Micromegas tracker in COMPASS and NA48

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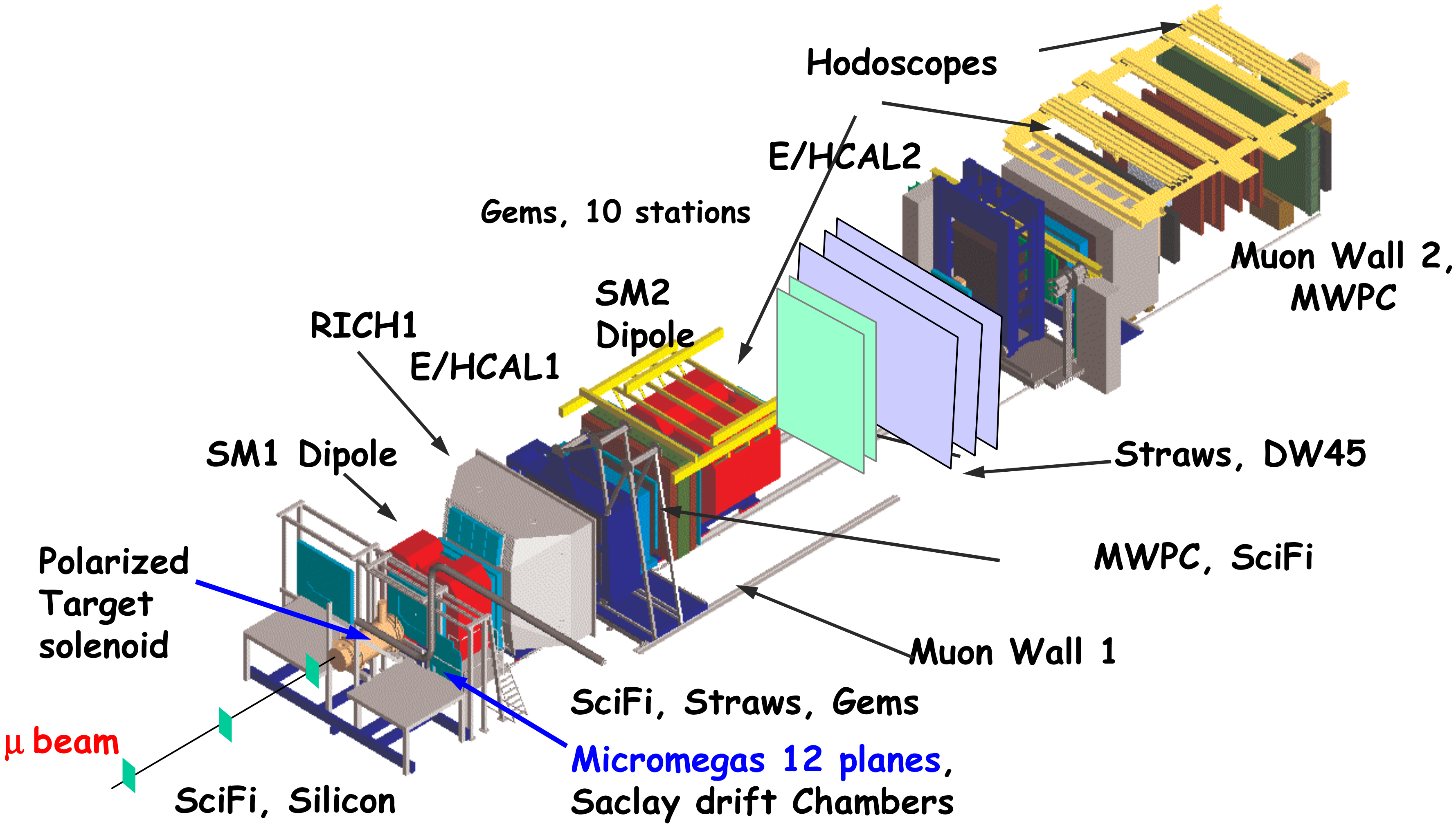
NA58 – COMPASS : High flux detector

- requirements
- description
- performances
- perspectives

NA48 – KABES : Mini TPC mode

The COMPASS experiment

- Nucleon spin structure : μ 160 GeV 2.10[8] μ/5s spill
- Charm spectroscopy + exotics : p, π 100 - 300 GeV



COMPASS first spectrometer requirements

Detector requirements:

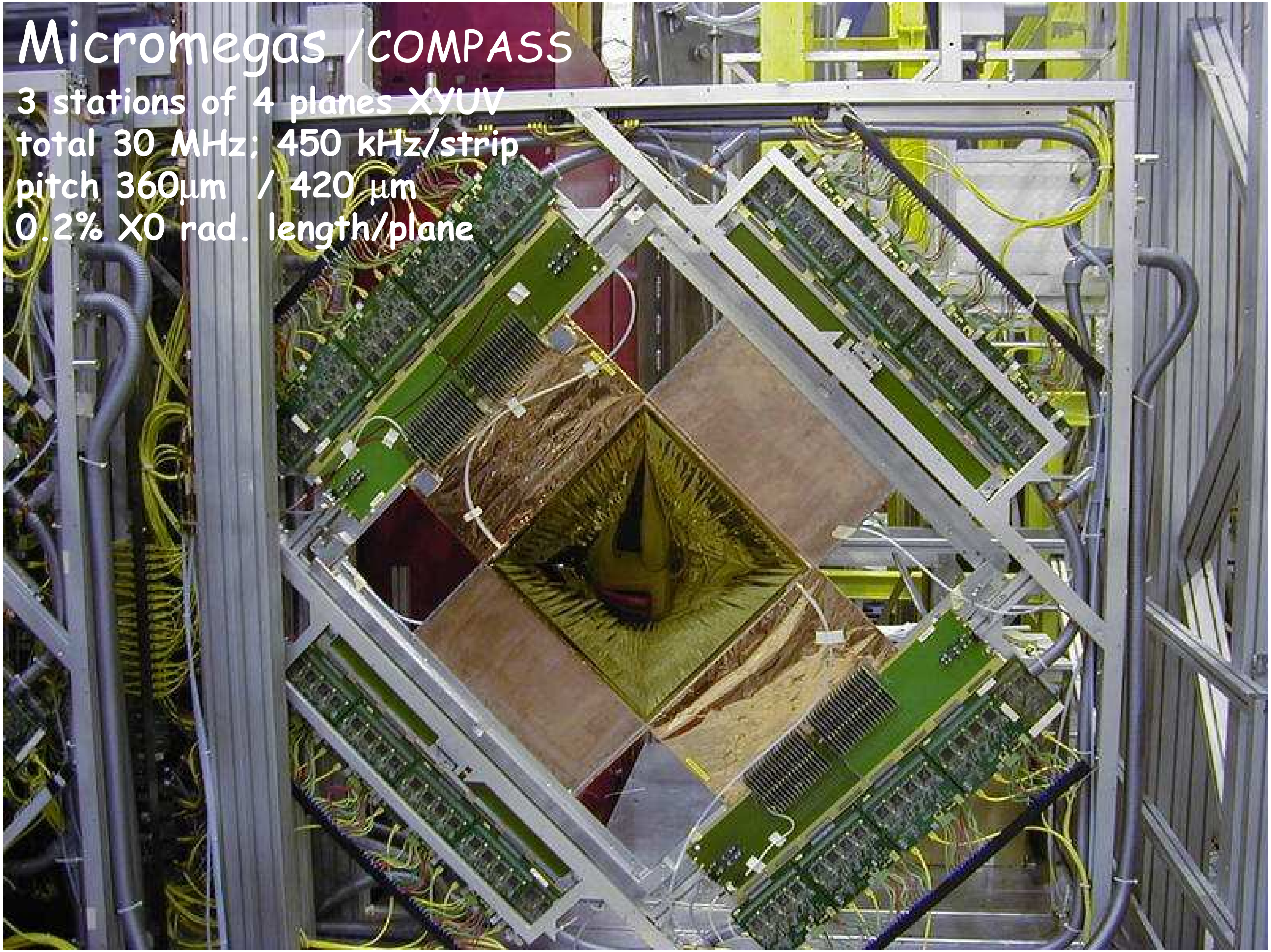
- Particle rates up to 5.10^{5} /s/cm^2

  30 MHz integrated flux, beam area excluded
- Must work in fringe fields of dipole and solenoid
- Resolution better than 100 μm
- Low material budget

Micromegas:
High rate
High resolution
Low mass

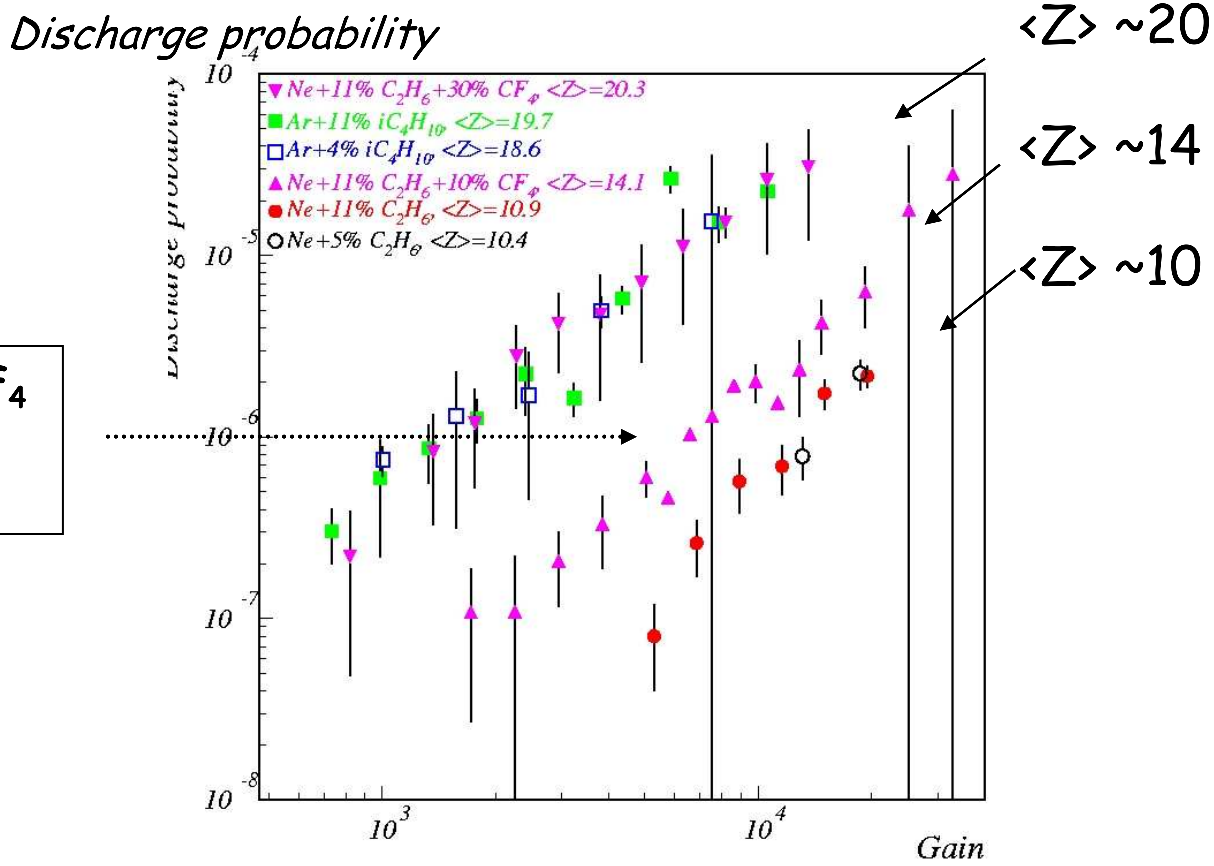
12 planes 40x 40 cm^2

3 stations X Y U V (+/- 45°)


