DIRAC experiment

Evidence for □□ atoms with DIRAC

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DIRAC collaboration

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University of Messina
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KEK *Tsukuba, Japan*

Kyoto Sangyou University
Kyoto, Japan

Tokyo Metropolitan University
Tokyo, Japan

IFIN-HH
Bucharest, Romania

JINR
Dubna, Russia

SINP of Moscow State University
Moscow, Russia

IHEP
Protvino, Russia

Santiago de Compostela University
Santiago de Compostela,Spain

Bern University
Bern, Switzerland

Zurich University
Zurich, Switzerland

□K atom & □K scattering

What do we learn from measuring □K atom's lifetime?

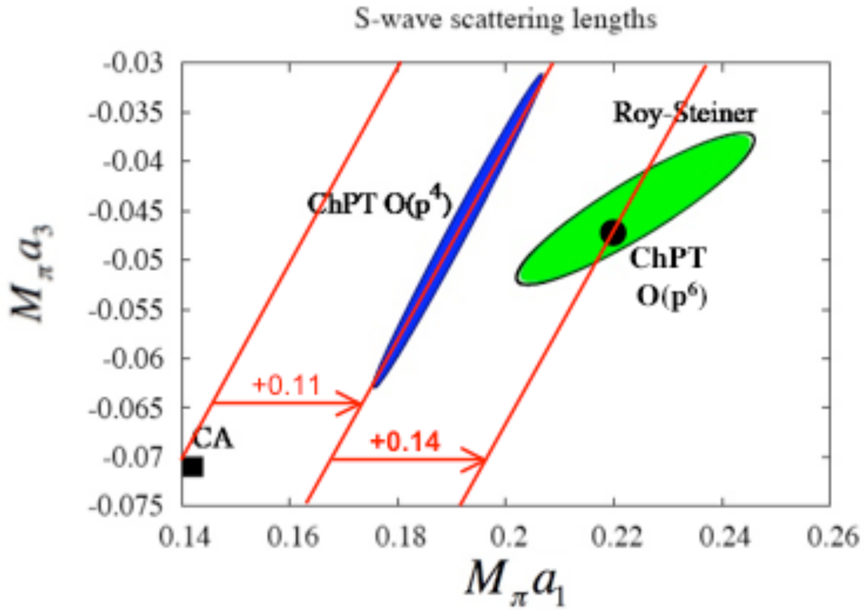
A measurement of the □K atom lifetime will shed new light on relevant S-wave □K scattering lengths.

A test of chiral perturbation predictions involving - besides the u and d quark - also the s quark (3-flavour case) is of substantial interest: it provides a way to investigate a potential flavour dependence of the quark condensate responsible for chiral symmetry breaking.

Scattering lengths calculations

Results on $M_\pi a_1,\ M_\pi a_3\ \&\ M_\pi(a_1 - a_3)$:

Authors:
Weinberg; Kubis, Meissner; Bijnens, Dhonte, Talavera; Buettiker, Descotes-Genon, Moussallam



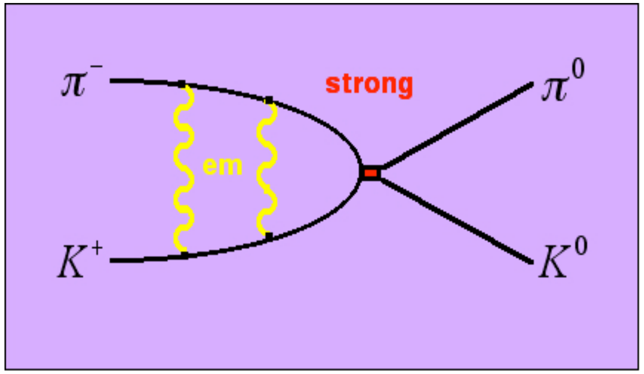
	$M_\pi(a_1 - a_3) \equiv A_{13}$	Ref.
CA	0.214	PRL 17 (66) 616
$O(p^4)$	0.238 ± 0.002	PL B529 (02) 69
$O(p^6)$	0.267	JHEP 0405 (04) 036
RS	0.269 ± 0.015	EP J C33 (04) 409
Exp	0.475 ± 0.013	NP B133 (78) 490

$$A_{13}\left(= 3a_0^{-}\right) = A_{CA}\left(1 + \delta_{1-loop} + \delta_{2-loop} + \ldots\right)$$

1 + 0.11 + 0.14 ...

CA -> Current Algebra
RS -> Roy-Steiner dispersion relations
Exp -> Kp scattering (OPE)

πK-atom lifetime



$a_1 = a_{1/2}$
$a_3 = a_{3/2}$
S-wave scattering lengths for isospin (πK)=1/2, 3/2

$$\Gamma_{\pi^0 K^0} = \frac{8}{9}\alpha^3 p^* \mu^2 \left| a_1 - a_3 \right|^2 (1+\delta)$$

Isospin breaking:

$\delta = (4.0 \pm 2.2)\, 10^{-2}$

$p^* = 11.8$ MeV/c

μ = reduced mass = 109 MeV

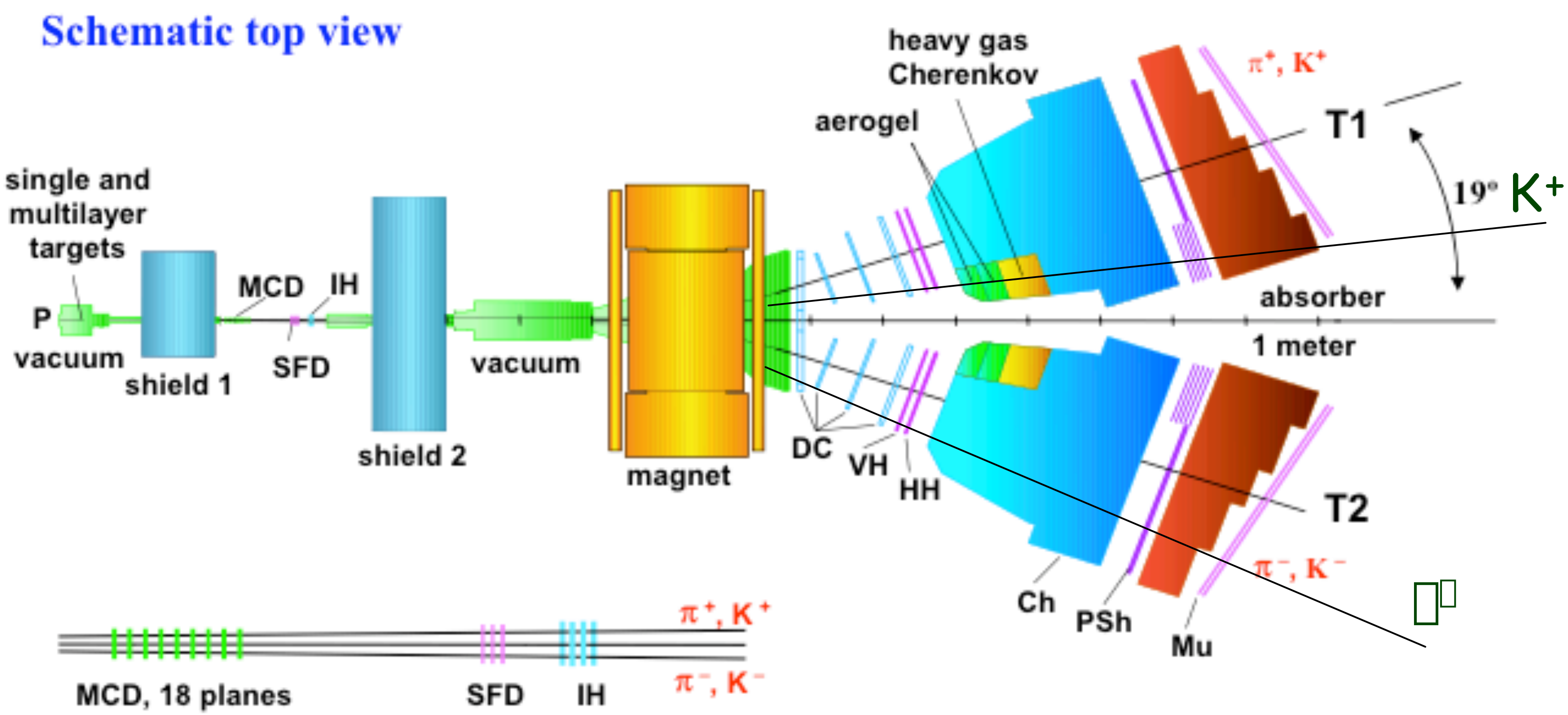
$\left(\tau^{-1} = \Gamma_{1S} \approx \Gamma_{\pi^0 K^0}\right)$ $a_1 - a_3 = \Delta$

$$\frac{\Delta\tau}{\tau} = 20\% \quad \Leftarrow \quad \frac{\Delta\Delta}{\Delta} = 10\%$$

From Roy-Steiner dispersion relations:

$a_1 - a_3 = 0.269 \pm 0.015$ | | $\tau = (3.7 \pm 0.4)\, 10^{-15}\,\mathrm{s}$

Upgraded DIRAC experimental setup



Type of Kπ events

a) Accidentals

K and π are produced by two different interactions proton->target

b) Non Coulomb

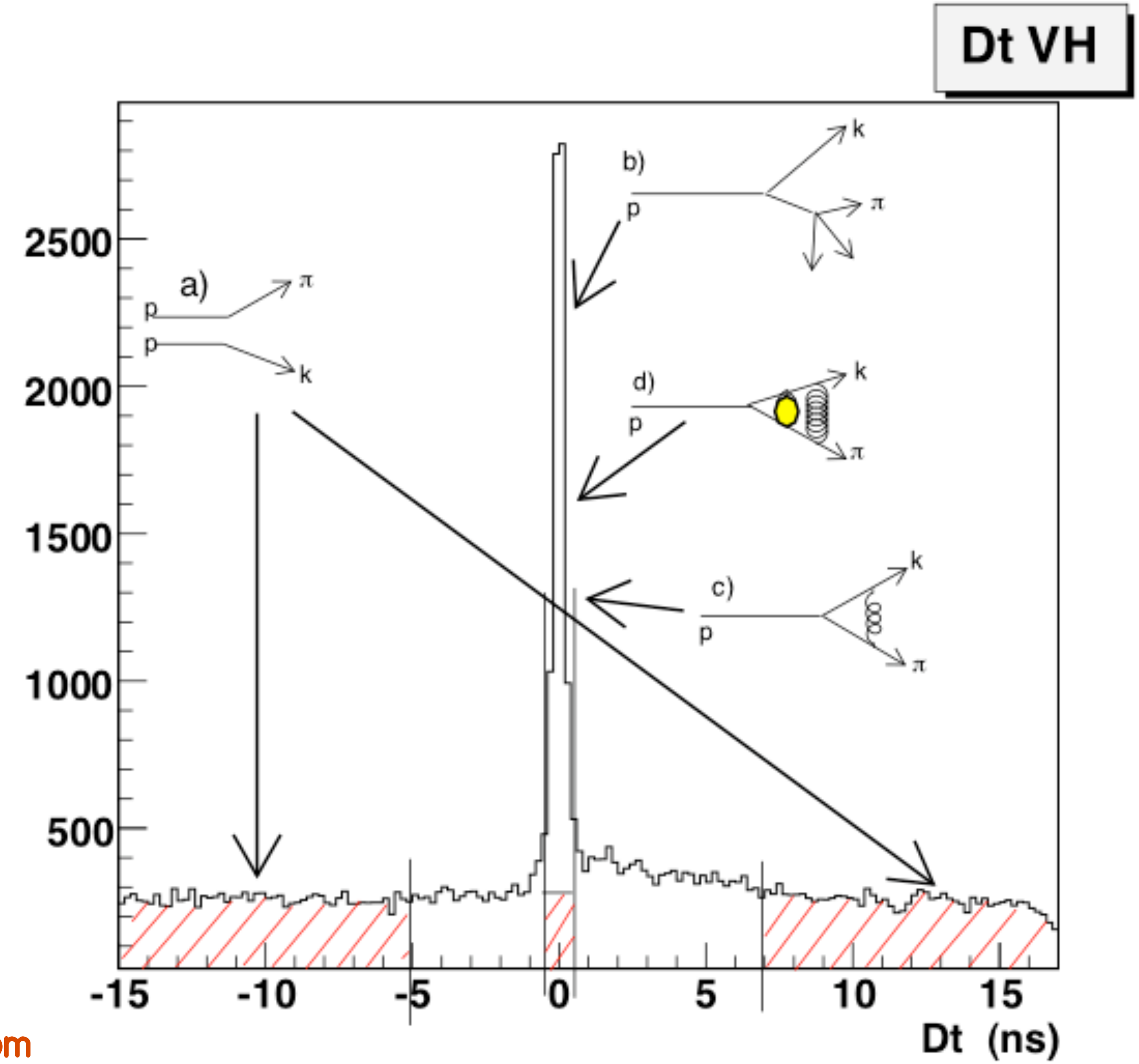
Proton interaction generates a k and a long-lived resonance, that then decays in a pion

c) Coulomb

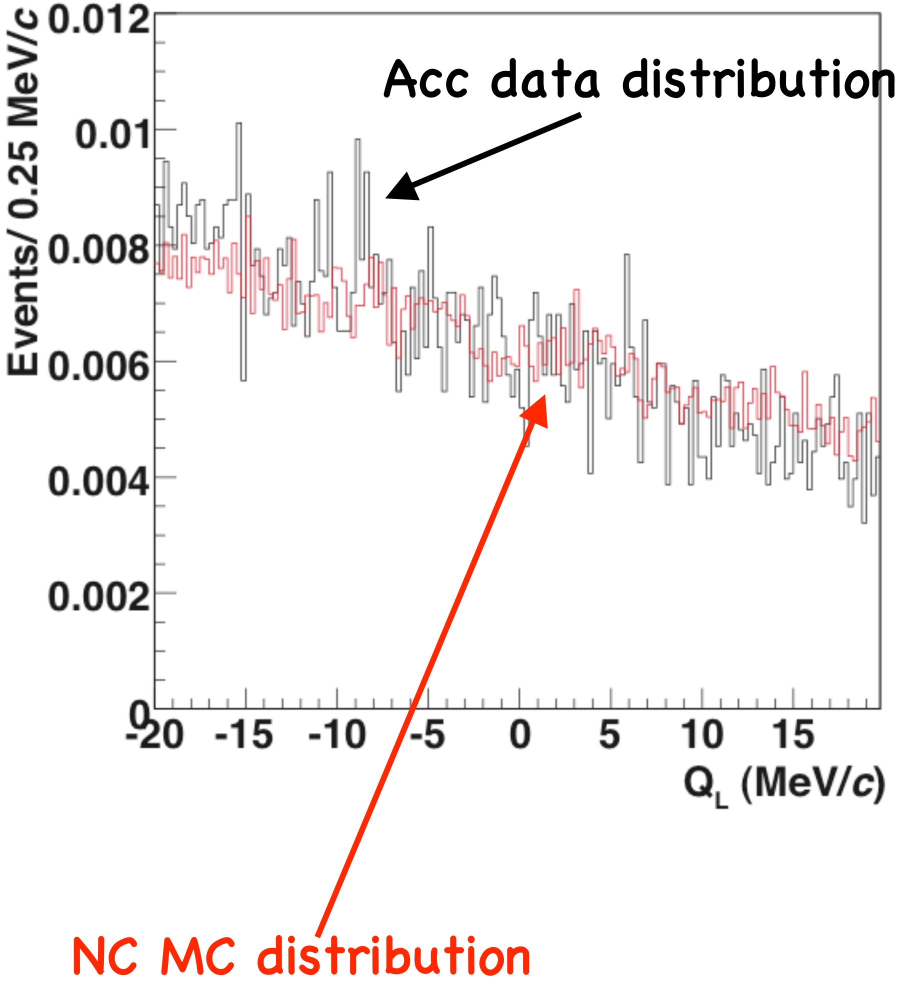
π and k are produced closer than the Bohr Radius then feel Coulomb Final Interaction

