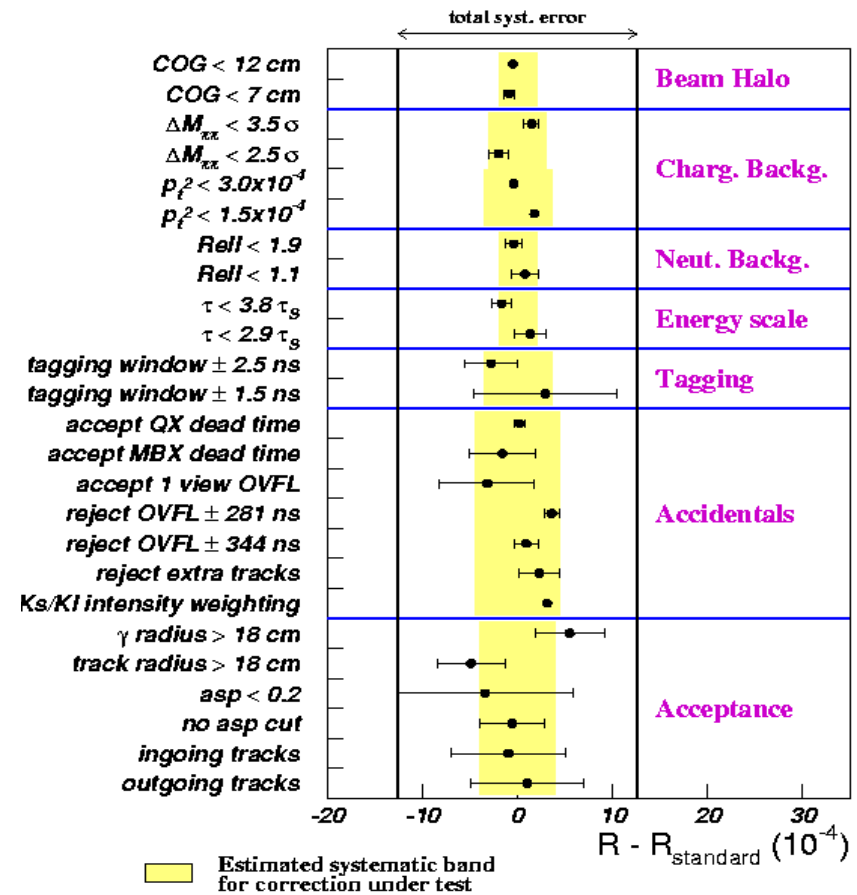
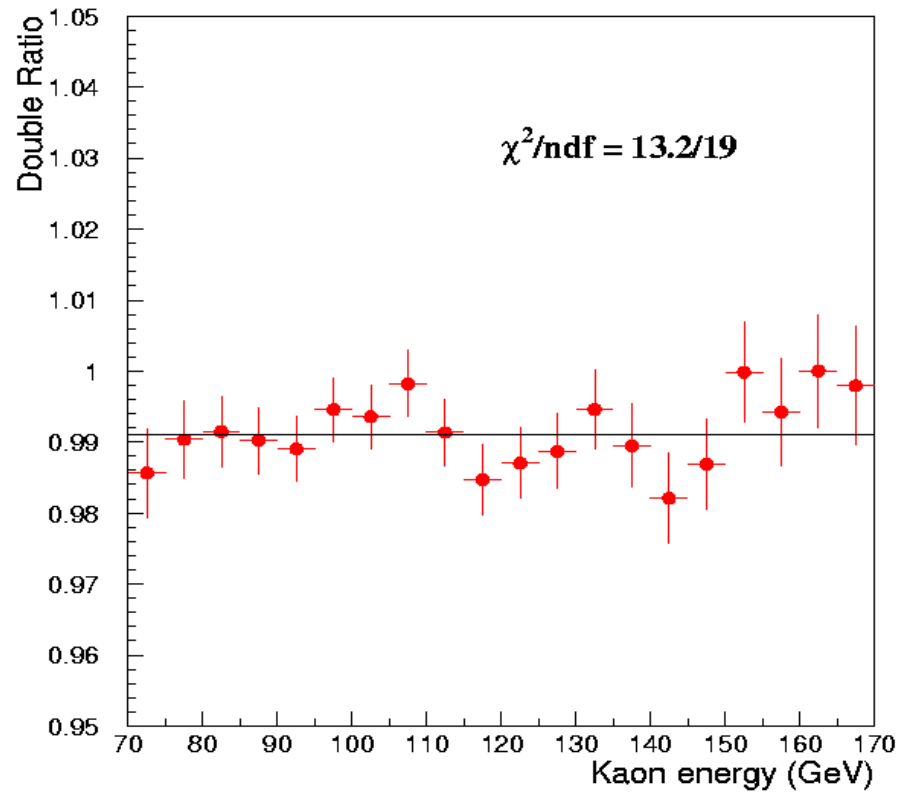
$$\text{Re}(\epsilon'/\epsilon) = (15.3 \pm 2.6) 10^{-4}$$

Event Weighting and Acceptance Correction



Systematics Checks and Result

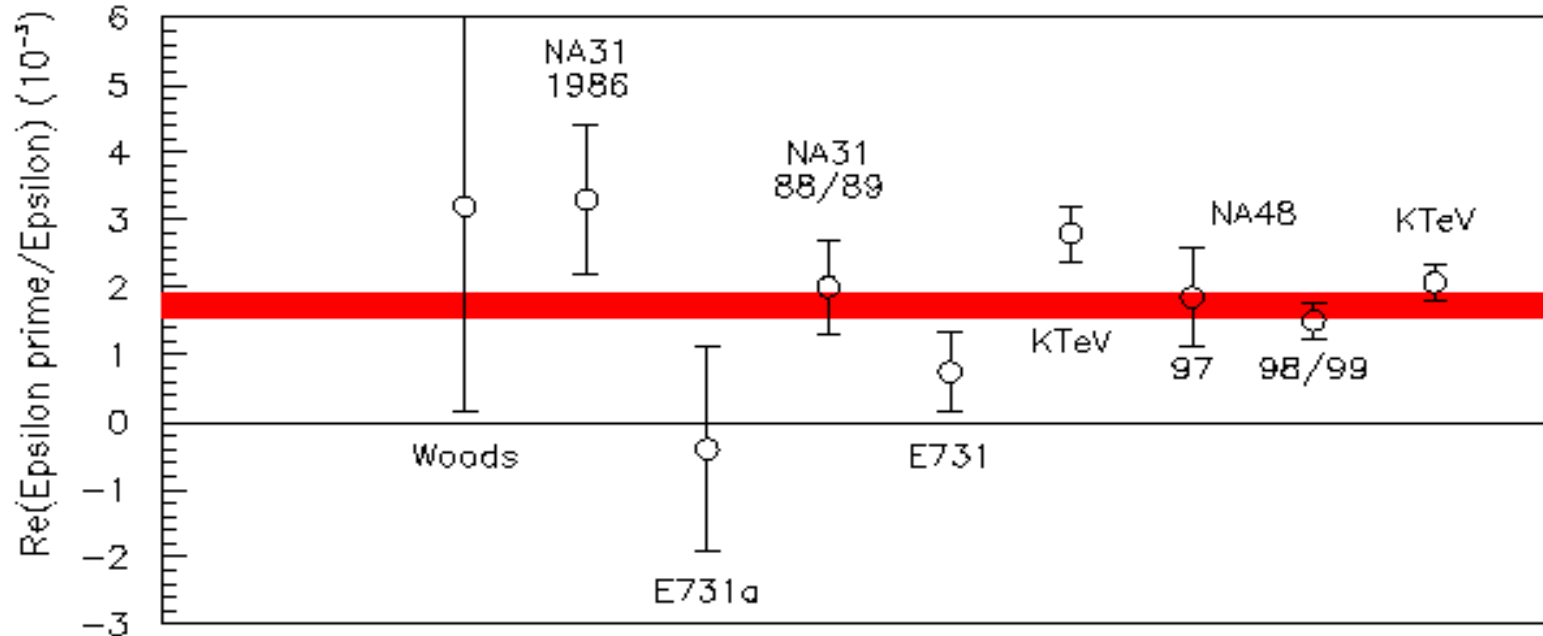
R stability against cut variations



Main systematic uncertainties and corrections to R (units: 10^{-4})

