Status Reports of NA48 and NA48/1

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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

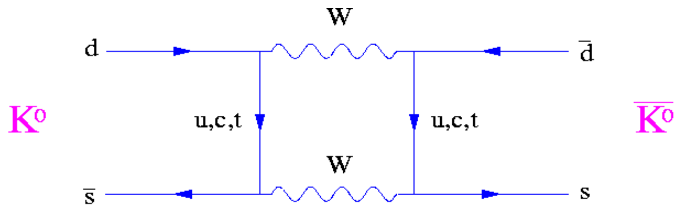
NA48 Phys. Motivation: Direct CP Violation

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

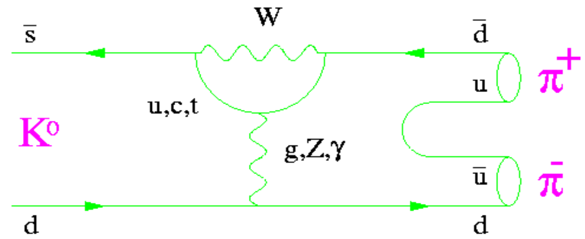
$\eta_{+-} = \varepsilon + \varepsilon'$
$\eta_{00} = \varepsilon - 2\varepsilon'$

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

ε: CPV in K^0 -K^0bar mixing
Indirect CPV



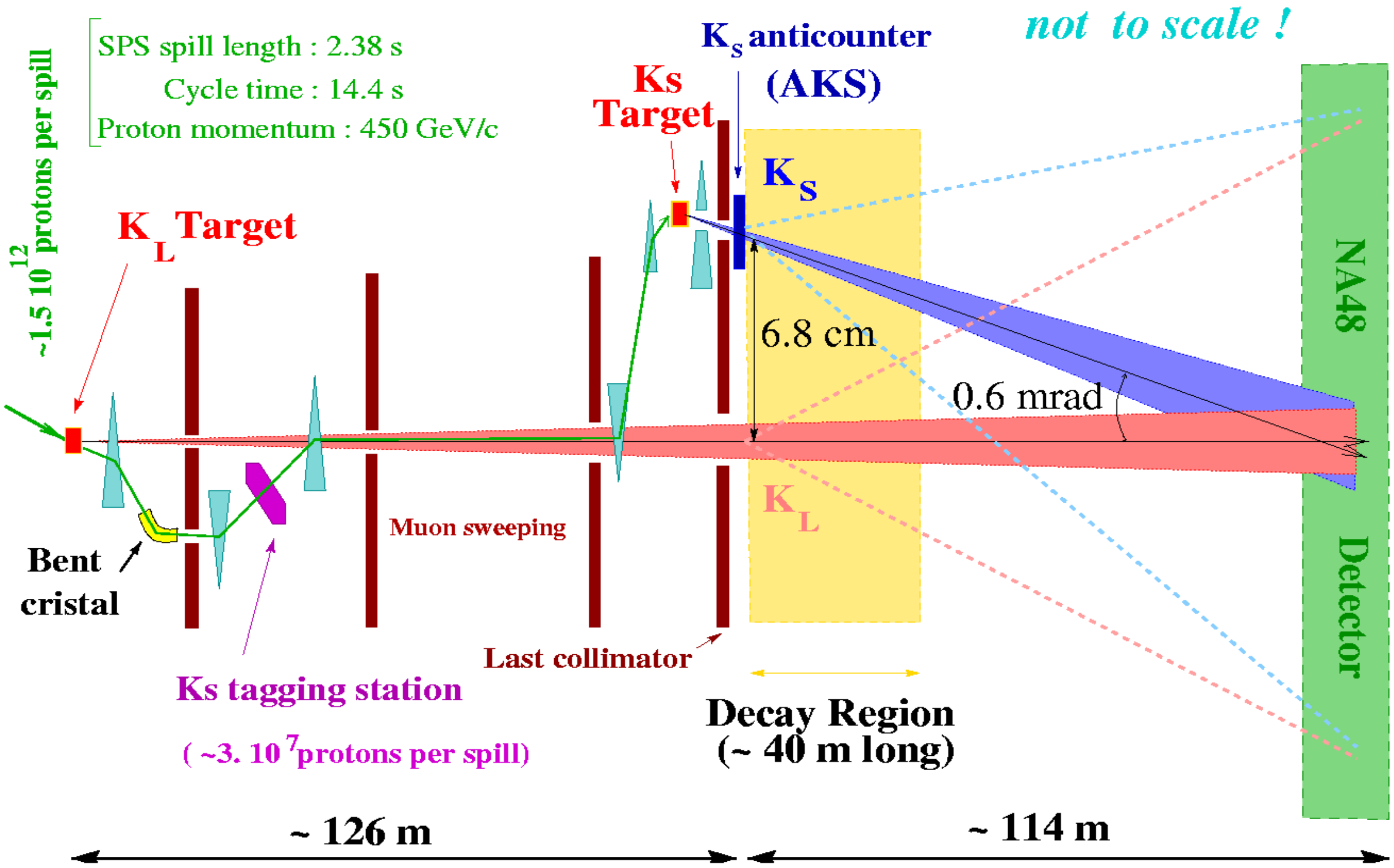
ε': CPV in decay amplitude
Direct CPV



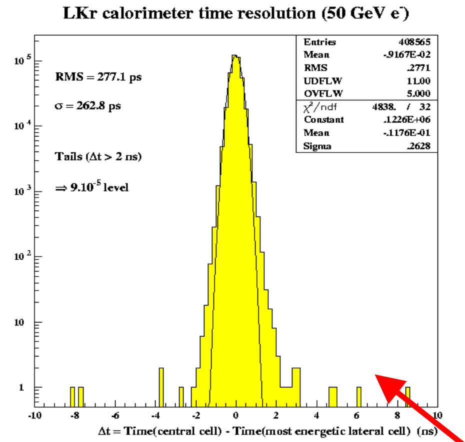
NA48 technique (reminder)

- Employ two almost collinear neutral beams
- Collect the four decay modes simoultaneously, 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

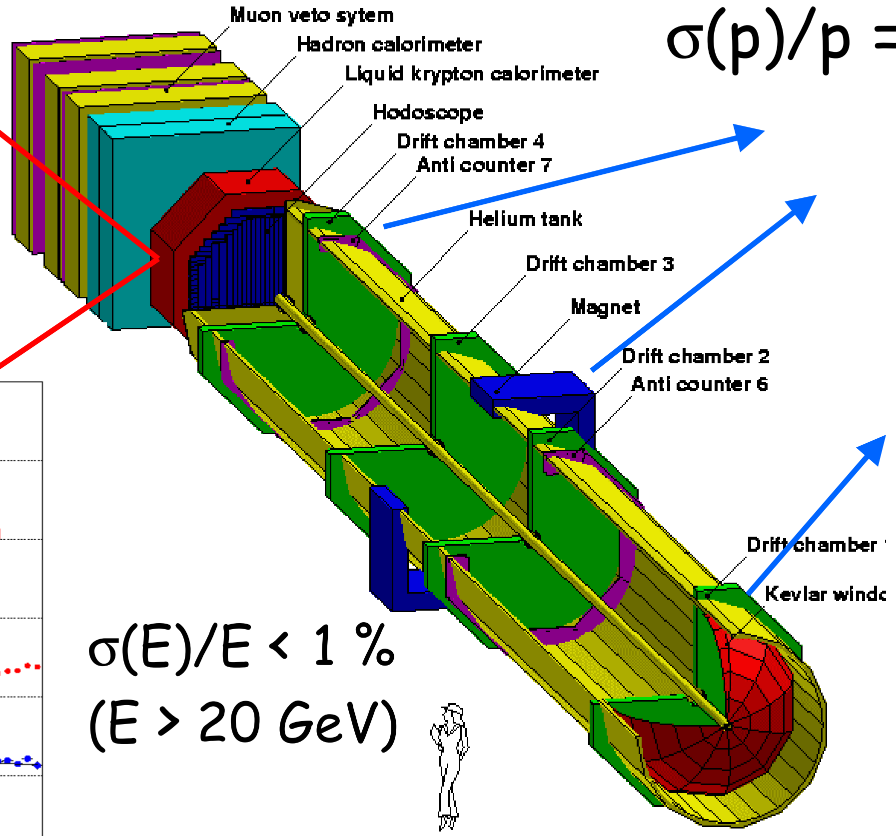
NA48 Beams (1999)