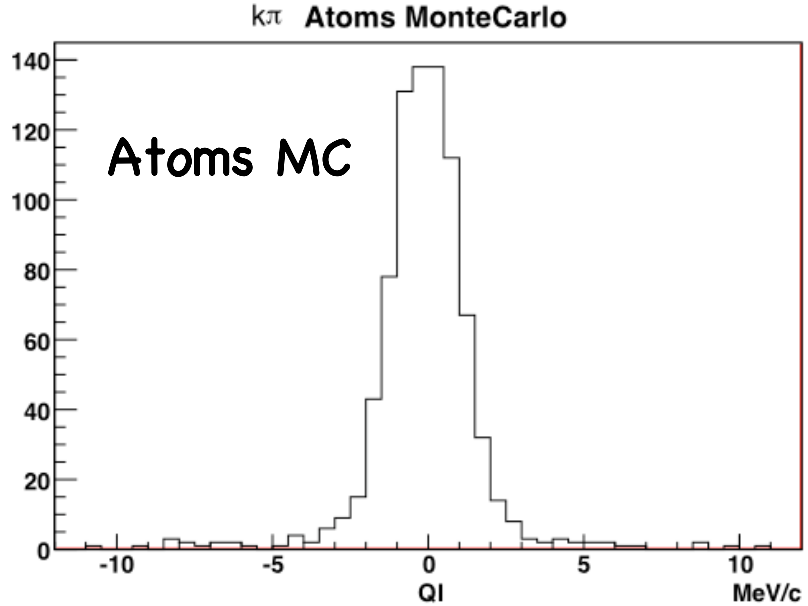
d) Atoms

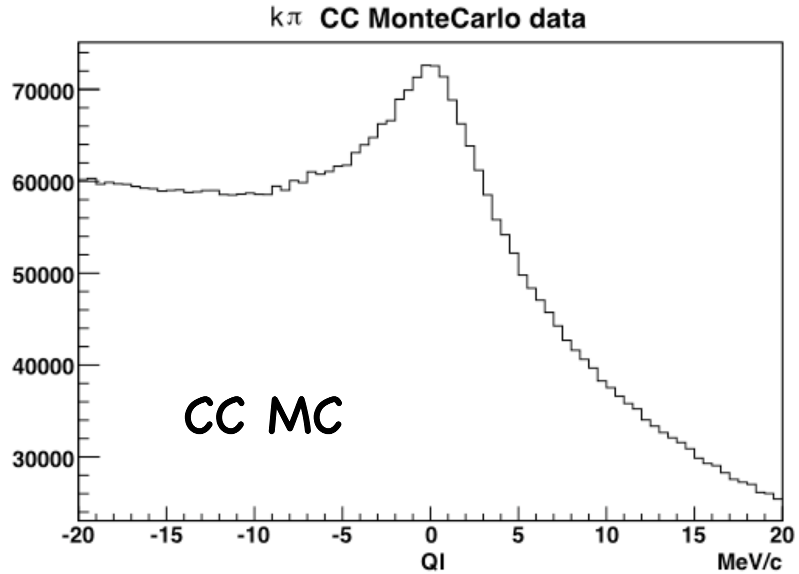
K and π are bound in an atom



Signal and background Ql distribution



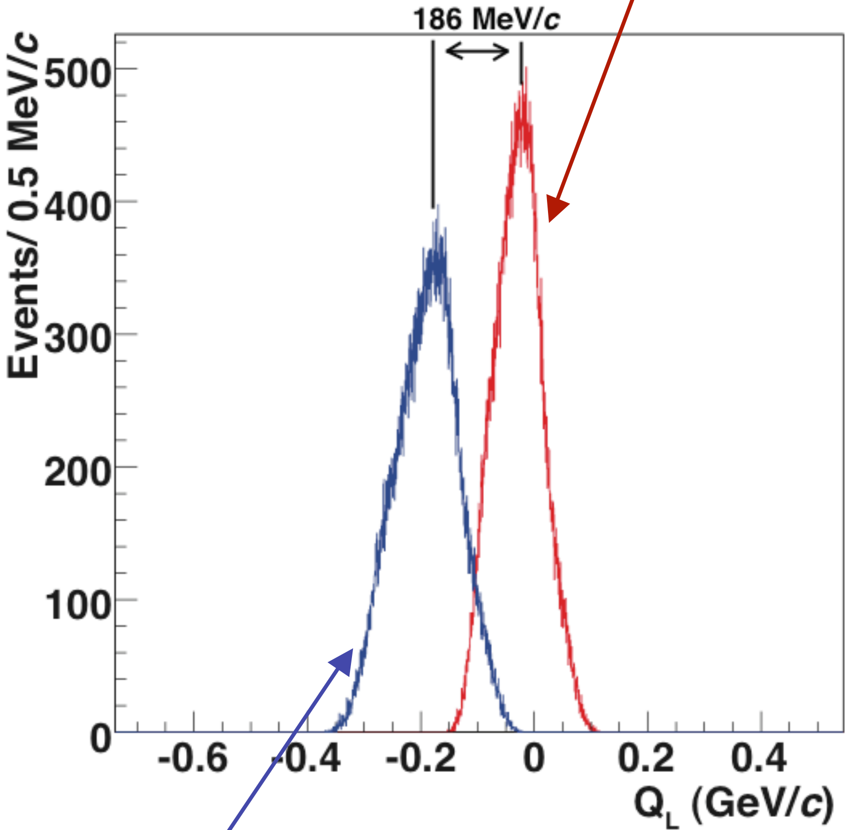




Events that fake K□ events

1) Proton-□ events

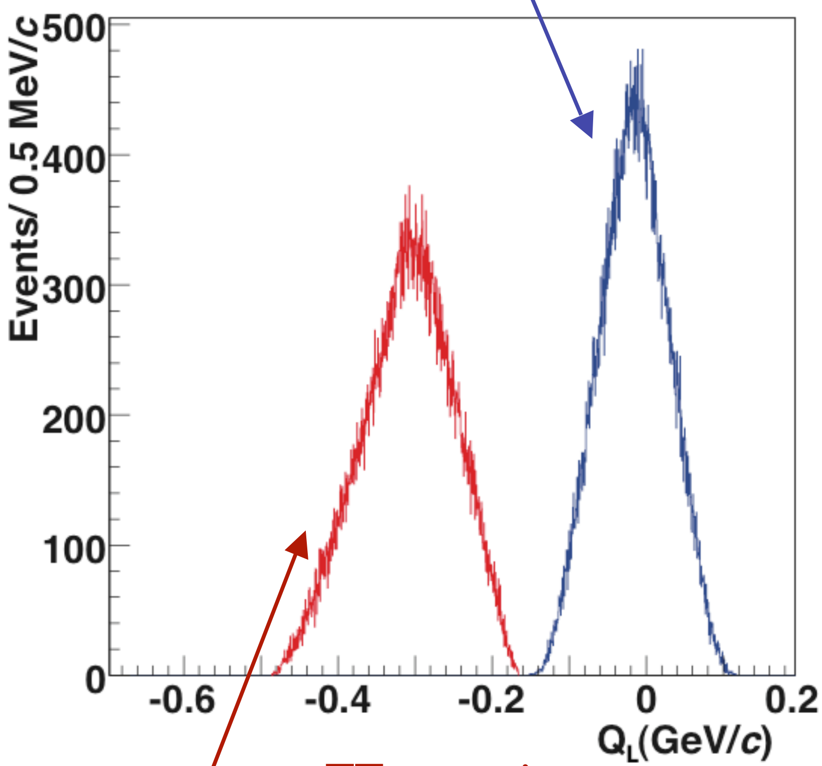