Reconstruction of $\pi^0\pi^0$	--	+/- 5.8
$\pi^+\pi^-$ trigger inefficiency	-3.6	+/- 5.2
Accidental Activity	--	+/- 4.4
Acceptance (stat)	+26.7	+/- 4.1
Acceptance (syst)		+/- 4.0
Accidental Tagging	+8.3	+/- 3.4
Background to $\pi^+\pi^-$	+16.9	+/- 3.0
Tagging Inefficiency	--	+/- 3.0
Adding other smaller	Corr.	& Unc.
TOTAL	+ 35.9	+/- 12.6

Epsilon'/Epsilon as a function of time....



New Average: $(17.0 \pm 1.8) 10^{-4}$

Data Taking in 2000 (No Drift Chambers)

- With simultaneous K_S and K_L beams, NA48 cannot measure the accidental tagging probability for $K_L \rightarrow \pi^0 \pi^0$
- We verified the assumption that the difference in tagging dilution can be measured using $3\pi^0$ events
 - During a 30 day run we have collected $1.5 \cdot 10^6$ $2\pi^0$ and $3\pi^0$ events sending K_S protons through the tagging as usual but dumping them upstream of the K_S target to avoid the contamination from $K_S \rightarrow 2\pi^0$
- In addition, we collected large samples of π^0 and η decays to 2γ and $3\pi^0$ to check the calorimeter reconstruction and calibration

Reconstruction of the Drift Chambers

- Damaged by the 1999 beam-pipe implosion
- Repaired in 18 month
 - 45 Technicians and Physicists from CERN, Dubna, INFN and Saclay
 - First wire soldered on June 2000
 - Last wire soldered in July 2001
 - Spectrometer operational by July 20th
- NA48 data taking with full apparatus (four chambers) in 2001

Reconstruction of the Drift Chambers



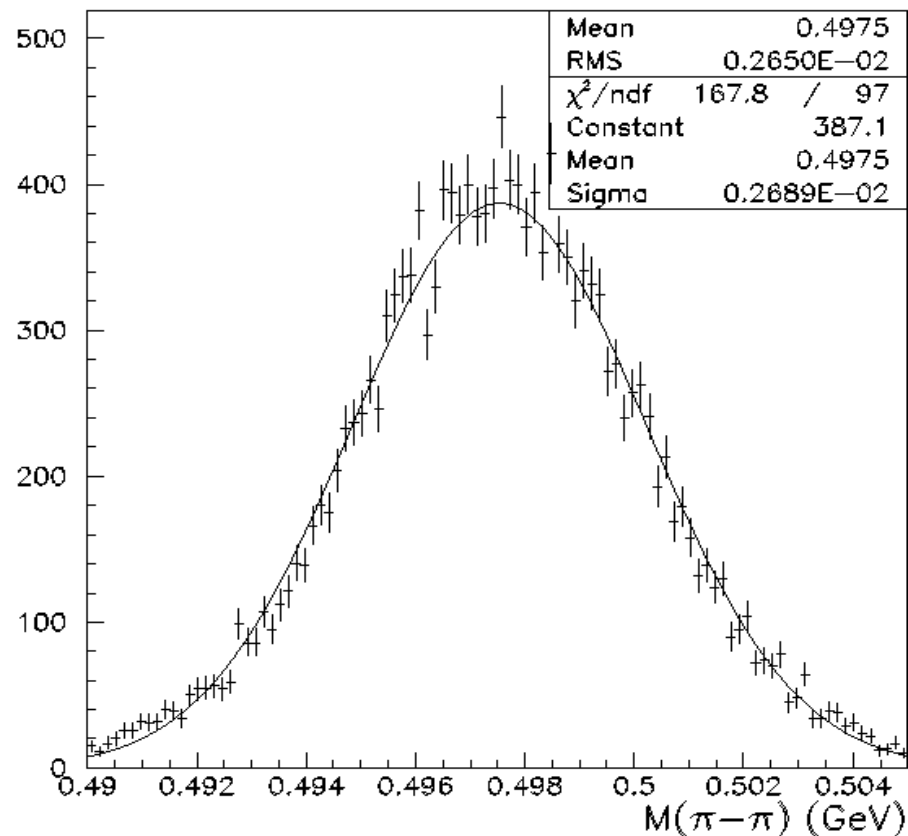
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Operation of the New Drift Chambers

- High Voltage (HV) 2.3 kV
 - Ar(50%) Ethane (50%)
 - A few HV trips observed on some planes during the run
 - Test in dry air foreseen
 - Inspection of a drift chamber may be needed
- Plan to operate drift chambers at lower HV in the future



$$\sigma(m_{\pi\pi}) = 2.7 \text{ MeV}/c^2$$

The New Beam-pipe

- New aluminium beam-pipe
 - Designed and machined at CERN
 - 1.1 mm thick
 - Stainless steel sections replaced by aluminium ones



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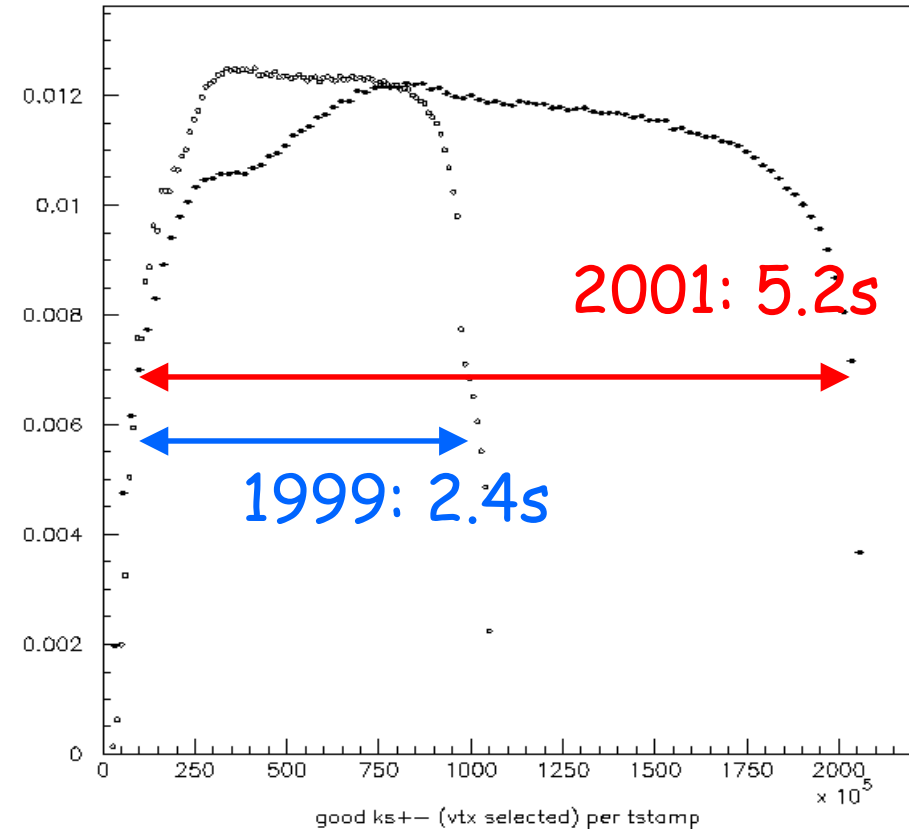
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Data Taking in 2001