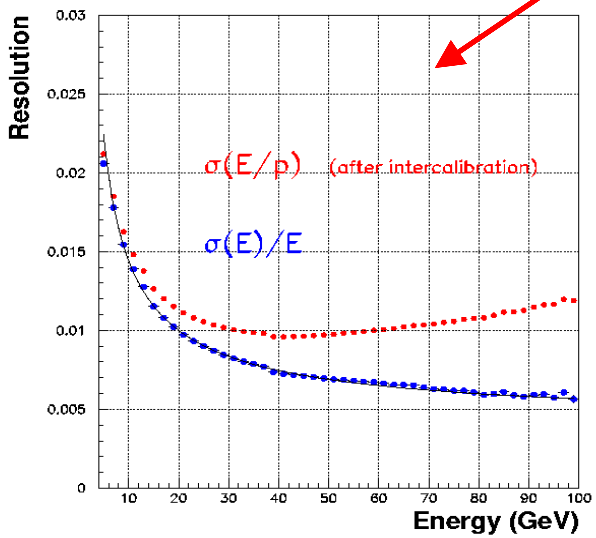
NA48 Detectors



σ_t = 230 ps

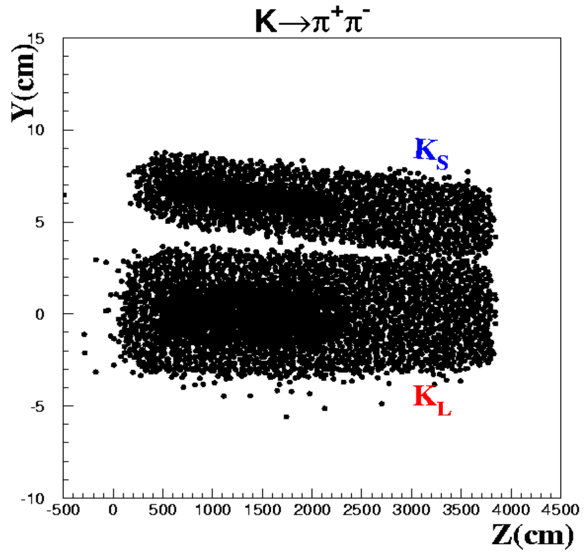


$\sigma(p)/p = 0.48\% \oplus 0.009p\%$



$\sigma(E)/E < 1\%$

($E > 20$ GeV)

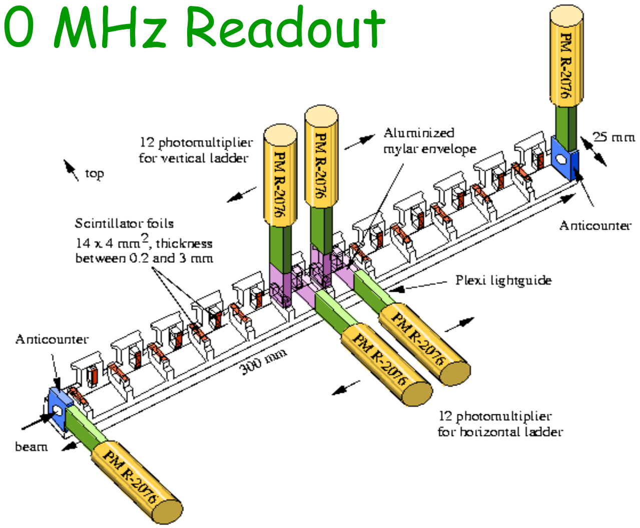


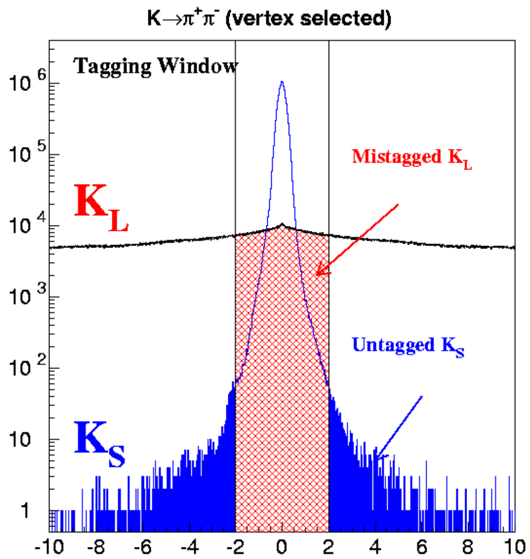
K_S Tagging

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

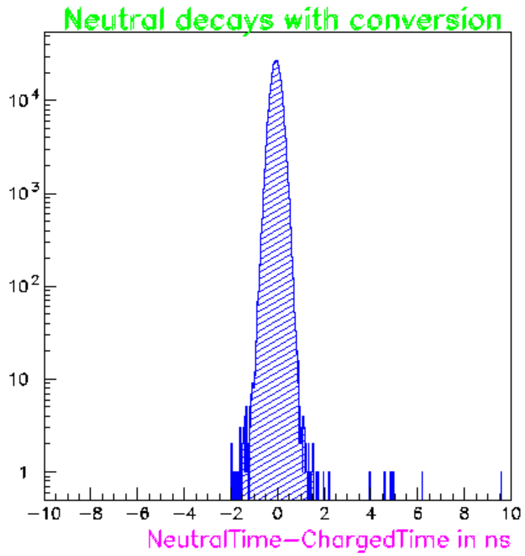
$\Delta\alpha_{LS}$ = difference in accidental tagging between $\pi^+\pi^-$ and $\pi^0\pi^0$