p□ events
reconstructed as p□



p□ events reconstructed as K□ events

2) □□ events

k□ events



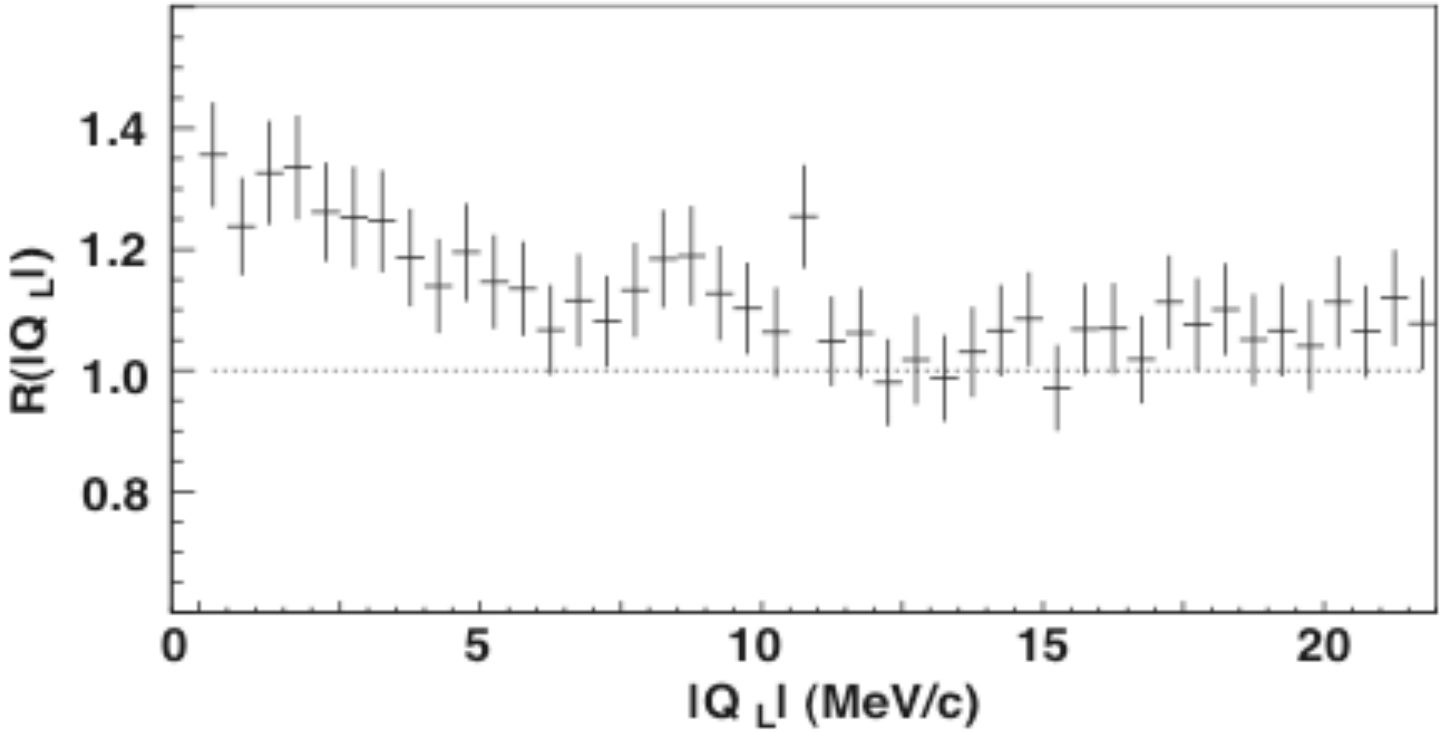
□□ events
reconstructed as K□ events

Coulomb Correlation OBSERVATION

No MonteCarlo

2007 Data

Qt < 8 MeV/c