- Completion of Epsilon'/Epsilon program
 - 400 GeV protons instead of 450 GeV
 - Flux of useful kaons reduced by 19%
 - The loss is more than offset by the longer duty cycle available in the post-LEP era
 - Duty cycle $\sim 30\%$, about two times better than before
- Check of beam-intensity related systematics
 - Data taking conditions chosen to:
 1. Run under significantly different instantaneous rate
 2. Collect a large enough sample of data to make a valid test
- Ran at 2/3 of the nominal 1999 intensity
- Collected 1.4×10^6 $K_L \rightarrow \pi^0\pi^0$ (stat. limiting mode)

RUN 2001: Systematic Cheks

- New Beam Monitor to study beam structure at the 100ns scale
- Improved Beam Monitor
 - Fine tuning of the delay between K_L and K_S
- More down-scaled triggers
 - to reduce the uncertainty due to the charged trigger inefficiency (second largest syst. uncertainty for the published data)

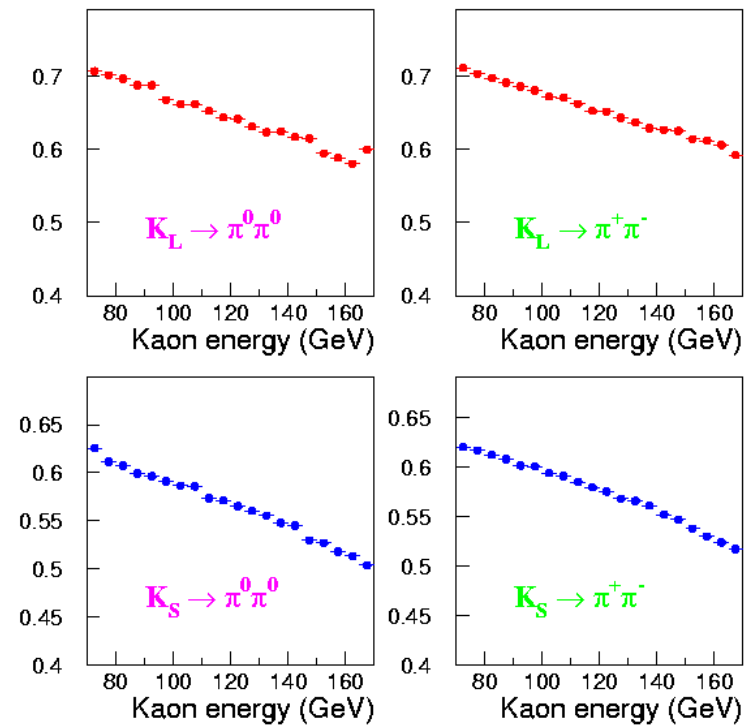
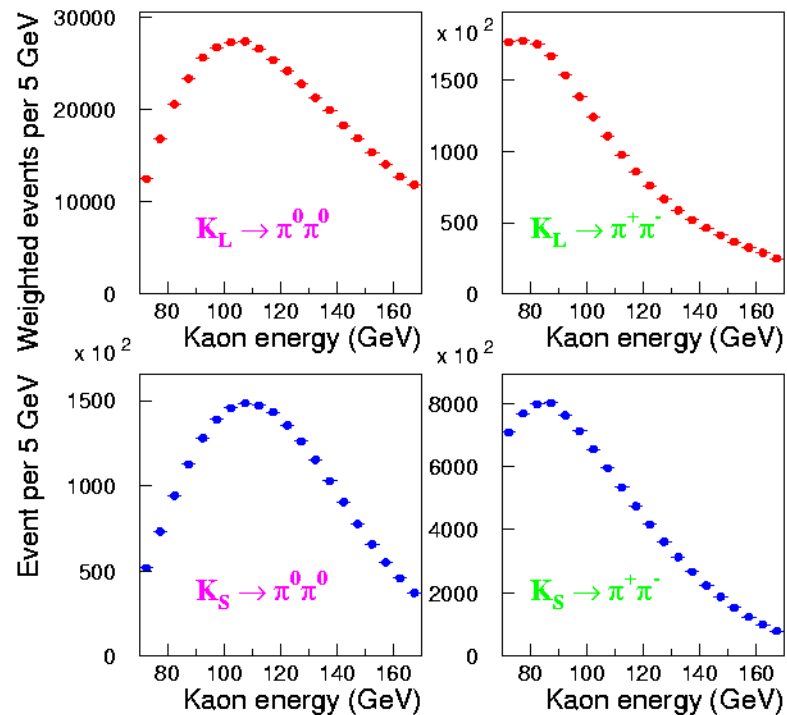


Time Stamp Distribution

Comparison of Decay Spectra

2001

2001/1999



1998-1999/2001 Comparison

	1998-1999	2001
Accidental Tagging Probability	10.6 %	8.4%
MBX Efficiency	98.3%	99.2%
Drift Chamber Overflows ($\pi^0 \pi^0$)	21.5%	11.8%
STAT Error (10^{-4} on R)	10	15

Conclusions (NA48)

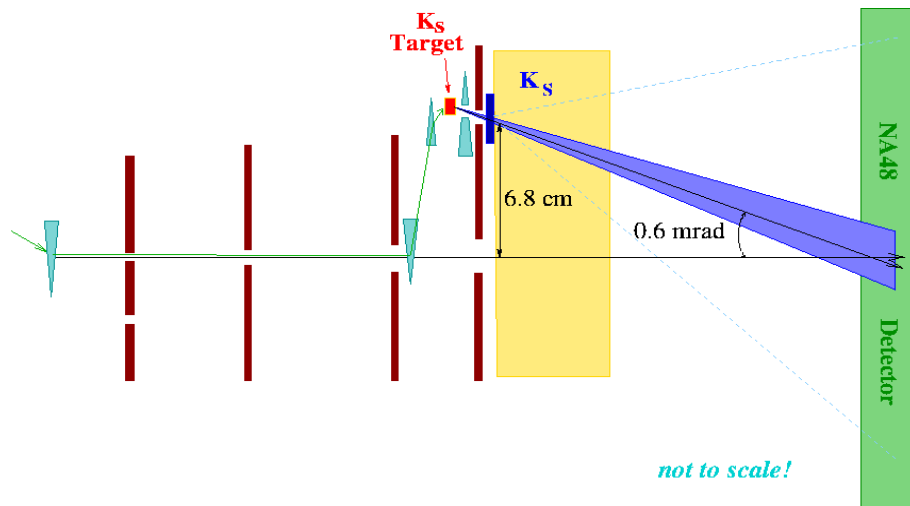
- Data Taking is over
 - 1997 and 1998-2000 ε'/ε data sets are published
 - 2001 data to be used to further reduce systematics
- The NA48 measurement of ε'/ε is the most precise to date
- Not Covered in this status report
 - Strong K_L rare decay program. Example (very recent):
 $BR(K_L \rightarrow \pi^0 \gamma\gamma) = (1.36 \pm 0.03(\text{stat}) \pm 0.03(\text{syst}) \pm 0.03(\text{norm}))10^{-6}$
 $a_\gamma = -0.46 \pm 0.03(\text{stat}) \pm 0.03(\text{syst}) \pm 0.02(\text{theory})$
 $BR(K_L \rightarrow \pi^0 \gamma\gamma, 30 \text{ MeV}/c^2 < m_{\gamma\gamma} < 110 \text{ MeV}/c^2, 0 < \gamma < 0.2) < 6 \cdot 10^{-9}$