- 12+12 counters
- 960 MHz Readout





<2.5 x 10^{-5}



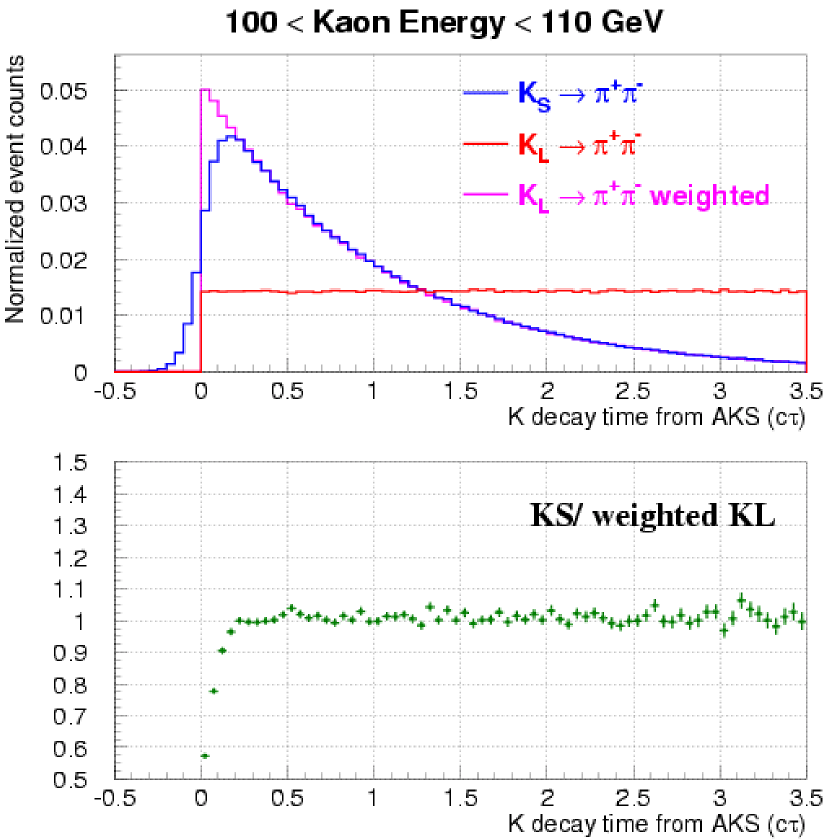
New Epsilon'/Epsilon Result

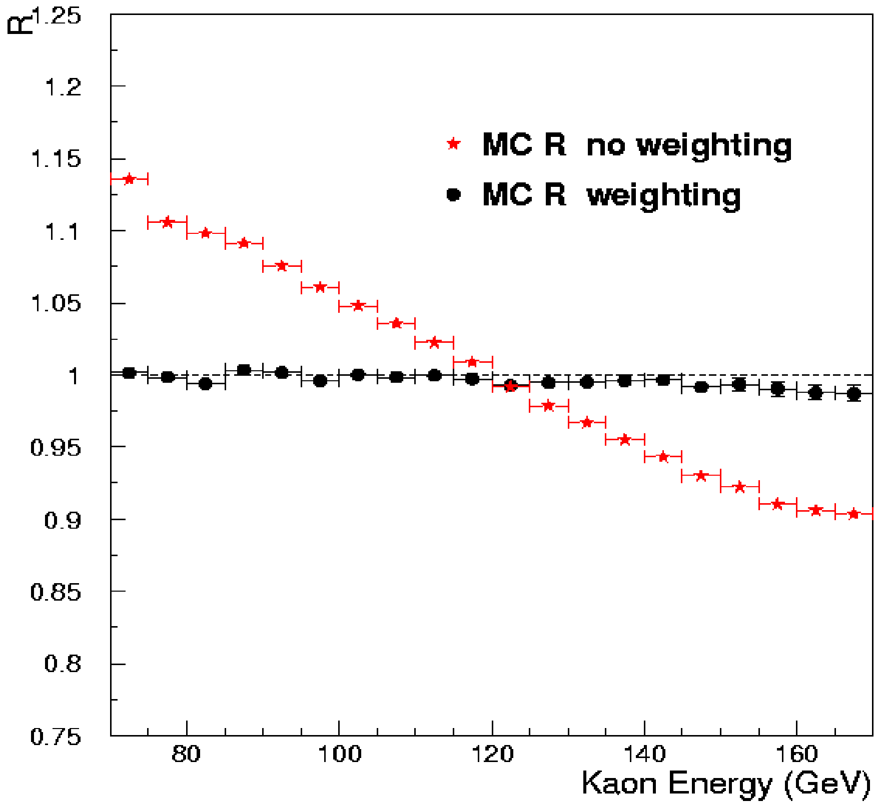
- The European Physical Journal C has accepted for publication the NA48 measurement based on the 1998-1999 data sample
- CERN-EP/2001-067
- $Re(\varepsilon'/\varepsilon)=(15.0 +/- 1.7 (stat)+/-2.1 (syst))10^{-4}$
- $Re(\varepsilon'/\varepsilon)=(15.0 +/- 2.7)10^{-4}$

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

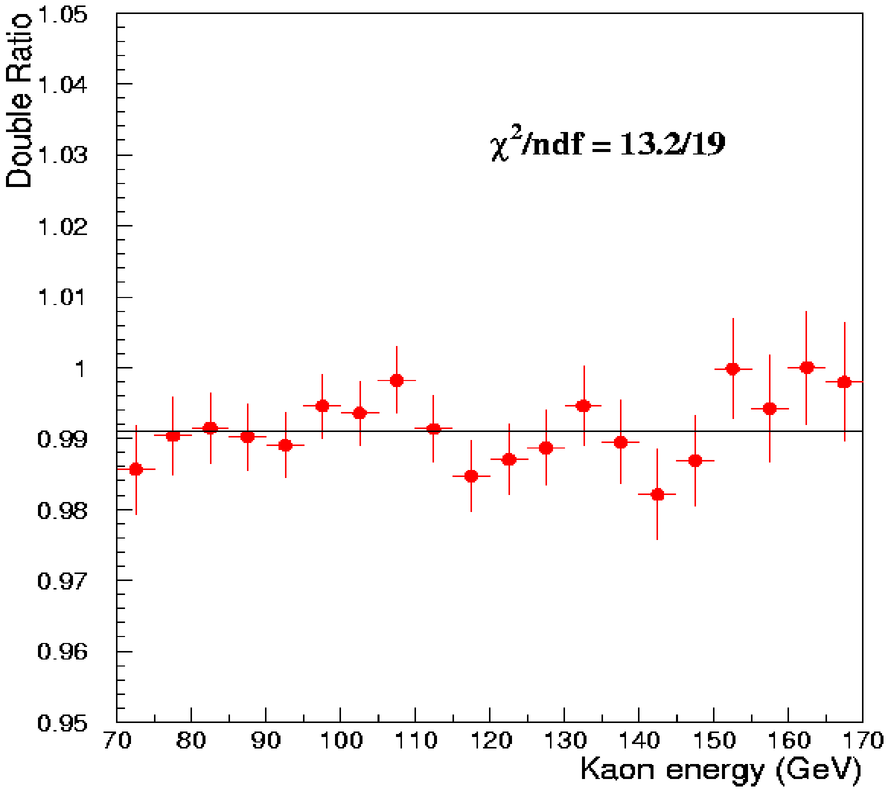
$$Re(\varepsilon'/\varepsilon) = (15.3 +/- 2.6)10^{-4}$$

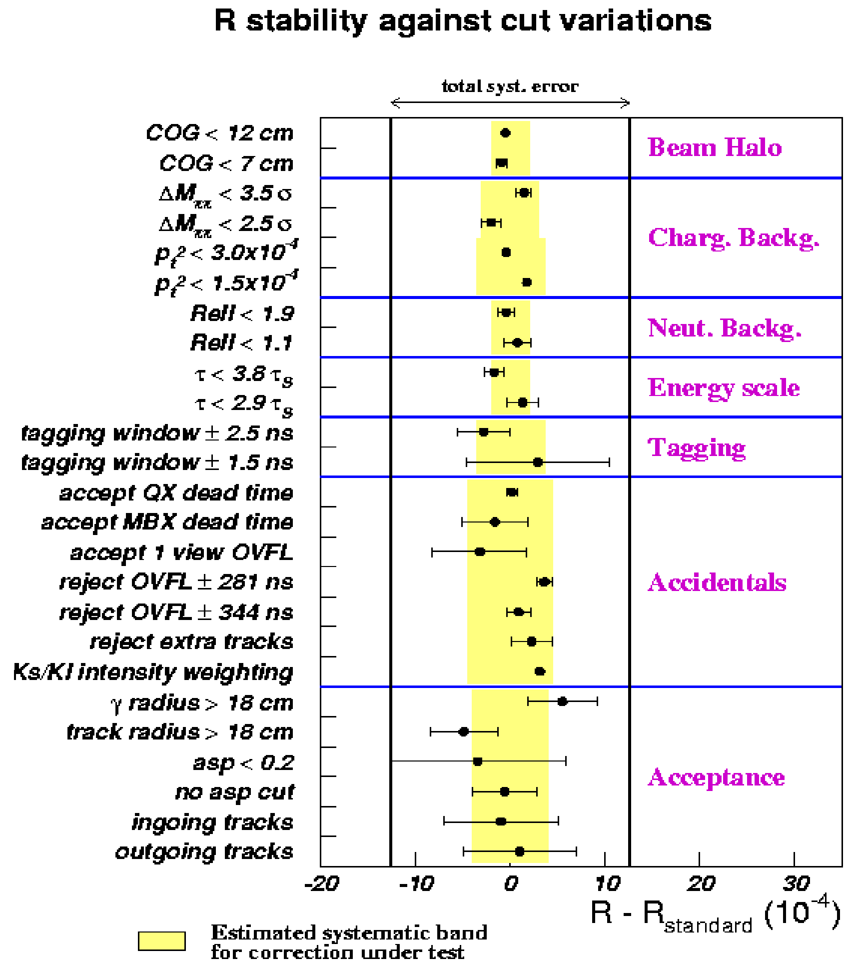
Event Weighting and Acceptance Correction