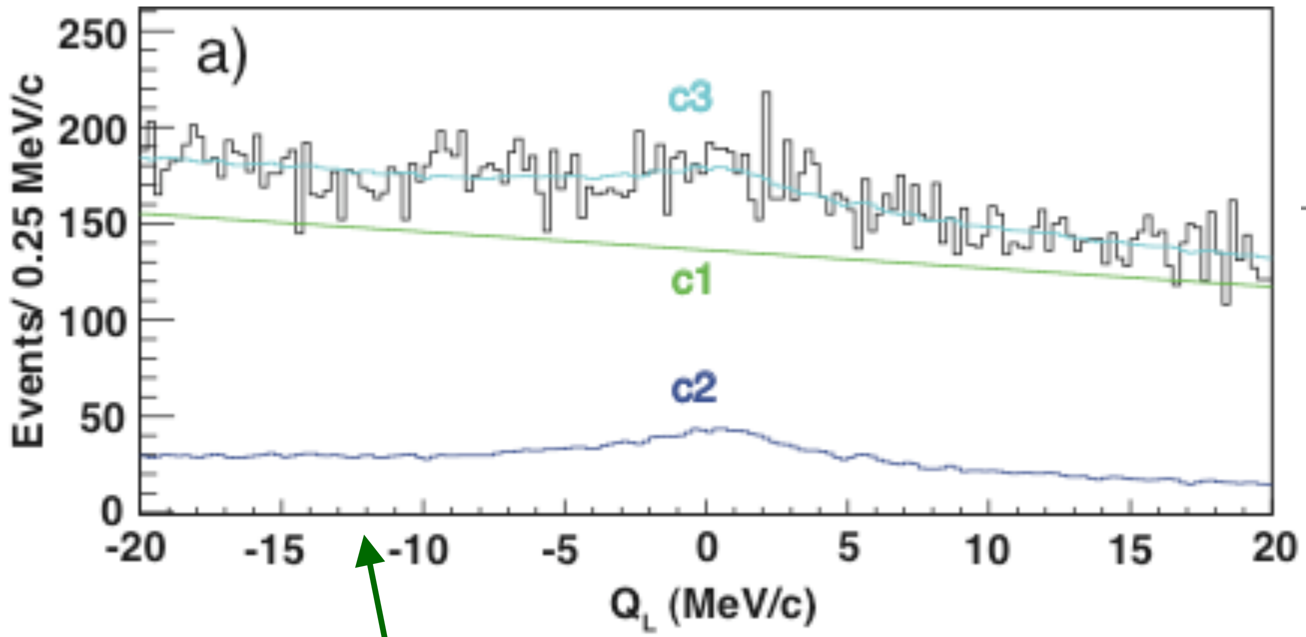


Prompt pairs / Accidentals = <u>Correlation function</u> R as a function of |Ql| for K+π- pairs.

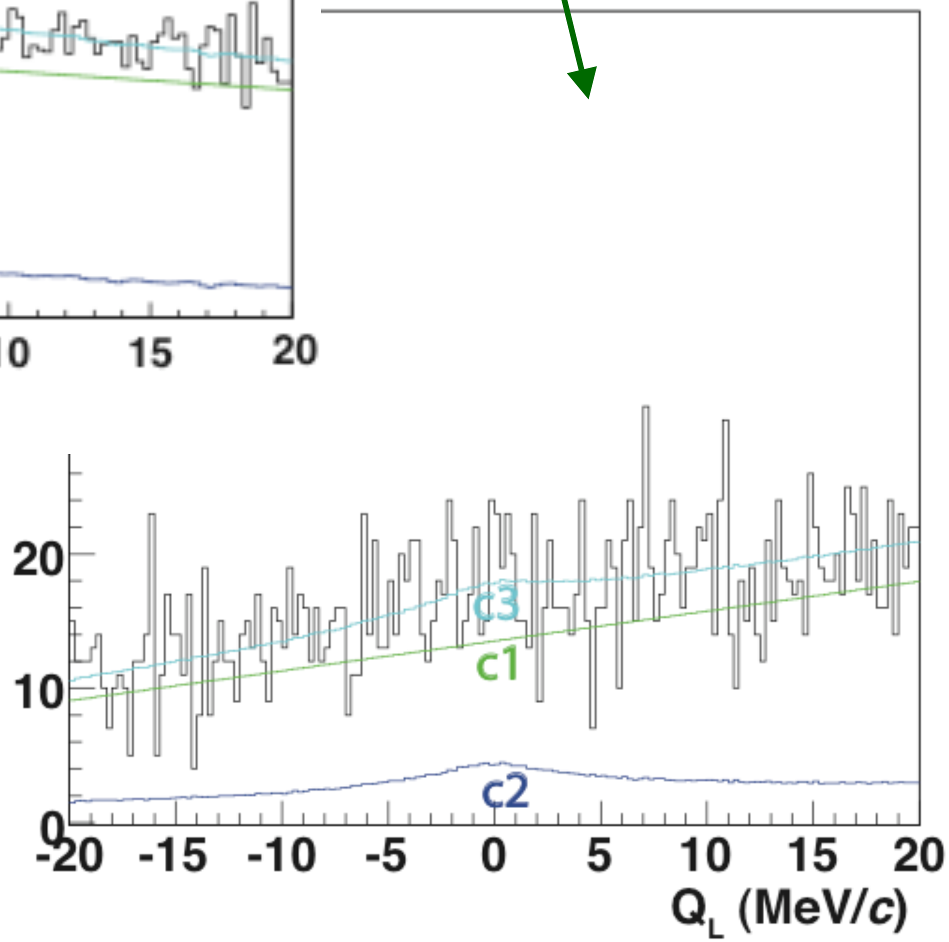
The deviation from the horizontal line proves the existance of Coulomb correlated Kπ pairs --> production of Atoms