NA48/1: Physics Motivation

- $K_S \rightarrow \pi^0 l^+ l^-$, $l=e,\mu$
 - Bound Indirect CP Violation in the decay $K_L \rightarrow \pi^0 l^+ l^-$ to $< 10^{-12}$
- Search for CPV in K_S decays
 - $K_S \rightarrow 3\pi^0$, $K_S \rightarrow \pi^+ \pi^- \pi^0$
- Study of time dependent CPV asymmetry $K_{S,L} \rightarrow \pi^+ \pi^- \gamma^*$
- Test of Chiral Perturbation Theory
 - $K_S \rightarrow \gamma\gamma$, $K_S \rightarrow \pi^0 \gamma\gamma$, $K_S \rightarrow \pi^0 \pi^0 \gamma\gamma$
- Study K_S Dalitz and semi-leptonic decays
- Semi-leptonic and radiative neutral hyperon decays
 - $\Xi^0 \rightarrow \Sigma^+ e^- \nu$, $\Xi^0 \rightarrow \Sigma^+ \mu^- \nu$, $\Xi^0 \rightarrow \Sigma^0 \gamma$, $\Xi^0 \rightarrow \Lambda \gamma$
-

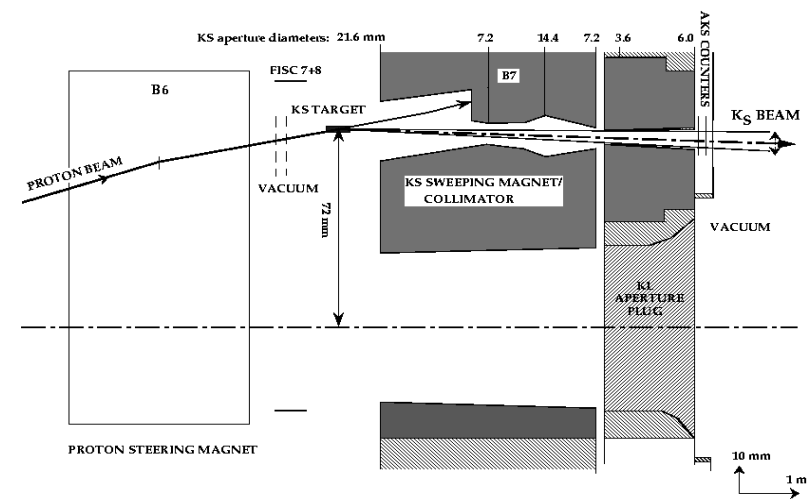
NA48/1: Unique Opportunity

- Use NA48 Detectors and beam-line
- Sensitivity better than a factor of 10 or more over the competition
 - Exploits the NA48 collimator technique
 - Intensity can be increased hundred times wrt to double beam



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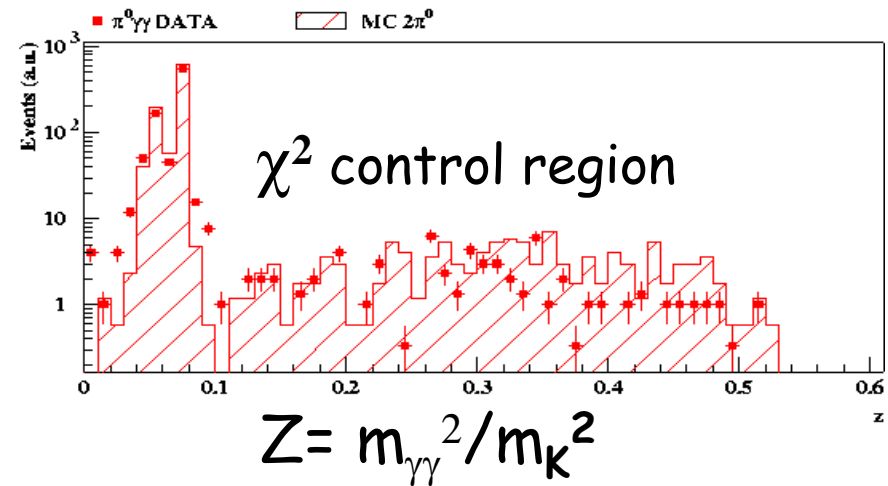
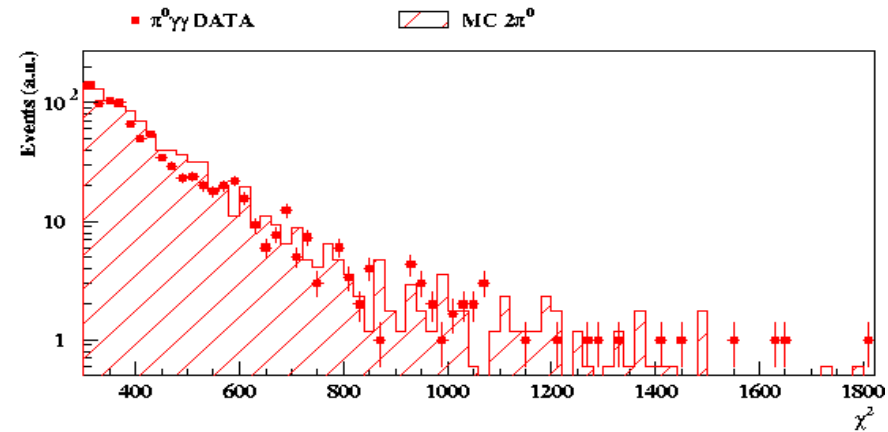
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NA48/1: Data Taking so far

- 1999: 40h test run
 - Proof of principle
 - Physics results (published):
 - $BR(K_S \rightarrow \gamma\gamma) = (2.6 \pm 0.4 \pm 0.2) 10^{-6}$ PL B493 (2000) 29
 - $BR(K_S \rightarrow \pi^0 e^+ e^-) < 1.4 \times 10^{-7}$ 90% CL PL B514 (2001) 253
- 2000: 45 days
 - No drift chambers; no beam-pipe
 - Extended vacuum down to LKr
 - 17000 $K \rightarrow \gamma\gamma$ collected (x 40 wrt 1999)
 - About 10^6 $3\pi^0/\tau_S$ are being studied to search for CPV in K_S decays
- End of 2001: Trigger Test
 - Improved hyperon trigger, added K_S and Ξ^0 muonic channels