Systematics Checks and Result

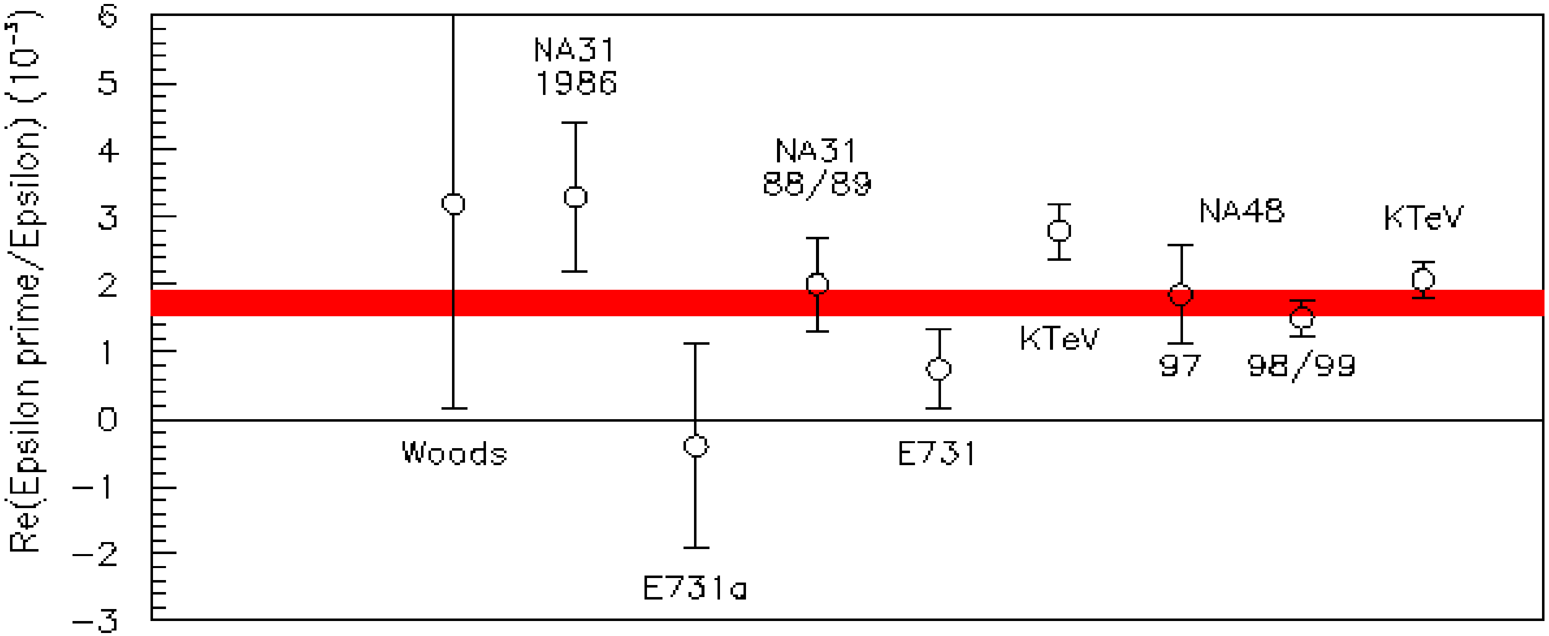




Main systematic uncertainties and corrections to R (units: 10^{-4})

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+/- 1.8)10^{-4}

Data Taking in 2000 (No Drift Chambers)

- With simoultaneous 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 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

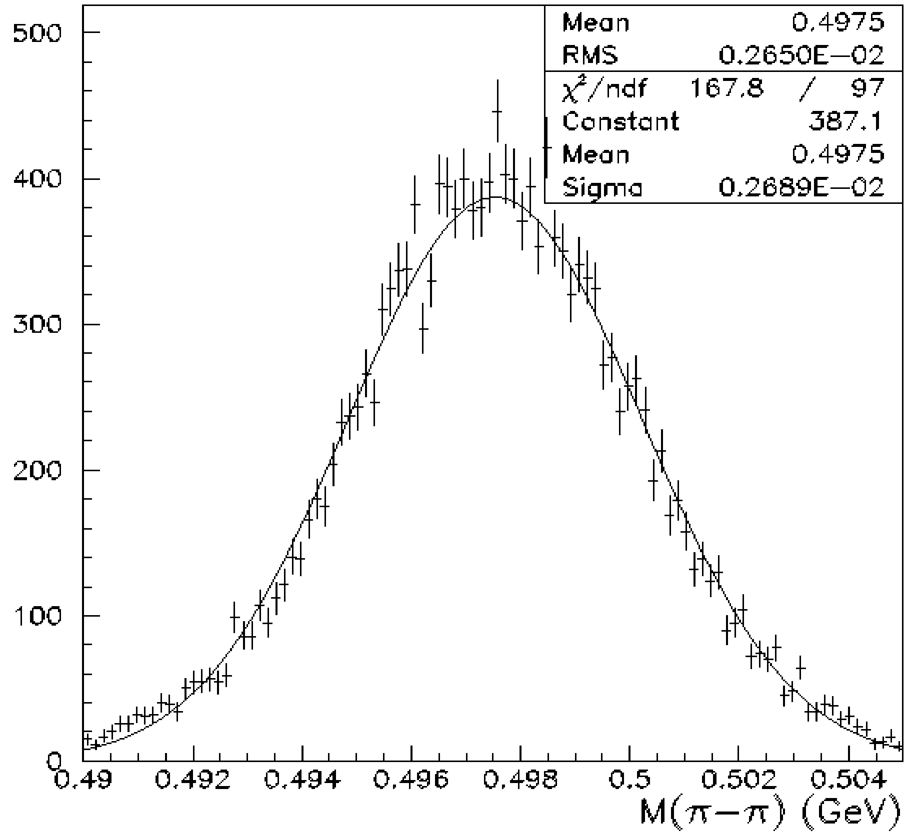
- Damaged by the 1999 beam-pipe implosion
- Repaired in 18 month
  - 45 Technicians and Physicists from CERN, Dubna, INFN and Saclay
  - First wire soldered on June 2000
  - Last wire soldered in July 2001
  - Spectrometer operational by July 20th
- NA48 data taking with full apparatus (four chambers)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

Reconstruction of the Drift Chambers

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



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

The New Beam-pipe

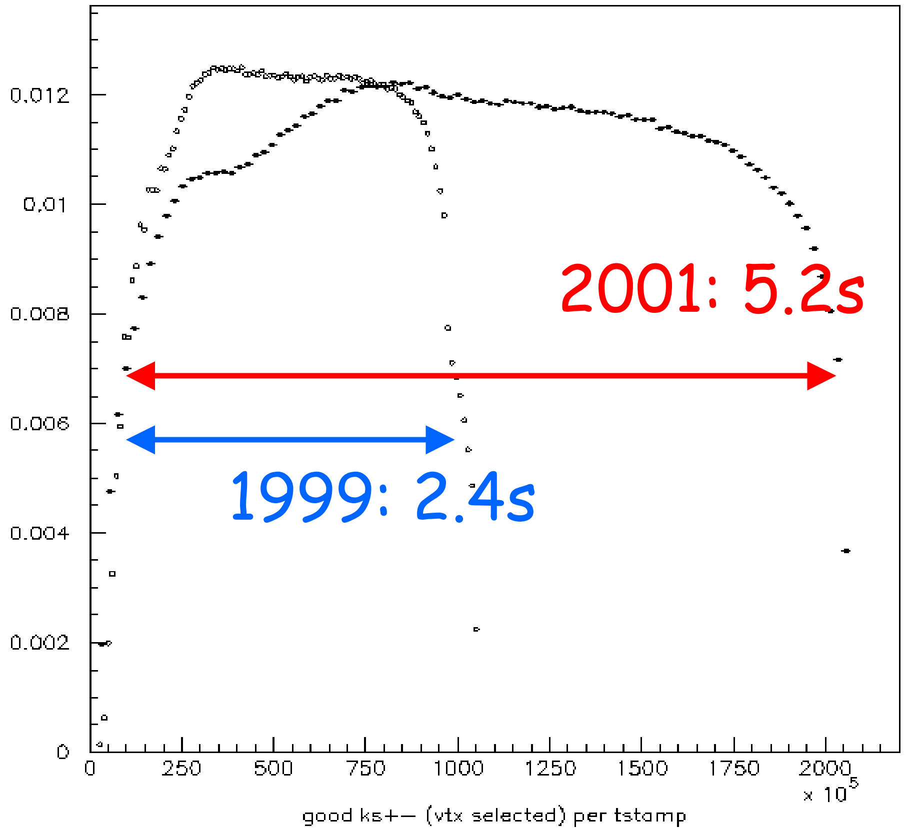
- New aluminium beam-pipe
  - Designed and machined at CERN
  - 1.1 mm thick
  - Stainless steel sections replaced by aluminium ones

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 ~ 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

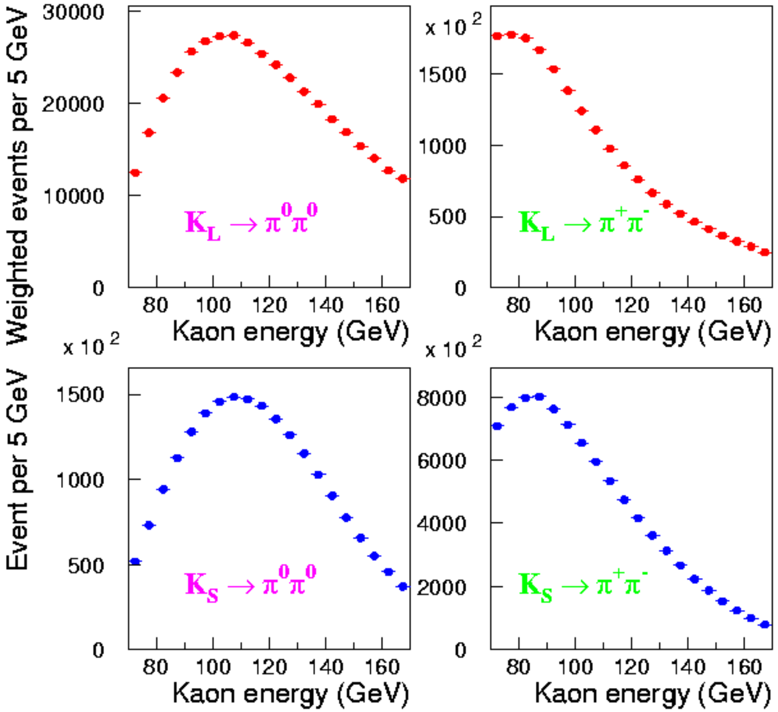
- New Beam Monitor to study beam structure at the 100ns scale
- Improved Beam Monitor
  - Fine tuning of the delay between K_L and K_S
- More down-scaled triggers
  - to reduce the uncertainty due to the charged trigger inefficiency (second largest syst. uncertainty for the published data)