Micromegas /COMPASS
3 stations of 4 planes XYUV
total 30 MHz; 450 kHz/strip
pitch 360µm / 420 µm
0.2% X0 rad. length/plane

Discharge probability in 10 GeV hadron beam

conversion gap : 2.5 mm
amplification gap : 100μm



Ne-C_2H_6-CF_4
gain ~ 10^4
P = 10^{-6}

D.Thers et al. NIM A 469 (2001)133

Discharges in COMPASS environment

40 MHz muon beam on 1 rad. length target

→ ~ 30 MHz in detector : beam halo + target halo + hadrons…

0.15 discharge/spill $P = 10^{-9}$ → ~ 0.1% hadrons

- Capacitive decoupling of strips reduces dead time per discharge to 3 ms → negligible effect on efficiency

- Increase gap from 2.5 to 3.2 mm → reduces rate by factor 5

  → 0.03 disch/spill

- Perfect behavior with muon beam
- Anticipate further increase of gap for future hadron beam

Gas mixture choice

$26x36cm^2$ prototype, 317 μm pitch, gap 2.5mm, in **10 GeV π beam**

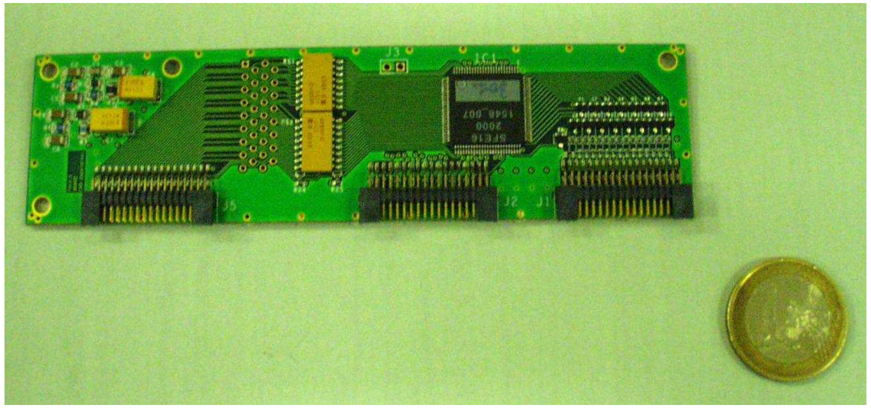
Gas	Ar - iC_4H_{10} 89-11 %	Ne - C_2H_6 89-11 %	Ne-C_2H_6-CF_4 79-11-10 %
Gain	3700	14000	6400
Cluster size	2.4	2.9	2.1
Jitter (σ, ns)	12.3	17.	8.8
Time over threshold (ns)	195	182	171
Resolution (μm)	62	80	50
Discharge probability	4. 10^{-6}	1.5 10^{-6}	9. 10^{-7}

Front End Electronics

12000 channels

Digital readout: SFE16 custom circuit developed to ensure

- 100 % efficiency at moderate gain where discharge rate is reduced
- occupancy below 3-4% in hottest region



preamplifier shaper, 16 channels

Noise < 900 e^- for 68pF detector capacitance

Adjustable peaking time → 85 ns

Record leading and trailing times → Time over threshold measurement

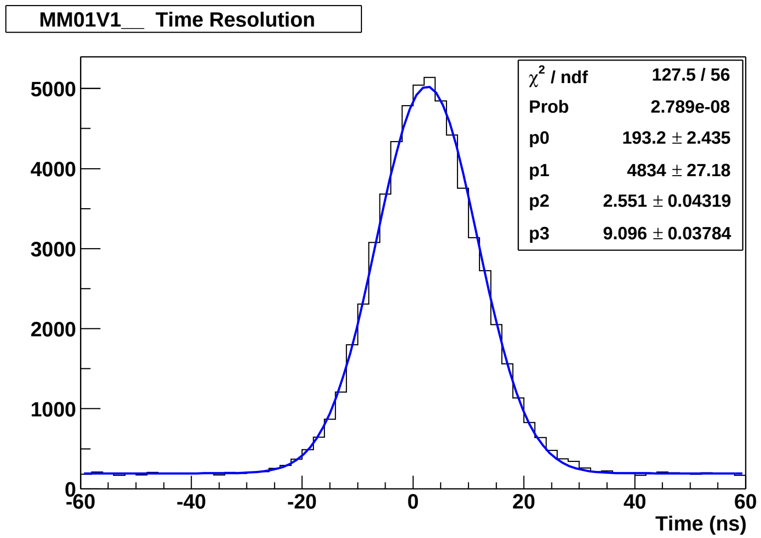
F1 multi hit TDC chips → COMPASS general DAQ

Micromegas + SFE16. Time distribution

Leading & trailing edges of signal

→ Mean Time σ = 9ns

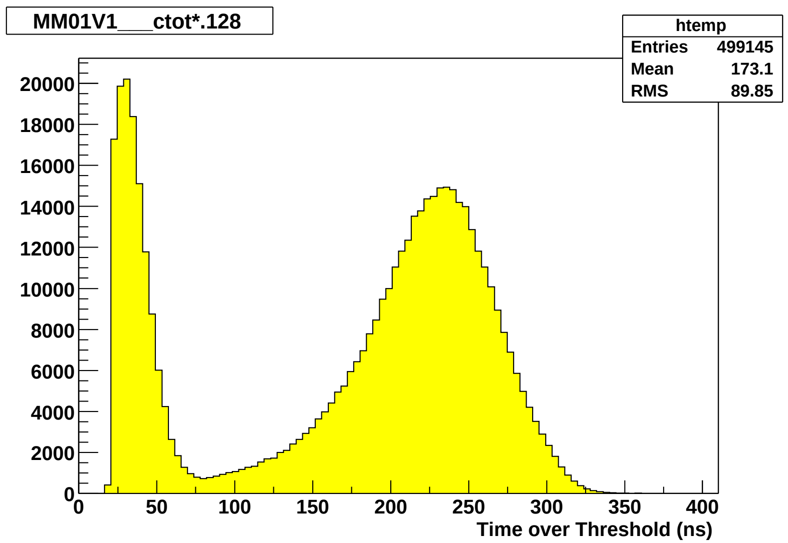
time walk suppressed



→ Time over threshold <ToT>=220 ns

Signal amplitude calculated from ToT:

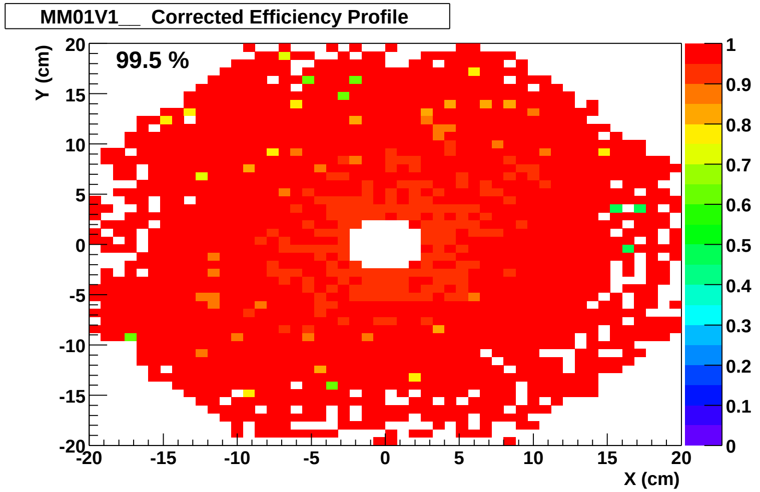
Improves background rejection and spatial resolution



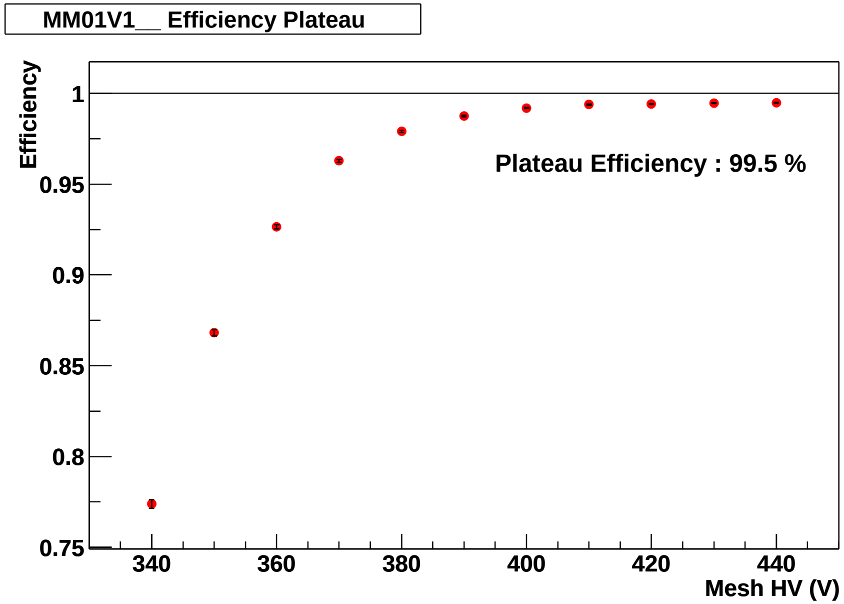
Micromegas efficiency & resolution

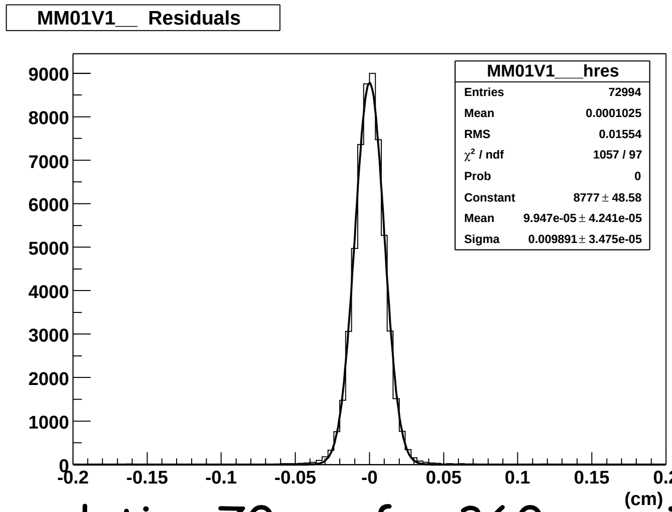
Low intensity ε ~ 99.5%

High intensity ε ~ 96 %



COMPASS environment, resolution 70/90 μm for low/high intensity





Resolution 70 μm for 360 μm pitch

Micromegas in COMPASS -Accumulated charge

Beam time, 3 years (muons) ~ $3 \times 5/16.8 \times 10^7$ s

Integrated flux since 2002:

$0.5 \times 10^6 \times 3 \times 5/16.8 \times 10^7$ ~ $5\ 10^{12}$ p/cm^2 in hottest region

or $1.6\ 10^{-19} \times 18$ e- $\times 6400 \times 5.10^{12}$ C/cm^2

→ 1 mC/mm^2

stable performances

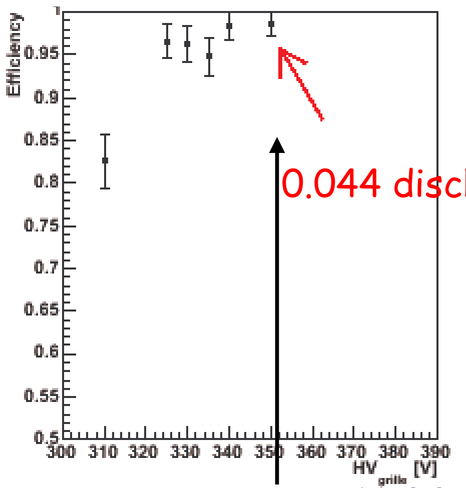
COMPASS hadron beam π 200 GeV - 2004

gas : Ne-C_2H_6 (no CF_4)

Increase Micromegas amplification gap 3.2 mm→ 5.5 mm:

More ionization #e-: 18→ 27 , efficient at lower gain

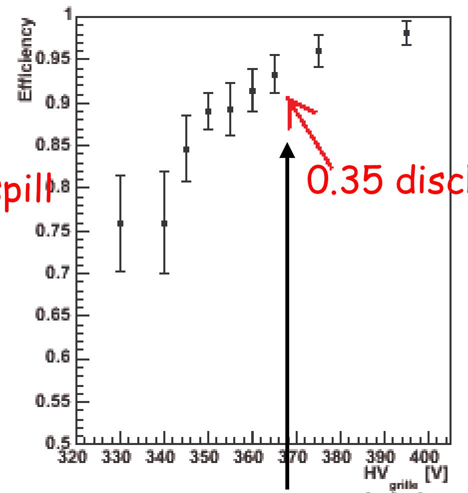
gap 5.5 mm



gain ~ 1300

→ **still room to increase hadron beam intensity**

gap 3.2 mm



gain ~ 2000 :

 # primary interactions too low
→ need higher gain

With 5.5 mm gap, discharge rate as low as in muon beam

→ Micromegas detectors performing well in hadron beam

COMPASS - Perspectives

COMPASS 2006-2010

Use alternately muon or hadron beams

μ 160 GeV 2.10^8 /spill

π, K 100 -300 GeV 10^8 /spill

KABES (KAon Beam Spectrometer)

Slides from J.Derré, Saclay

NA48 : CERN, Cambridge, Chicago, **Dubna**, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, **Saclay**, Siegen, Torino, Vienna

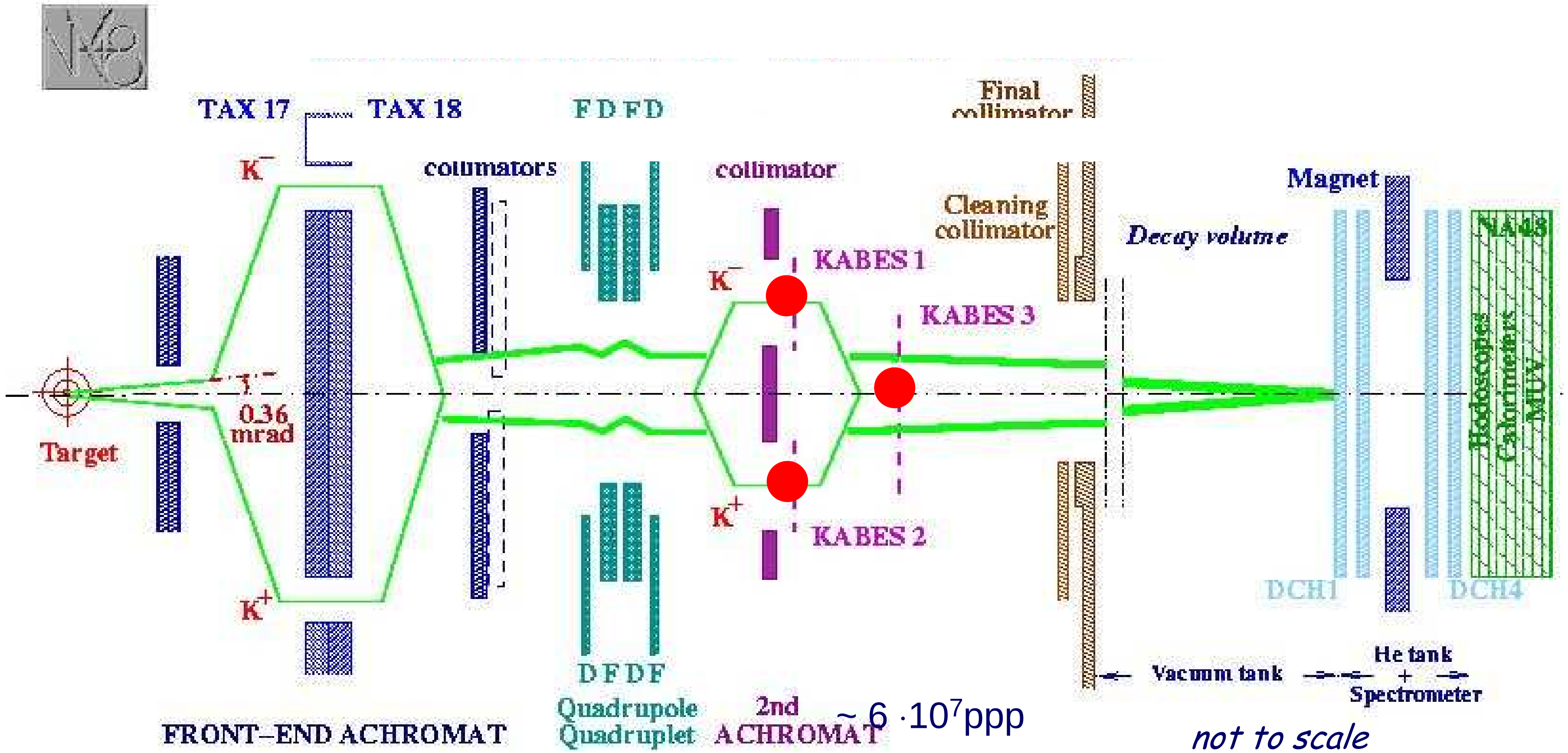
Mini TPC - precise measurement of incident track

- in high beam flux – 20 MHz /7cm^2 3.10^6/s/cm^2 π,K beam
- with low material budget