Background fit and signal extraction

$K^{-}\pi^{+}$ analysis



$K^{+}\pi^{-}$ analysis

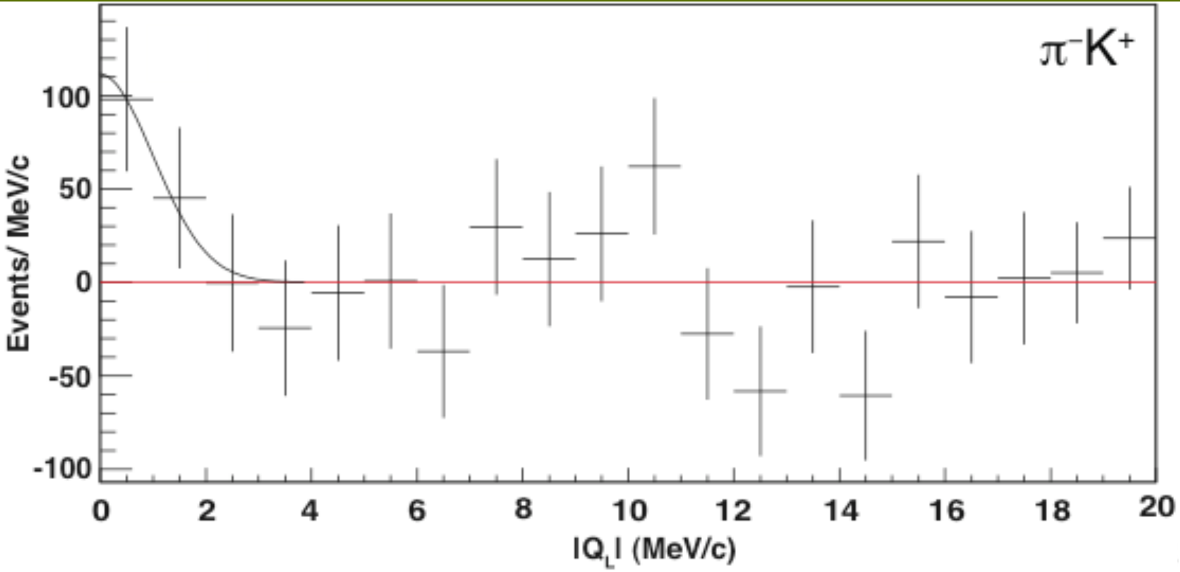


c1 = NonCoulomb and accidentals, fit with a straight line

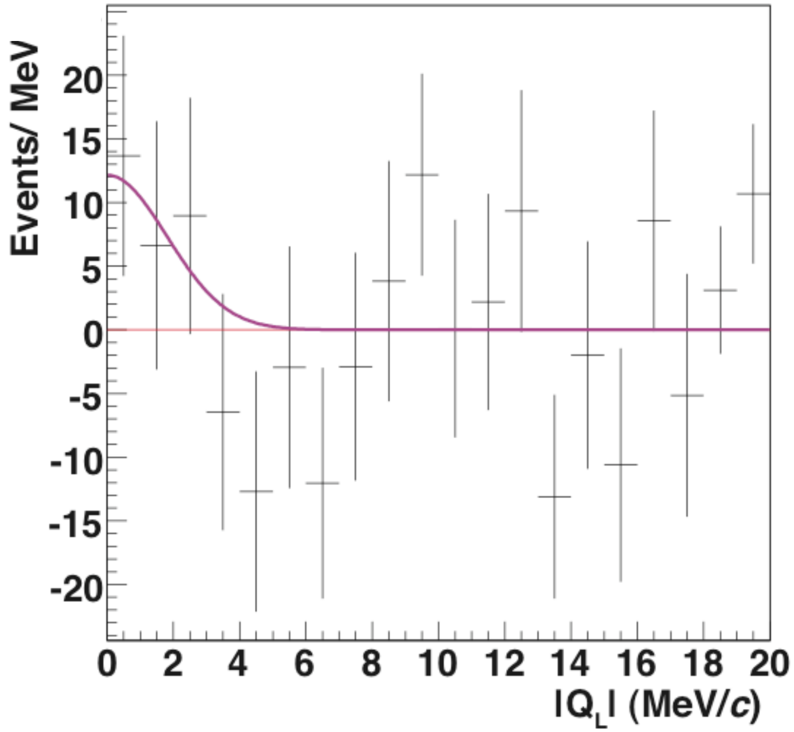
c2 = Coulomb Correlated

c3 = c1+c2

π^+K^- and π^-K^+ signal



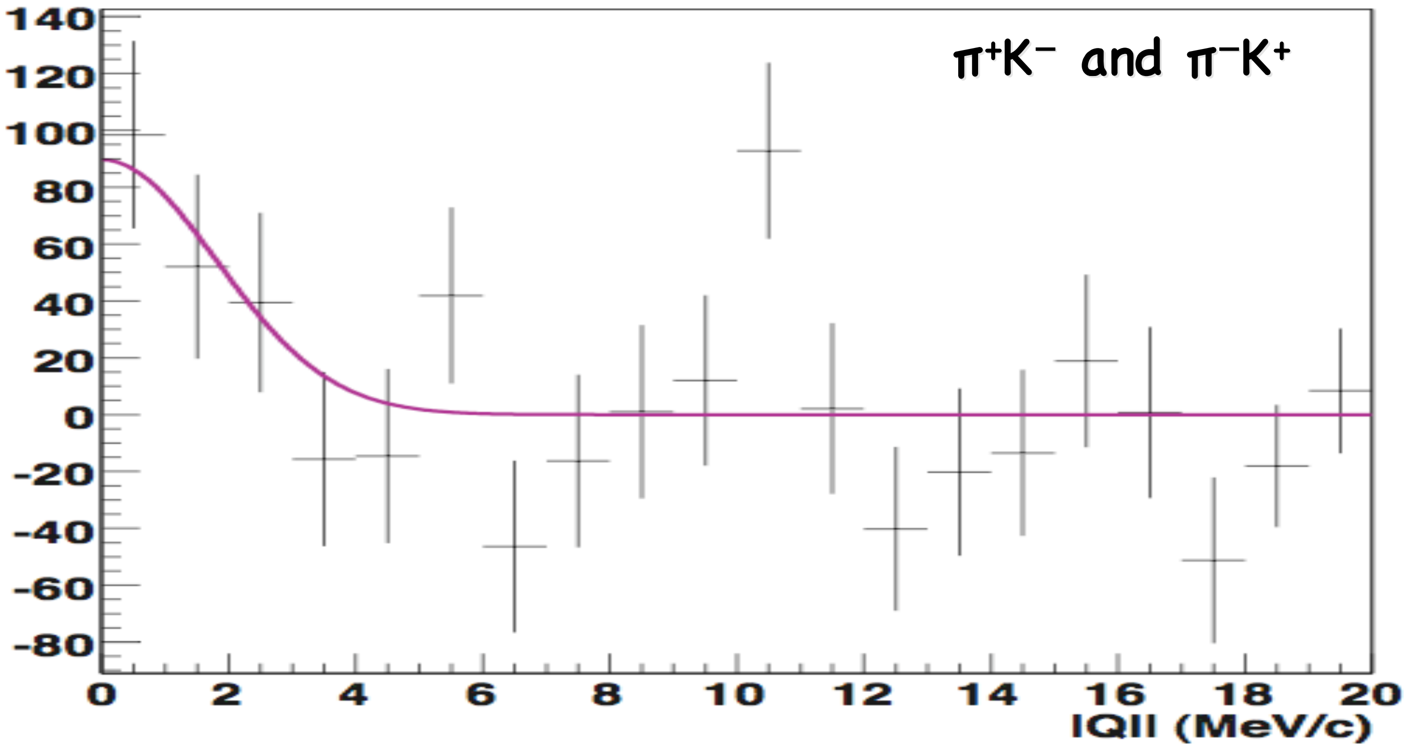
π^-K^+-atoms