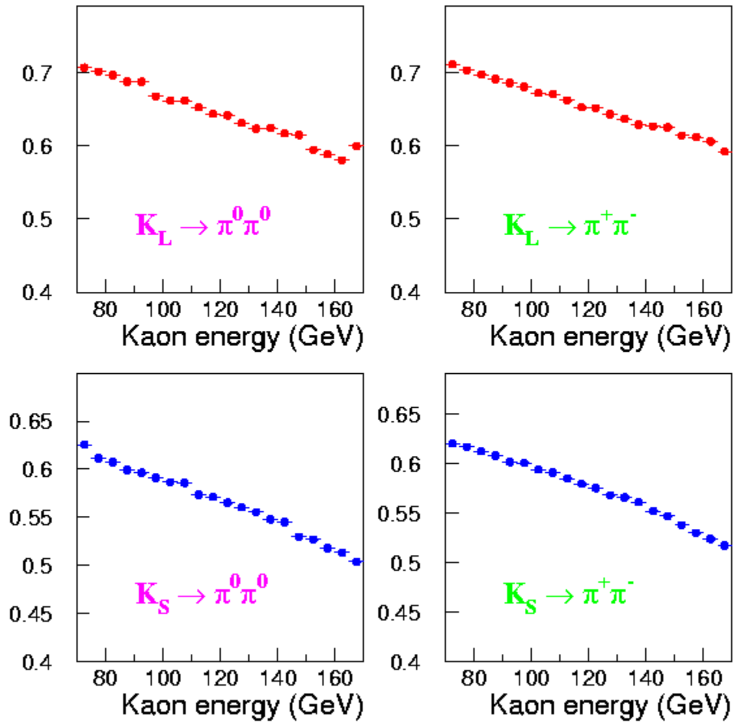
Time Stamp Distribution

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 (π^0 π^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):

$BR(K_L \rightarrow \pi^0 \gamma\gamma) = (1.36 +/- 0.03(stat) +/- 0.03(syst) +/- 0.03(norm)) 10^{-6}$

$a_V = -0.46 +/- 0.03(stat) +/- 0.03(syst) +/- 0.02(theory)$

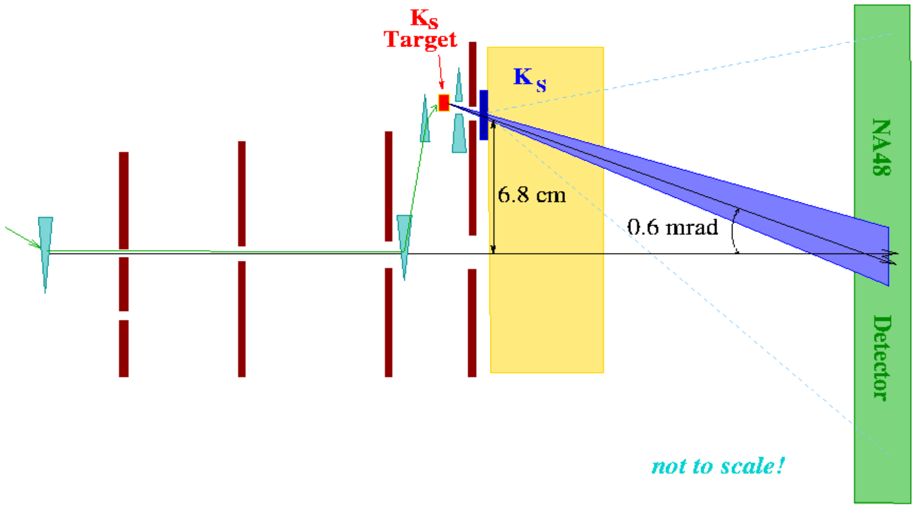
$BR(K_L \rightarrow \pi^0 \gamma\gamma, 30\ MeV/c^2 < m_{\gamma\gamma} < 110\ MeV/c^2, 0 < y < 0.2) < 6\ 10^{-9}$

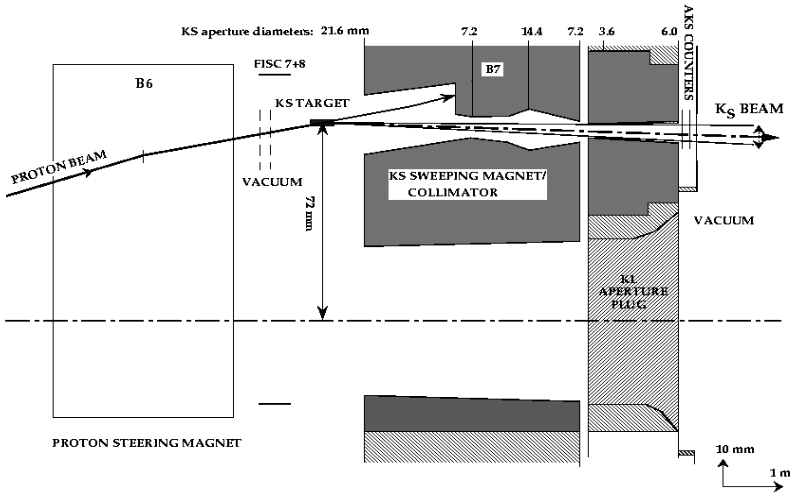
NA48/1: Physics Motivation

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

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





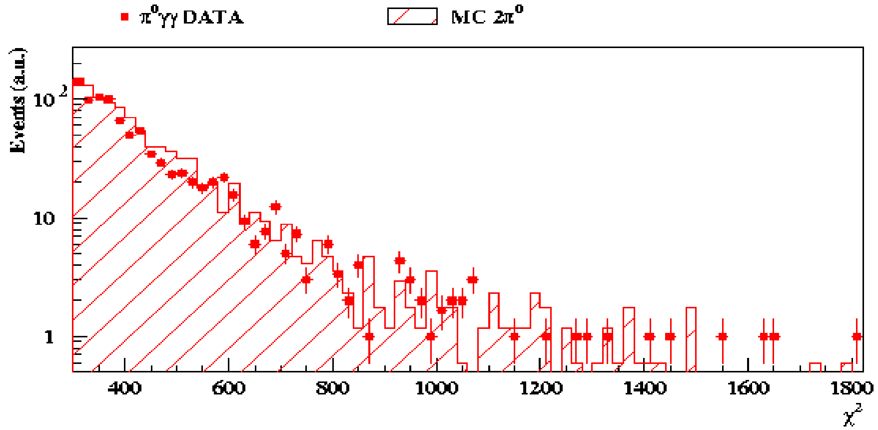
NA48/1: Data Taking so far

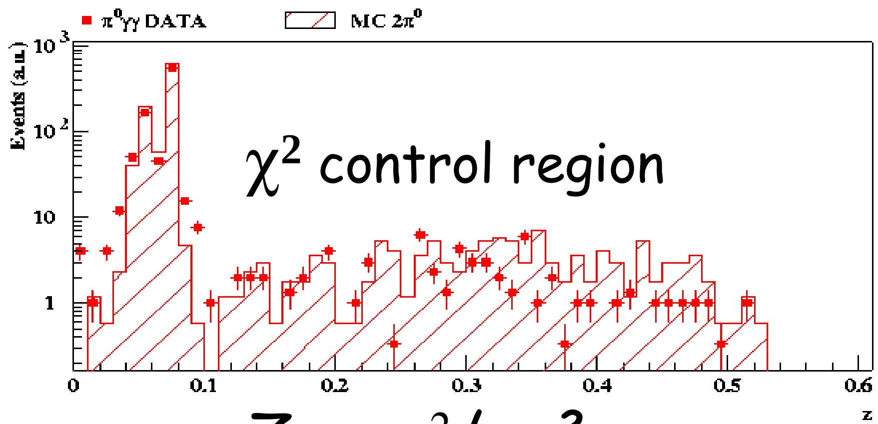
- 1999: 40h test run
  - Proof of principle
  - Physics results (published):
    - $BR(K_S \rightarrow \gamma\gamma)$ = (2.6 +/- 0.4 +/- 0.2) 10^{-6} PL B493 (2000) 29
    - $BR(K_S \rightarrow \pi^0 e^+ e^-) < 1.4 \times 10^{-7}$ 90% CL PL B514 (2001) 253
- 2000: 45 days
  - No drift chambers; no beam-pipe
  - 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 χ^2> 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)