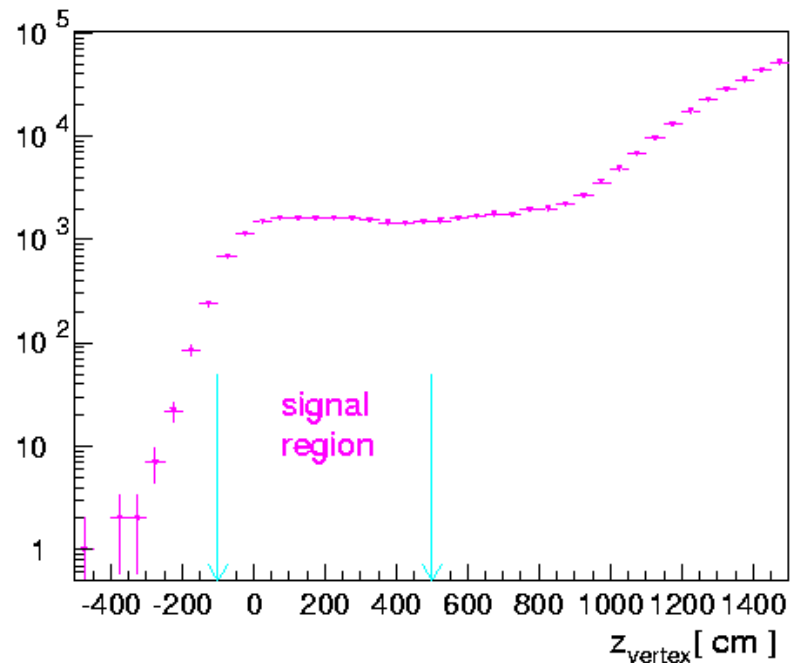
$K_S \rightarrow \pi^0 \gamma\gamma$ (40h, 1999 Preliminary)

- Signal region $\chi^2 \gtrsim 2000$
- Signal Background 1:1
 - Most of background from $K_L \rightarrow \pi^0 \gamma\gamma$ (irreducible)
- Data distributions well explained by MC simulation
- Upper limit soon to be released
- Sensitivity in line with expectations
- Data from 2000 show higher background (no Drift Chambers to veto charged particles)



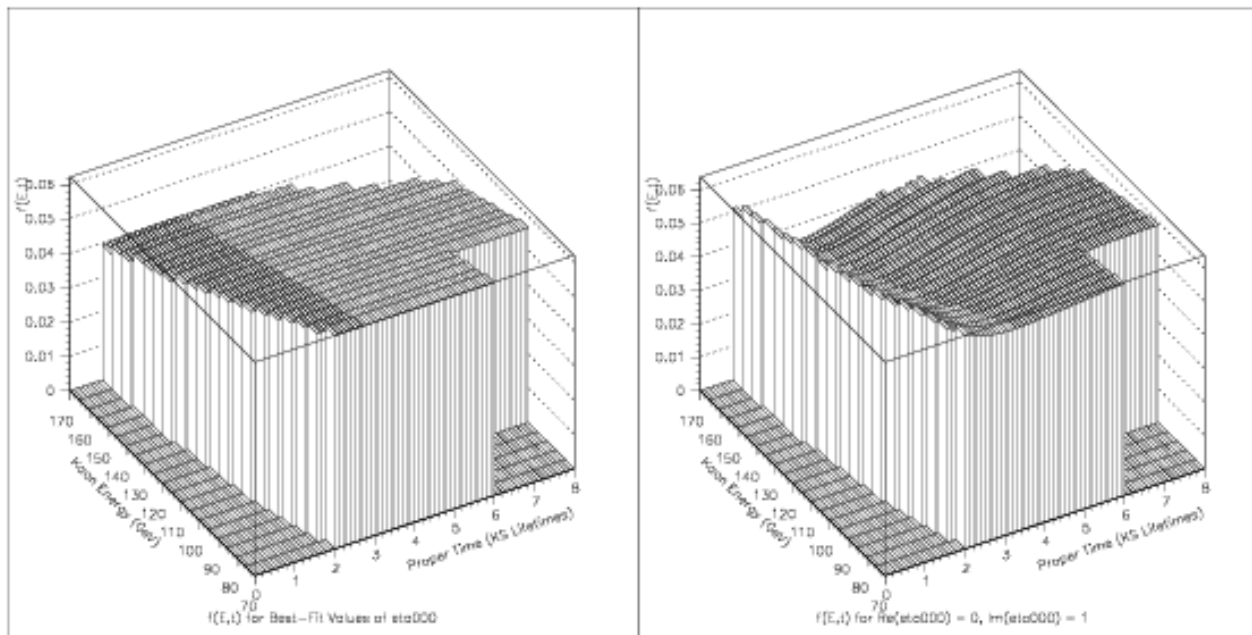
$K_S \rightarrow \gamma\gamma$ (45 day, 2000 Preliminary)

- 17000 $K \rightarrow \gamma\gamma$
- x40 the 1999 statistics
- New measurement to be released soon
- Evaluation of background from $K_S \rightarrow \pi^0\pi^0$ is being finalised



$K_{S,L} \rightarrow 3\pi^0$ (45 days, 2000 Preliminary)

- Search for interference at small proper time
- The analysis of 10% of the data is quite advanced:
 - Statistical error: $\text{Im}(\eta_{000}) = 2.8\%$ $\text{Re}(\eta_{000}) = 2.2\%$
 - Systematic errors under evaluation