→ Gaseous detector in TPC mode with Micromegas amplification

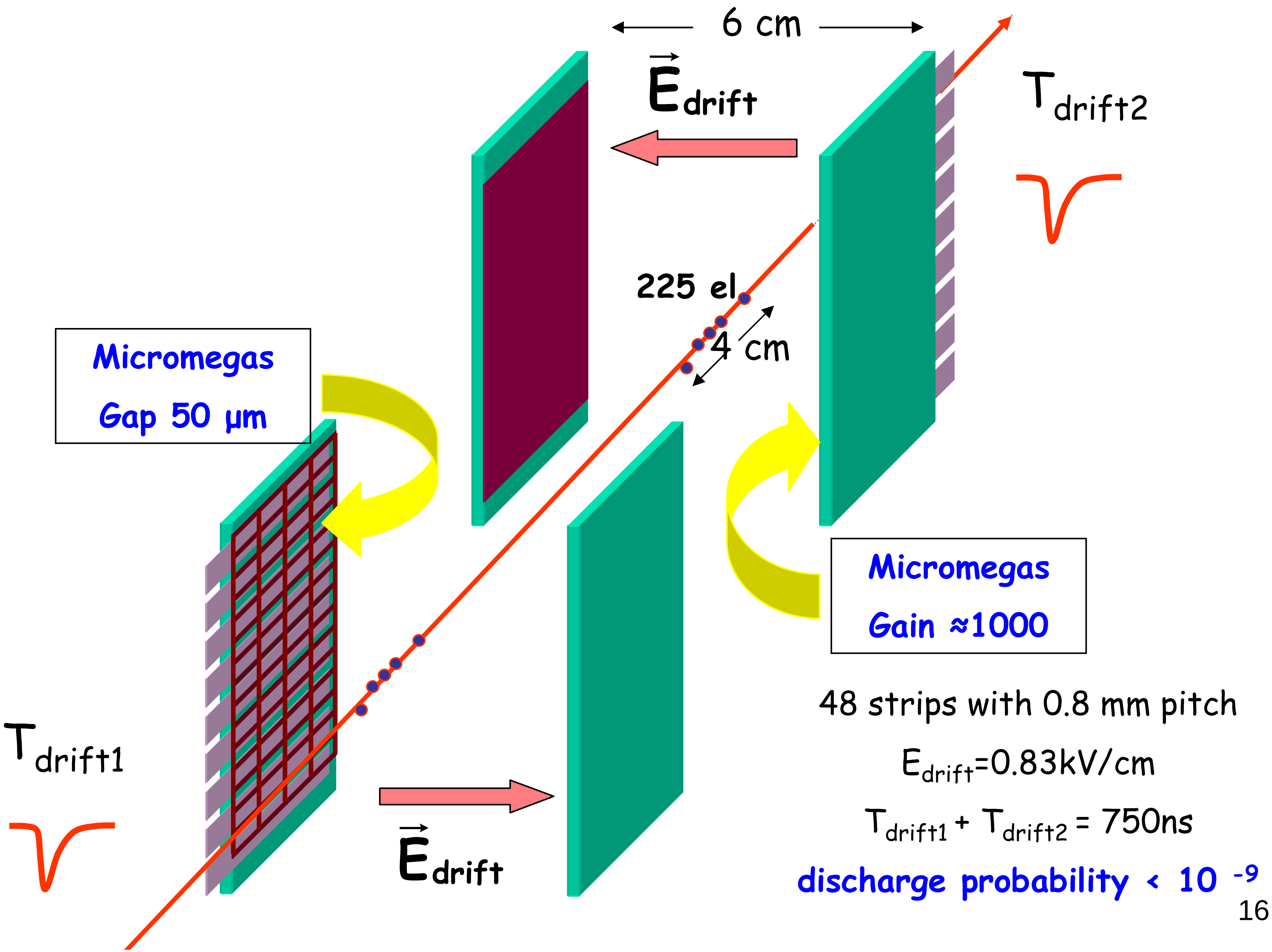
- $X/X_0 \sim 1.5\ 10^{-3}$
- excellent track time resolution < 1ns
- position resolution < 100 μm ; track momentum resolution $\Delta p/p$ 0.6%
- no spark (charge spread in space 4cm)

Simultaneous K⁺ and K⁻ beam lines



Select 60 GeV/c (Δp/p=3.5%)