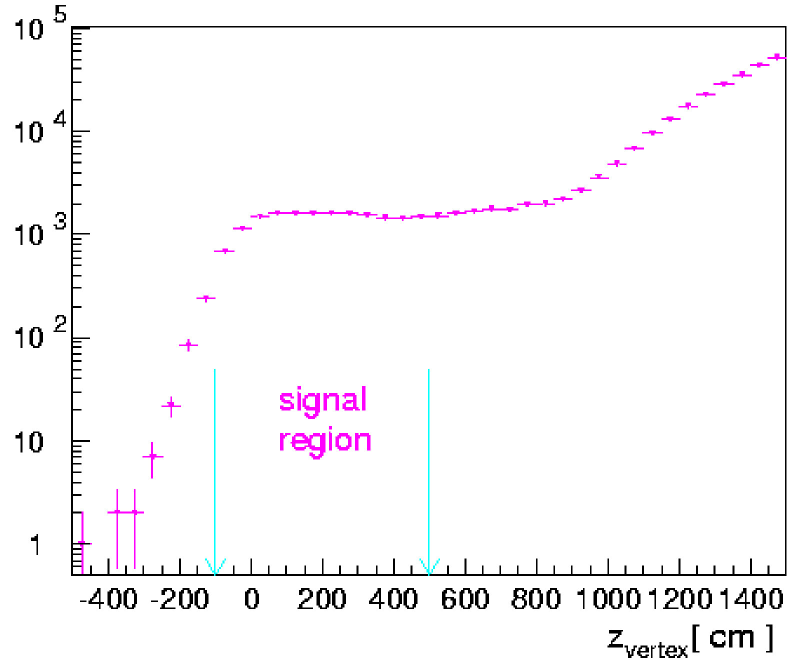




$Z = m_{\gamma\gamma}^2/m_K^2$

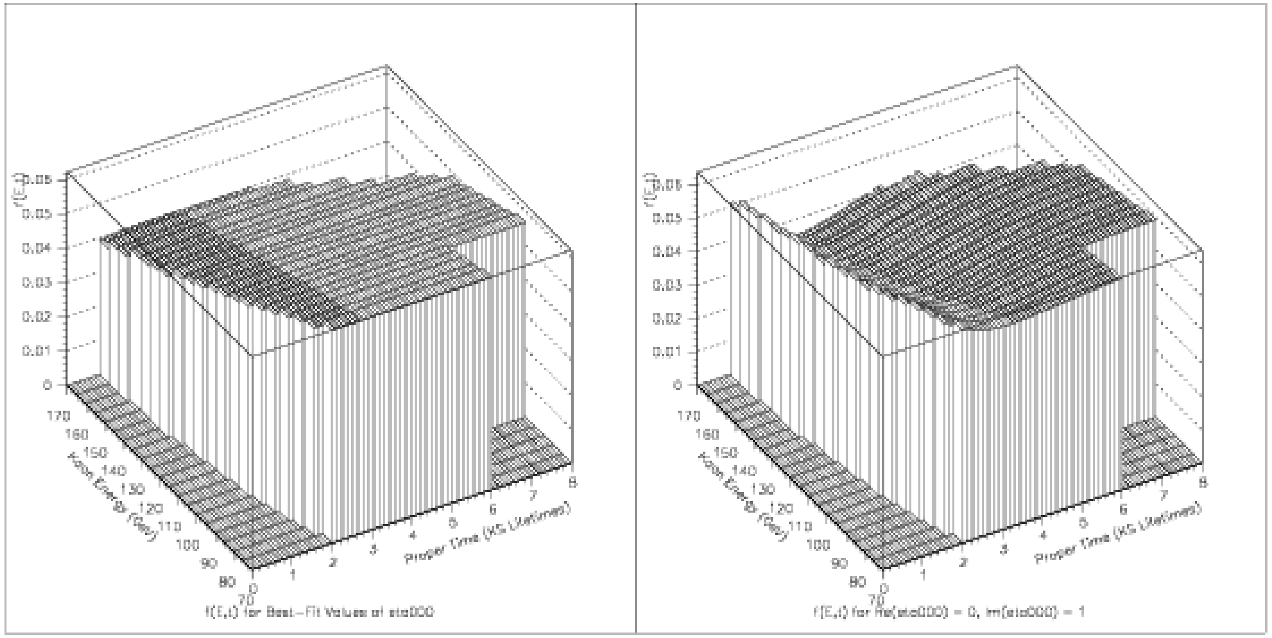
$K_S \rightarrow \gamma\gamma$ (45 day, 2000 Preliminary)

- 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

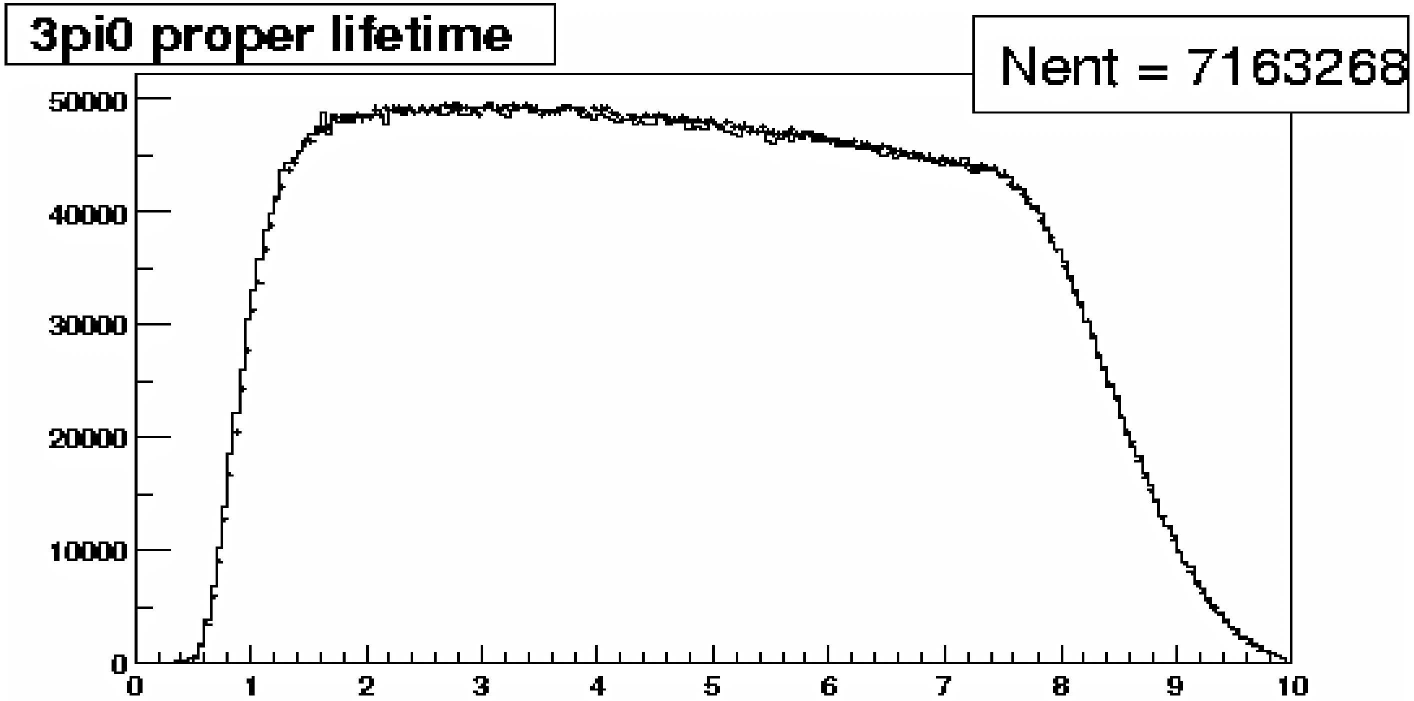


$K_{S,L} \rightarrow 3\pi^0$(45 days, 2000 Preliminary)