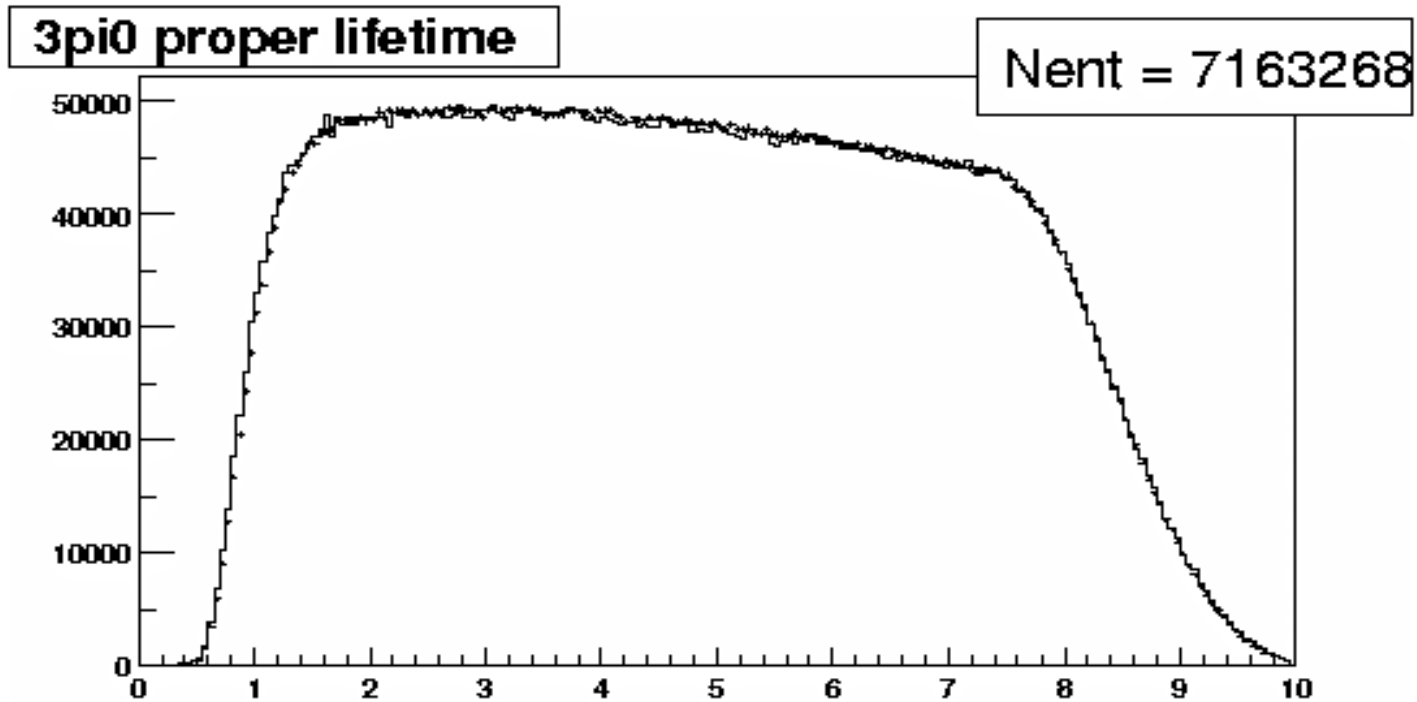


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$K_{S,L} \rightarrow 3\pi^0$ (45 days, 2000 Preliminary)



Data Monte Carlo Comparison (Full sample)

Trigger rates (measured, 2001)

Decay channel	Counts/ 10^{10} ppp
$K_S \rightarrow \pi^0 ee$, K_S Dalitz	5000
$K_S \rightarrow X \mu\mu$	1000
$K_S \rightarrow 3\pi^0$	8000
$K_S \rightarrow \pi^+\pi^-\pi^0$, $K_S \rightarrow \pi e\nu$	5500 D=5
$K_S \rightarrow \pi\pi ee$	2000
Radiative Ξ^0 decays	7000
$\Xi^0 \rightarrow \Sigma^+\pi^0 l \nu$ ($l=e,\mu$)	3000

NA48/1 Phase II

- Approved on November 23rd 2000
- Base for the approval was to achieve a Single Event Sensitivity (SES) of $2-3 \times 10^{-10}$ for $K_S \rightarrow \pi^0 e^+ e^-$
- Scheduled to run in 2002
- To achieve this sensitivity we need 105 days of protons with 400 GeV energy and the same duty cycle used in 2001 (5.2 s/16.8 s)
- 105 days correspond to the 120 days quoted in the proposal for a slightly worse duty cycle

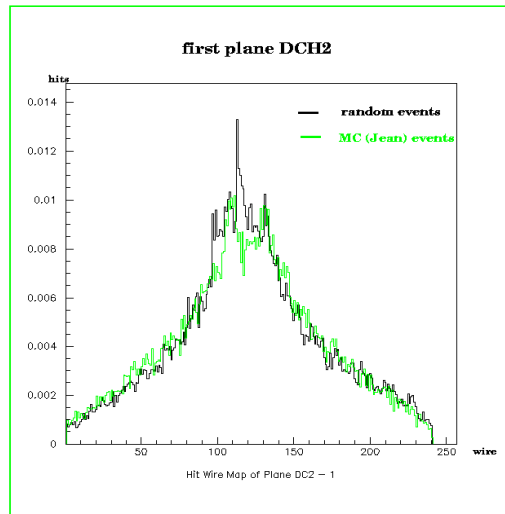
Sensitivity

- Instantaneous rate already achieved in 1999
 - 10^{10} ppp \rightarrow 3×10^{10} K_S decays x105 days
 - SES 6×10^{-10} for 5% acceptance x efficiency
- Upgraded Target Station (2002)
 - Expect x2 reduction in accidental rate
 - Increase beam intensity from 10^{10} ppp to 2×10^{10} ppp
 - SES $\rightarrow 3 \times 10^{-10}$ for 105 days
- Upgraded Drift Chamber Readout (2002)
 - Recover 30% of events (overflows)
 - SES $\rightarrow 2 \times 10^{-10}$ for 105 days

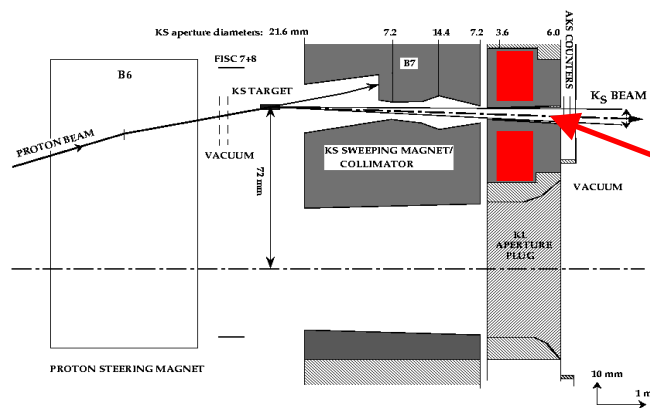
Preparations for 2002

- Modification of the KS target station
 - Installation of sweeping magnet
 - Provision for a photon converter
- Improvement to Drift Chamber front end
 - Better noise immunity → lower Drift Chamber High Voltage
- Upgrade of the Drift Chamber read-out
 - Remove loss due to overflows (30% in 1999 test run)
- New readout procedure for LKr and Upgrade of the online PC farm
 - Increase Level II bandwidth (currently limited by LKr)
 - Up to 1 Gbyte/burst

Modification of the K_S target station

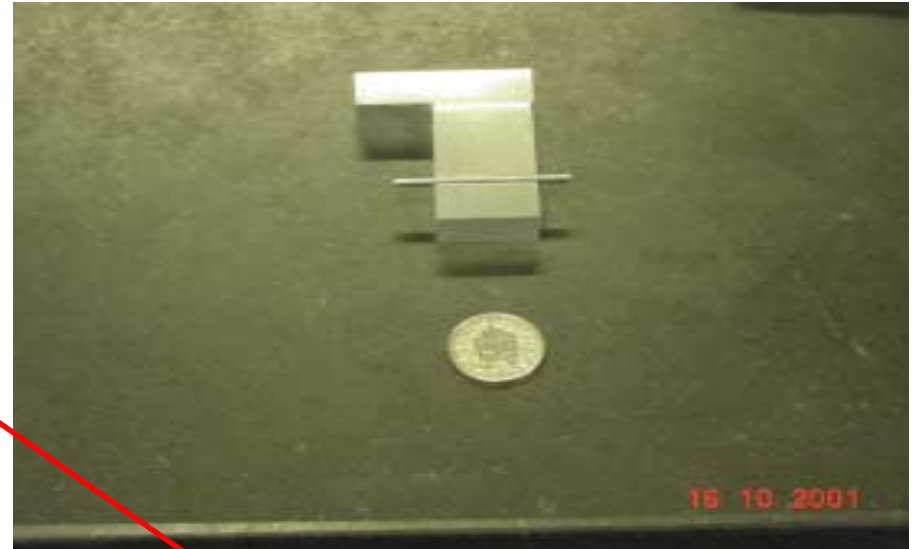


- Most of the accidental activity measured in the 1999 test data is explained by electromagnetic showers generated in the collimator
- According to a GEANT simulation, the accidental rate can be significantly reduced placing a magnetic field in the collimator
- A magnet is being prepared for this purpose