KABES principle: TPC + Micromegas



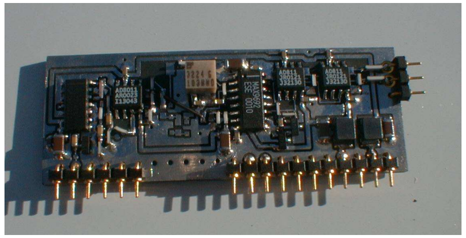
48 strips with 0.8 mm pitch

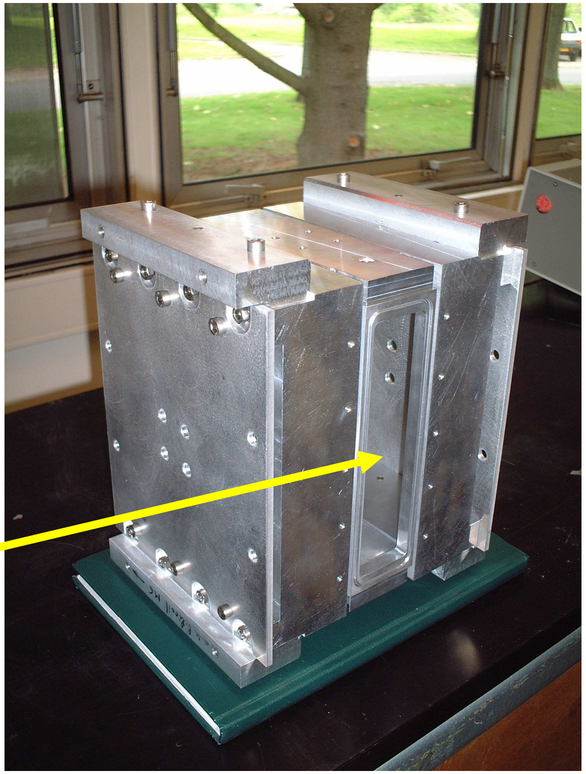
E_{drift}=0.83kV/cm

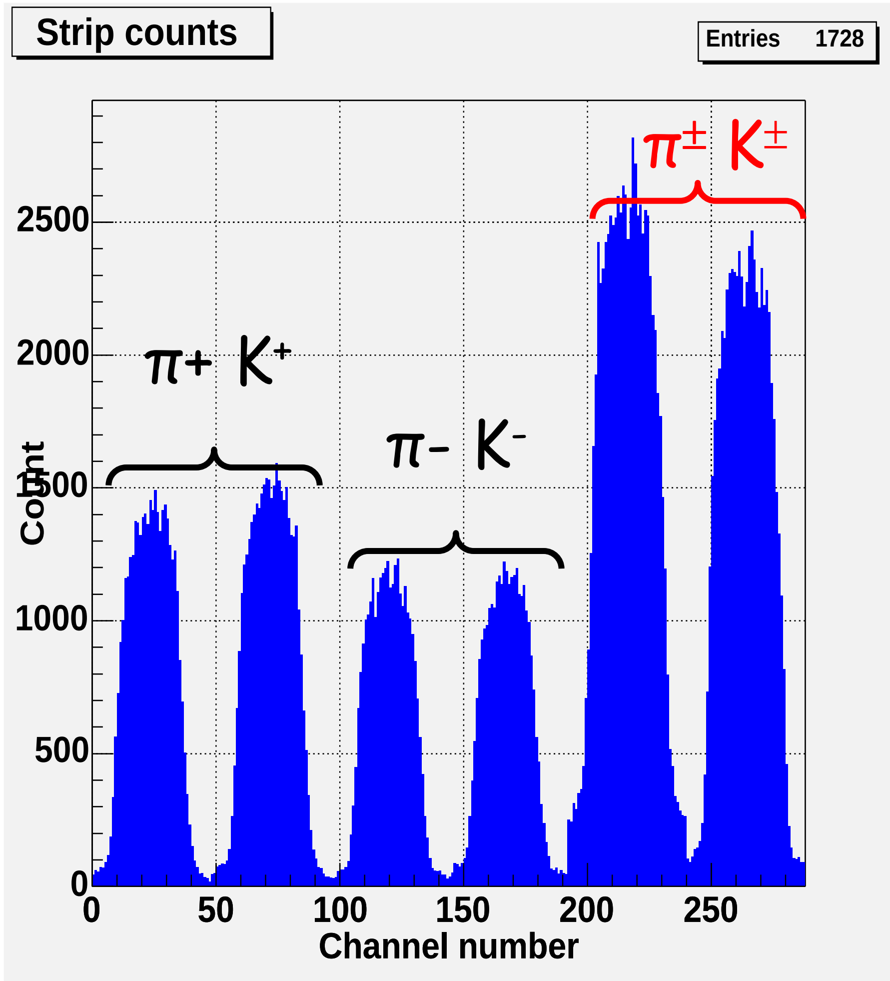
$T_{drift1} + T_{drift2}$ = 750ns

discharge probability < 10^{-9}

KABES in K12 ($K^+ + K^-$) beam line



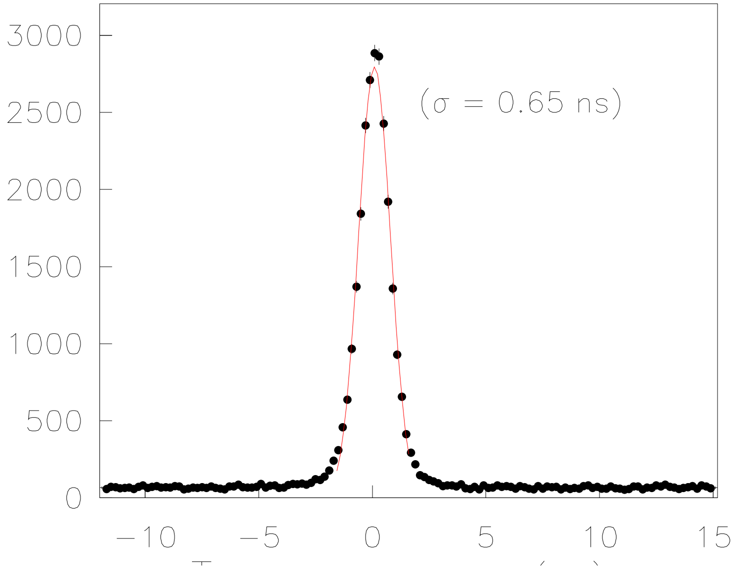



Strip counts
Entries 1728
π± K±
π+ K+
π- K-
Count
0
500
1000
1500
2000
2500
0
50
100
150
200
250
Channel number

KABES - time and Space resolutions

Time resolution: 0.6 ns

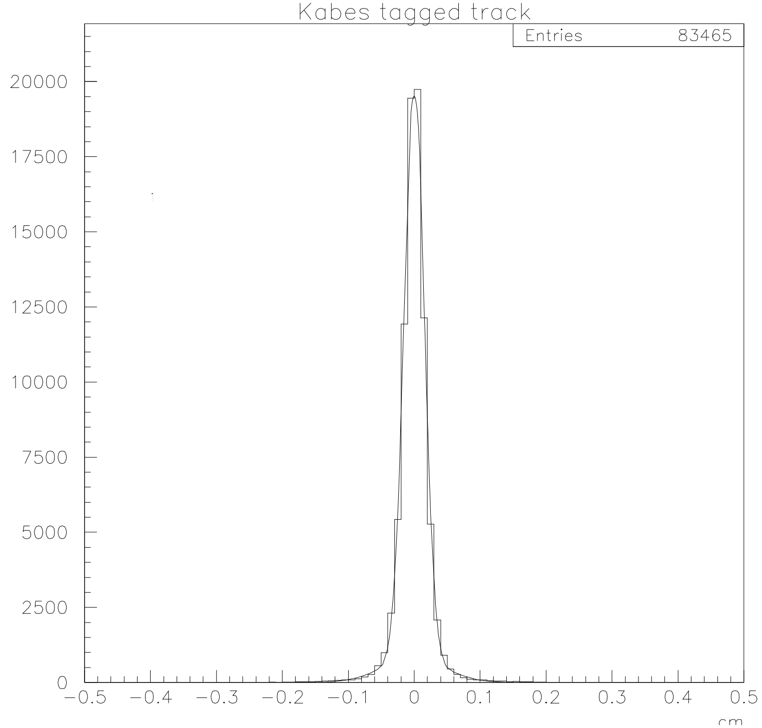
Using TOT to correct time slewing



$(T_0)_{KABES} - (T_0)_{Hodo\ Spectrometer}$ (ns)