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



$K_{S,L} \rightarrow 3\pi^0$ (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,μ)	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 x 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

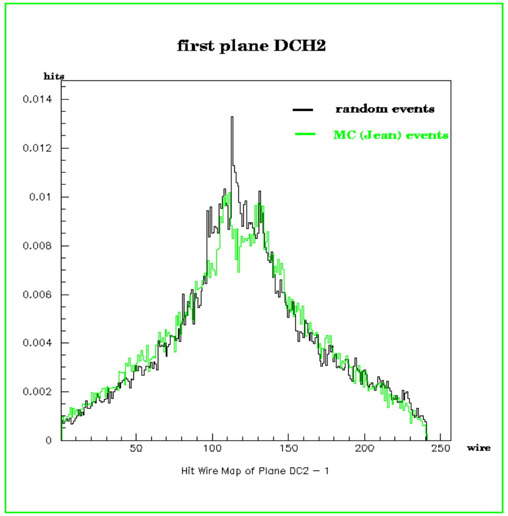
Sensitivity

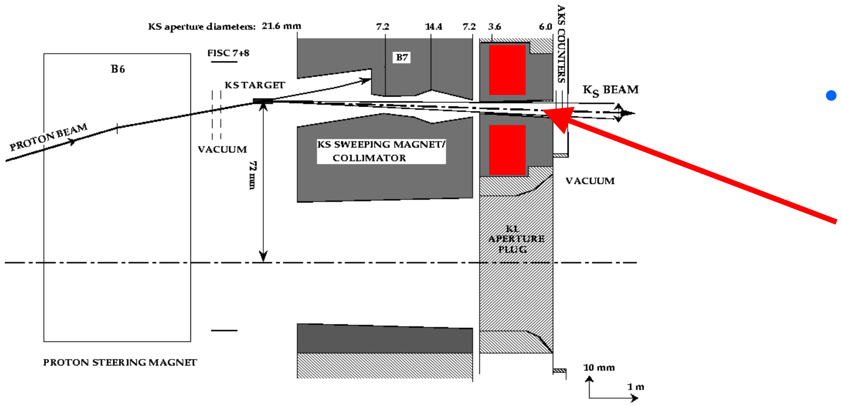
- Instantaneous rate already achieved in 1999
  - 10^{10} ppp → 3×10^{10} K_S decays x105 days
  - SES $6\ 10^{-10}$ for 5% acceptance x efficiency
- Upgraded Target Station (2002)
  - Expect x2 reduction in accidental rate
  - Increase beam intensity from 10^{10} ppp to $2\ 10^{10}$ ppp
  - SES → $3\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

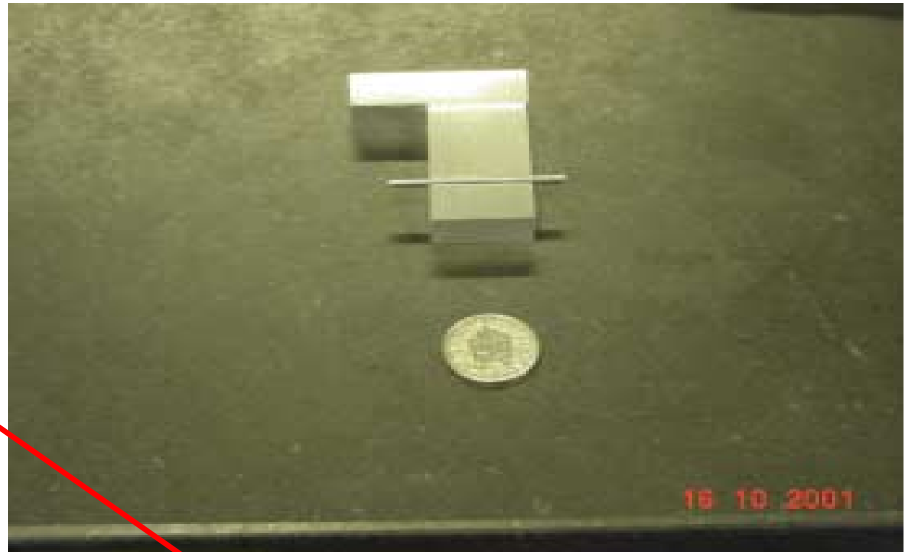




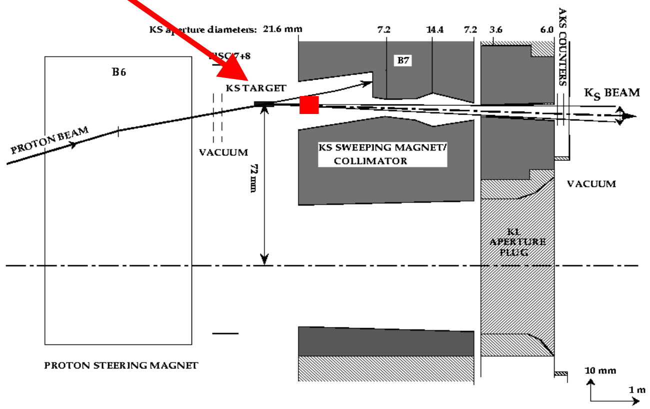
- *Most of the accidental activity measured in the 1999 test data is explained by electro-magnetic showers generated in the collimator*
- *According to a GEANT simulation, the accidental rate can be significantly reduced placing a magnetic field in the collimator*
- *A magnet is being prepared for this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



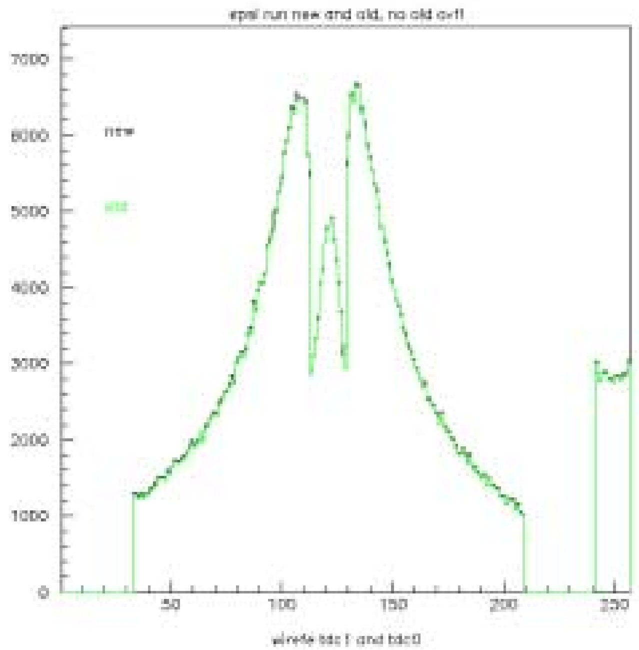
Improved Drift Chamber Front-end

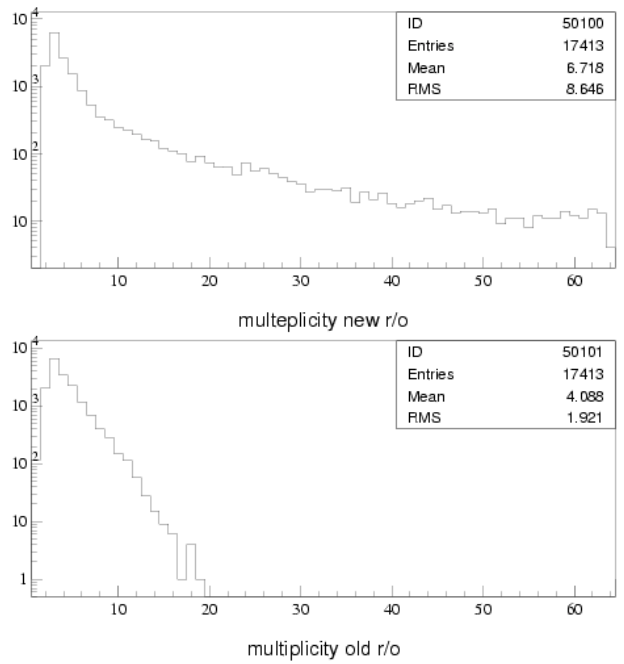
- Installed better cables between the Pre-Amplifier and the TDC (tested in 2001)
  - Reduction of noise → reduce threshold from 30 to 25 mV
  - Can reduce the HV by 50 Volts maintaining the same efficiency
  - Current in the drift chambers reduced by 40%
  - No modification of the Pre-Amplifier is necessary
- 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