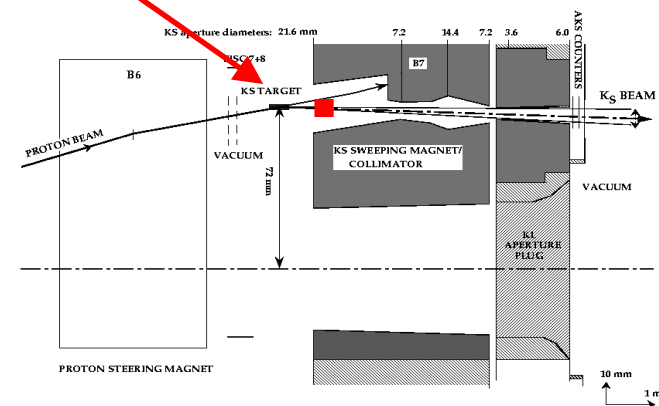


Provision for a photon converter

- We plan to convert photons downstream of the KS target using a platinum converter
- Kaon flux reduction per proton is offset by sending more protons on target



Length (mm)	X_0
24	8.0
32	10.7
40	13.4



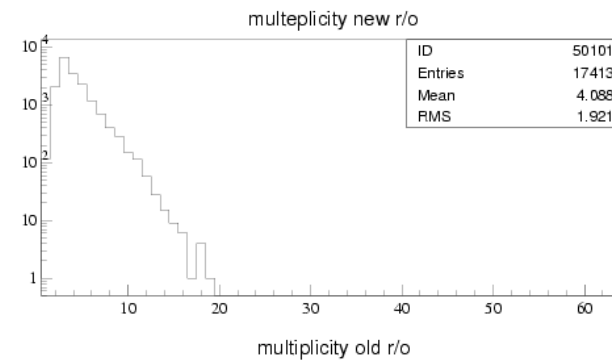
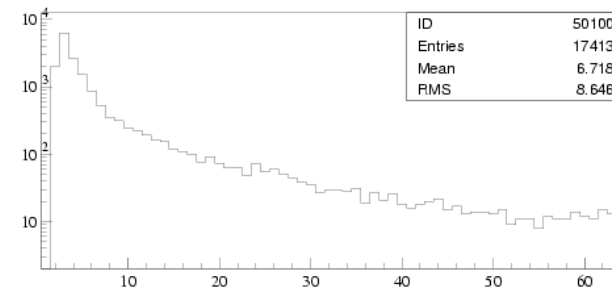
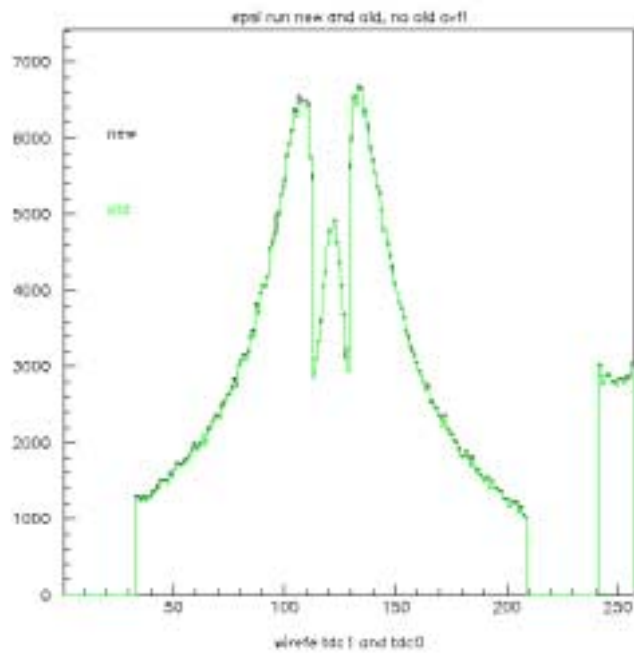
Improved Drift Chamber Front-end

- Installed better cables between the Pre-Amplifier and the TDC (tested in 2001)
 - Reduction of noise → reduce threshold from 30 to 25 mV
 - Can reduce the HV by 50 Volts maintaining the same efficiency
 - Current in the drift chambers reduced by 40%
 - No modification of the Pre-Amplifier is necessary
- Further reduction of HV under study
 - Trigger and reconstruction efficiency are not as critical as for the ε'/ε experiment
 - Trade off between performance and statistical sensitivity

New Drift Chamber Readout

- Remove overflow loss present in the current readout (30% in the 1999 data)
 - University of Ferrara/INFN
 - The system consists of 28 TDC-MB cards with CMC daughtercards
 - Choice of chip finalised in September 2000
 - The F1 chip -designed by University of Freiburg for COMPASS- is used
 - Tested 2 TDC-MB during the 2001 proton run reading one plane of the third Drift Chamber

Comparison Old/New Read Out



DCH Readout, Production Schedule

- 50% of the CMC cards to be delivered by the end of November
- The remaining cards are scheduled to arrive by the end of December 2001
- Orders for the FPGAs and other critical components are being placed
- The installation should start in February/March.
- Testing should be finished by April 15

The schedule is tight but the success of the design/prototyping phase -which was conducted under very tight time constraints- gives us confidence