Space resolution from drift time measurement: 70 µm

$K^{\pm}$ track, tagged by spectro



$X_{Station\ 1\ or\ 2} - X_{Station\ 3}$ (cm)

Tagging with reconstructed $K^{\pm} \rightarrow \pi^{\pm}\, \pi^{+}\, \pi^{-}$

Kabes momentum resolution: 0.6%

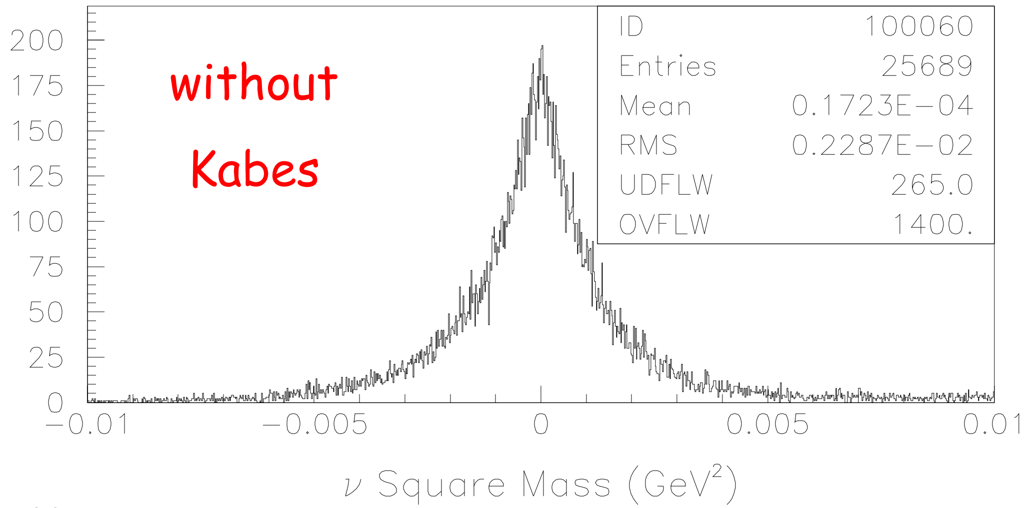
(DCH Spectrometer: 0.8%)

High ionisation

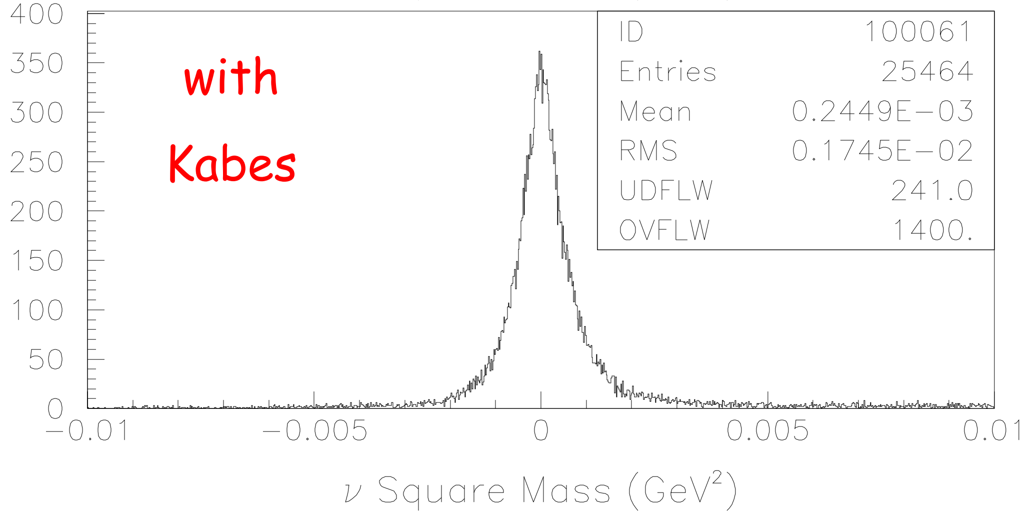
Kinematics $K^{\pm} \to e^{\pm} \pi^{+} \pi^{-} \nu$

$\Delta p/p$

3.5%



0.6%



KABES - accumulated charge

KABES accumulated beam time (150 days) ~ 1.5×10^7 s

Rate per strip (hottest): 7.10^6 /s/cm^2 $2\ 10^6 / (20 \times 0.1 \times 0.1 \times 1.5)$ cm^2

Integrated flux since beginning:

$7 \times 10^6 \times 3/15 \times 1.5\ 10^7$ ~ $2\ 10^{13}$ p/cm^2 in hottest region

or $1.6\ 10^{-19} \times 150$ e- $\times 1000 \times 2.10^{13}$ C/cm^2

→ 4 mC/mm^2

stable performances

KABES - Perspectives

Towards higher flux…

Tested in 2004:

- amplification gap reduced from 50 to 25 μm

→ reduced ToT , less occupancy

- 1 week at 20x higher intensity: 400 MHz

Future:

New electronics (famas)+ 25μm gap

→ reduce occupancy from 30 to 10 ns

Conclusions Micromegas for COMPASS and KABES

Two high precision, high rate and low mass detectors

COMPASS:

- 12 planes 40x40 cm^2 in 30 MHz total flux , 12000 channels
- operated reliably from 2002 to 2004, no aging
- resolutions : 70/90 μm , 9 ns
- future: hadron beams

KABES:

- 3 stations of 2 mini TPCs - 48 strips per plane
- 50 μm gap (smaller possible, to reduce occupancy)
- K beam tracking; resolutions : 70 μm, 0.6 ns, $\Delta p/p$ = 0.6 %
- accumulated flux since beginning ~ 4 mC/mm^2 in hottest region
- future: higher flux