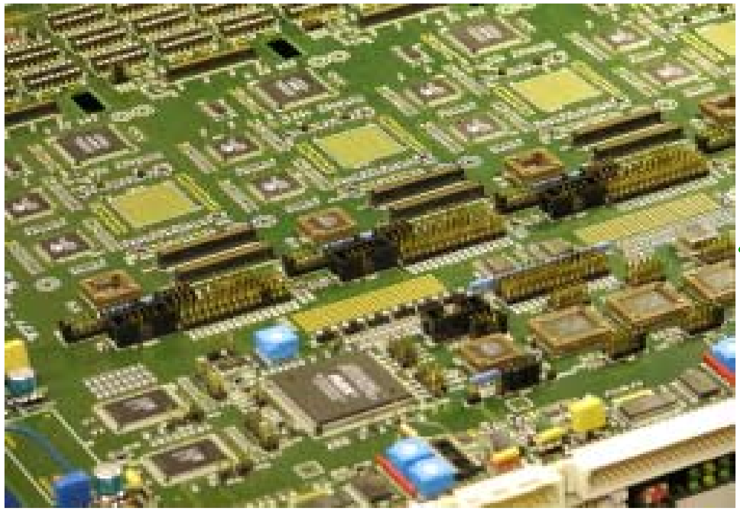
- 50% of the CMC cards to be delivered by the end of November
- The remaining cards are scheduled to arrive by the end of December 2001
- Orders for the FPGAs and other critical components are being placed
- The installation should start in February/March.
- Testing should be finished by April 15

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

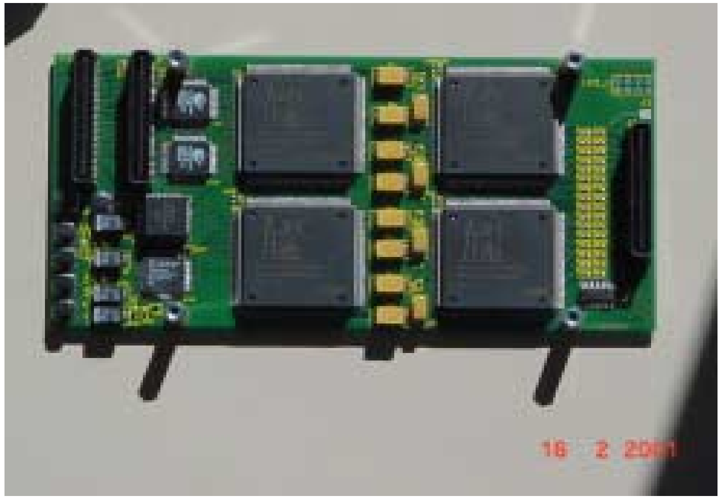
New Drift Chamber Readout

CSC

MSC



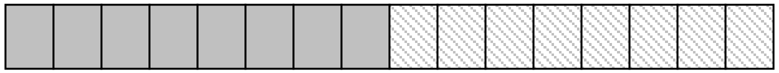
TDC-MB



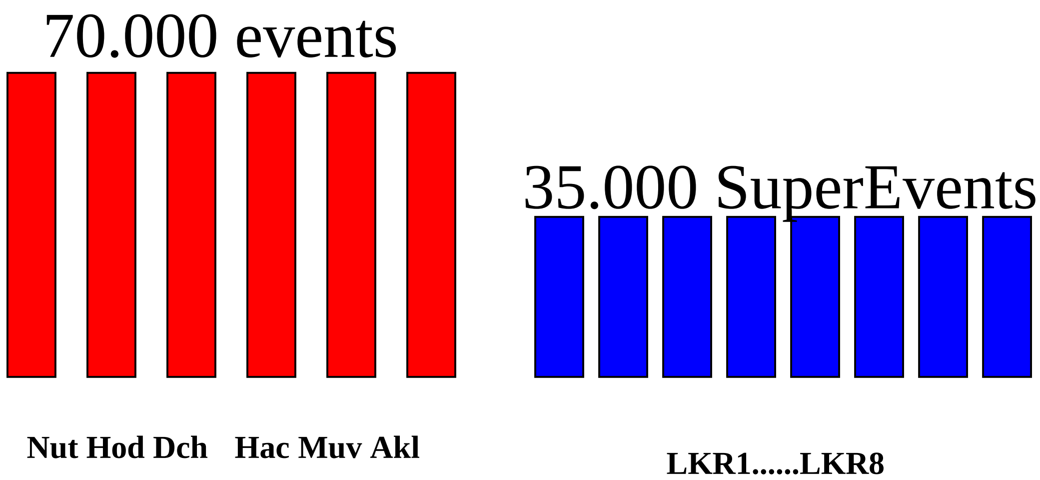
CMC

Upgrade of LKr Readout and Online PC farm

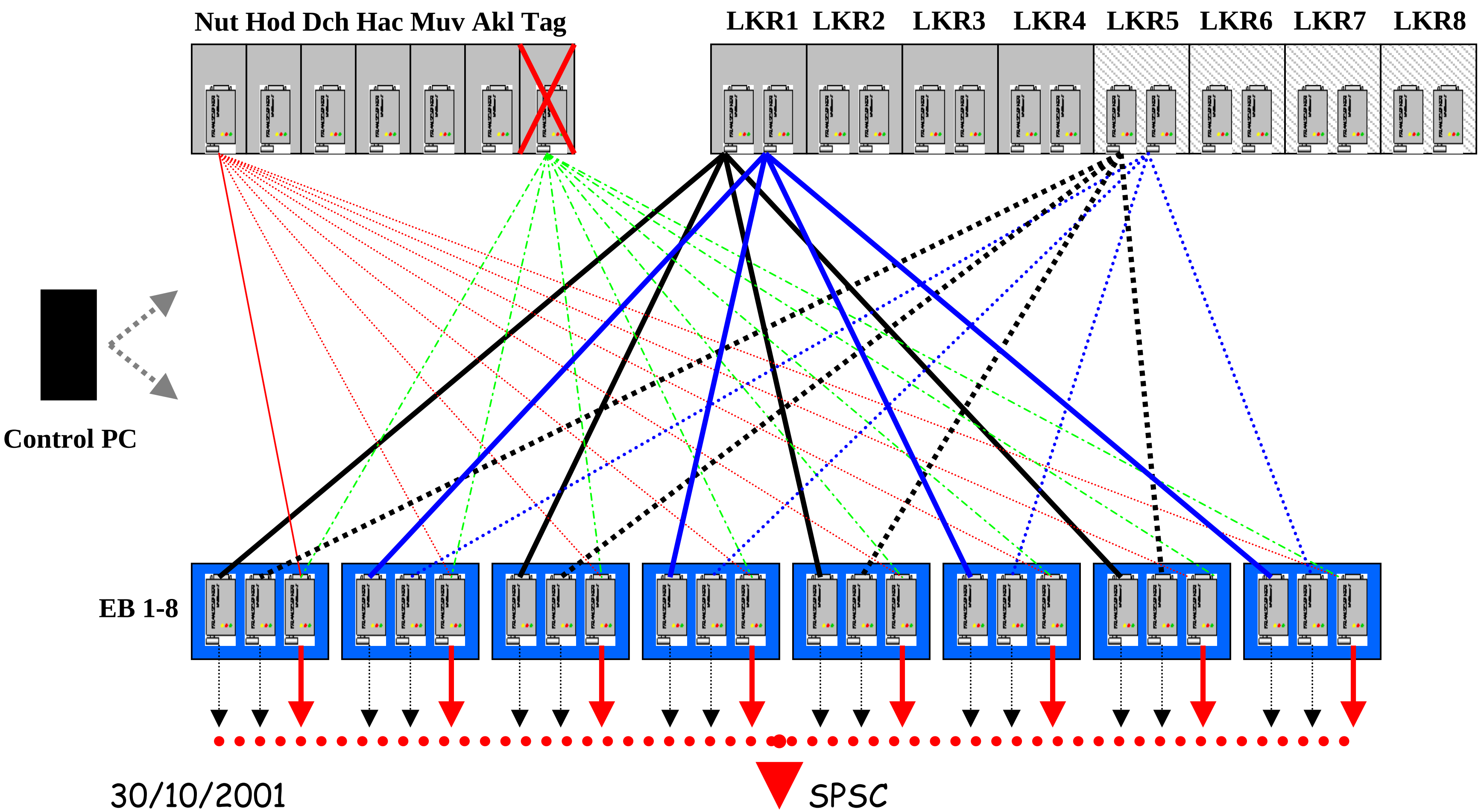
Two 8 sample LKR event are packed into a 16 sample SEvent:



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