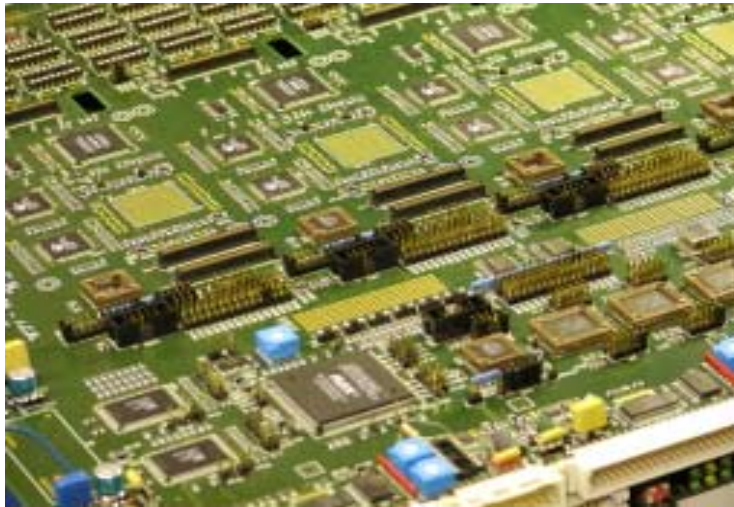
New Drift Chamber Readout



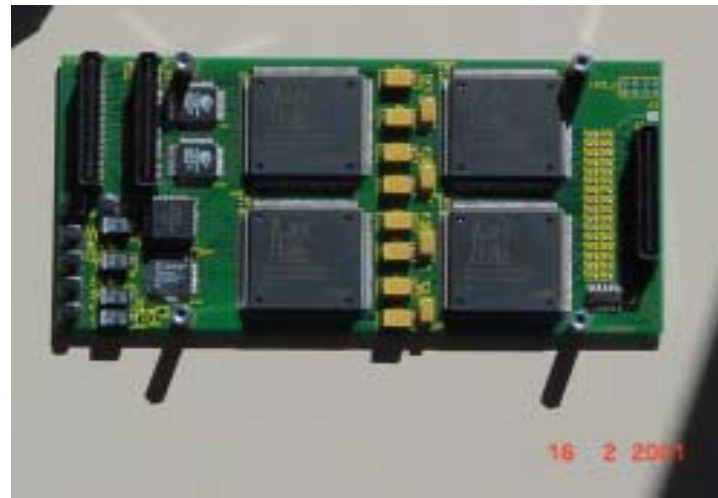
CSC



MSC



TDC-MB



CMC

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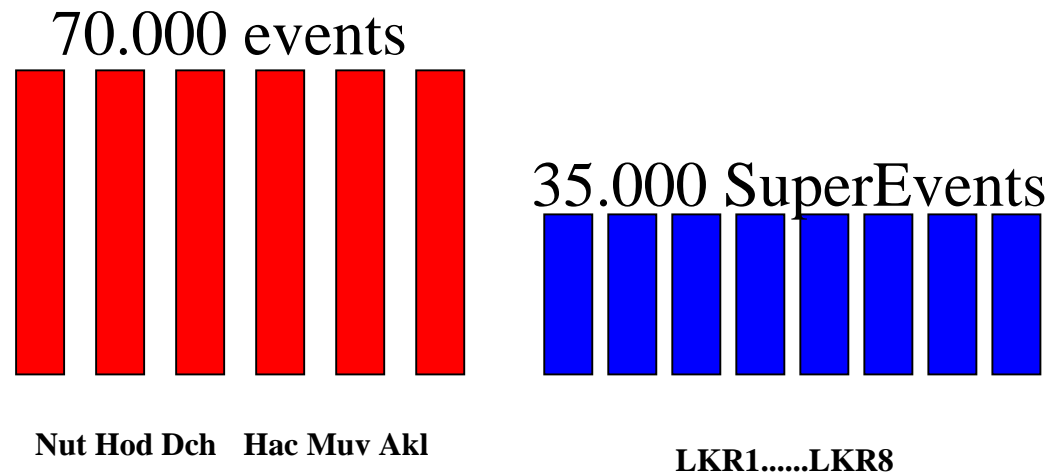
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Upgrade of LKr Readout and Online PC farm

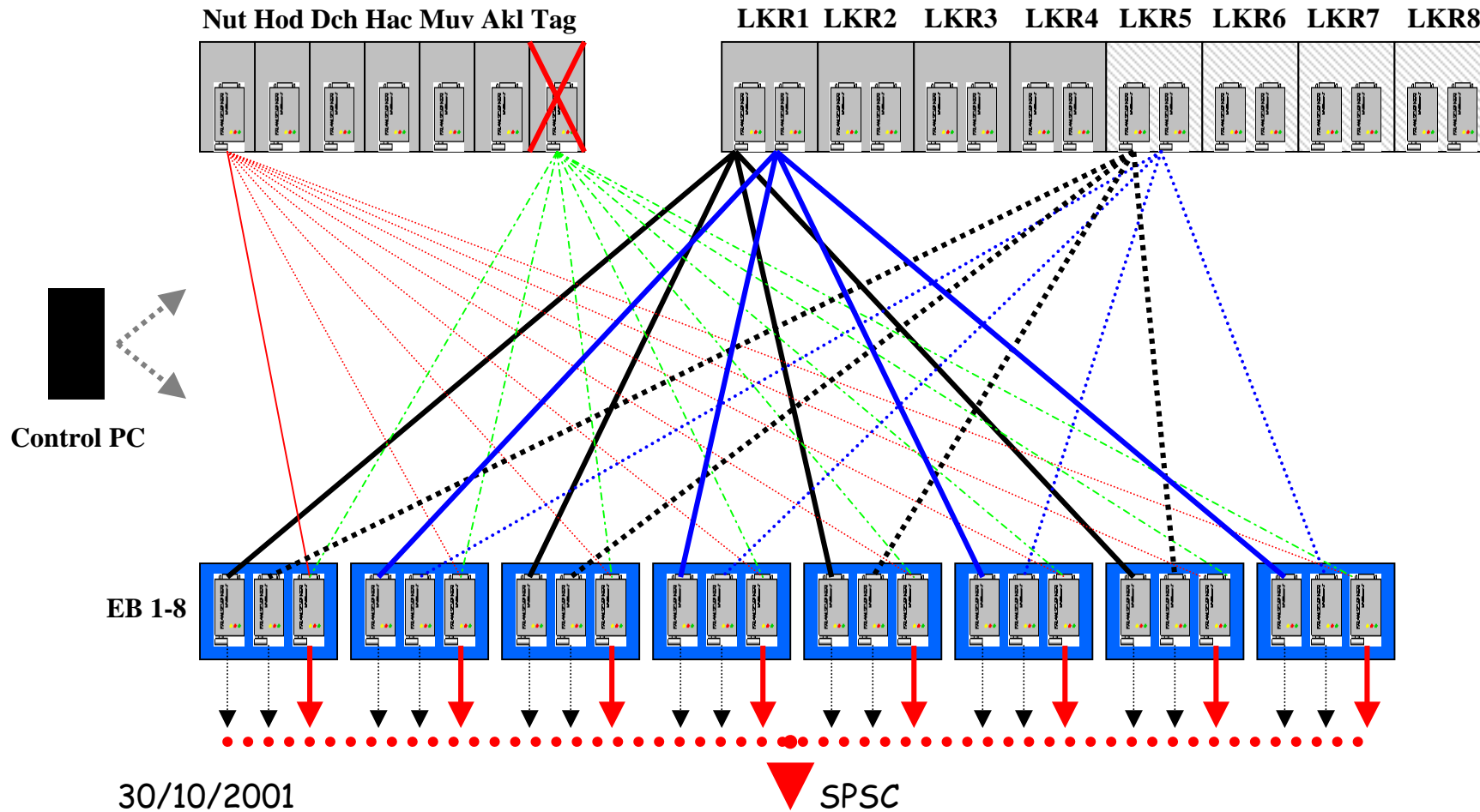
Two 8 sample LKR event are packed into a 16 sample SEvent:



LKR readout has to extract only half of the L2 rate:



Event Building Network 2002



CDR and Real Time Reconstruction

- Third Level Software trigger used in cutting mode last year
 - Data reduction online demonstrated
 - Foreseen amount of data to tape for 2002 20 TB (raw) + 10 TB (filtered)
- Computing needs 2002
 - 25 800 MHz dual processor PCs, 2 TB additional disk
 - 50% COCOTIME
 - 50 Collaboration (non-CERN Institutions)
 - Tape drives + PC maintenance
 - COCOTIME
 - Tapes: Collaboration

Conclusions and Outlook

- We look forward to collecting K_S and neutral hyperon decays during the 2002 SPS proton run
- We are confident that the proposed sensitivities can be achieved in 105 days of protons and a 30% duty cycle:
 - We point out that the most efficient way to run NA48/1 is to use the longest possible SPS flat top at a proton energy of 400 GeV
 - Proton energies lower than 400 GeV would result in drastic loss and softening of the spectrum of K_S accepted

Proton Energy (GeV)	400	350	300
Factor	1.0	0.74	0.49