π^+K^--atoms

atom	n_A	χ/ndf
π^-K^+	143±53	122/130
π^+K^-	29±15	164/130

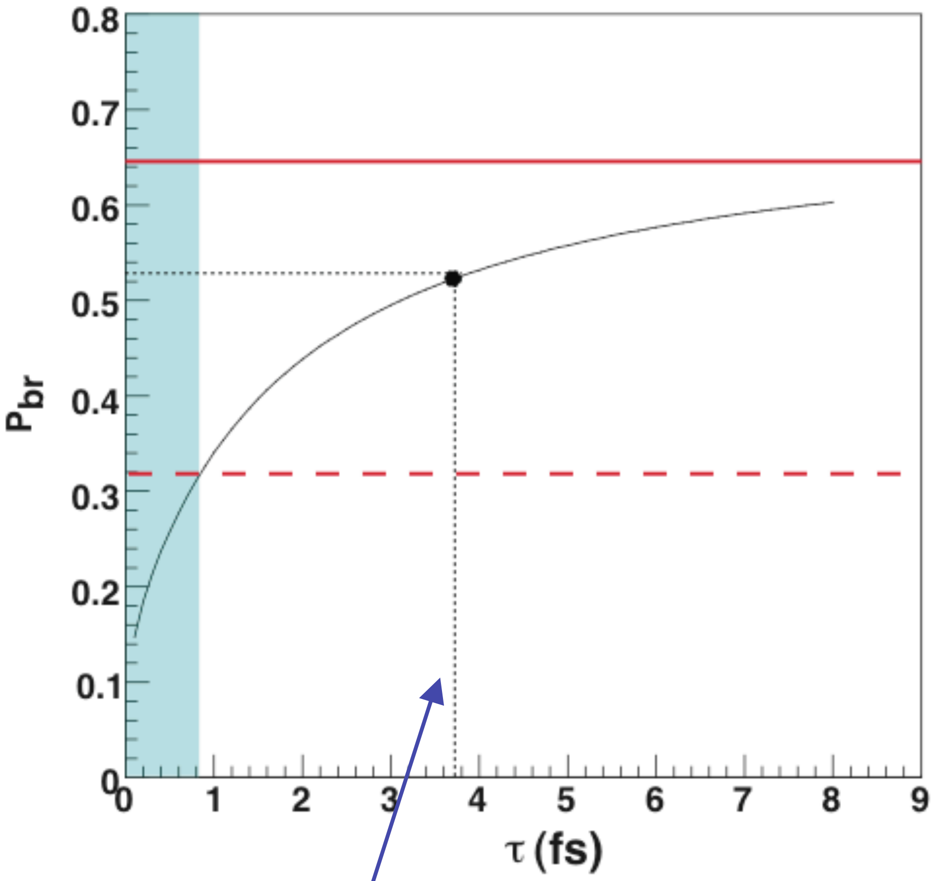
πK SIGNAL



In total **173±54 πK-atoms are observed** with a significance of 3.2 sigma.

The probability that the excess in the 3 first bins is due to statistical fluctuations is 1‰.

Breakup probability and lifetime



Br. Pr. = (64±25)%

90% CL

LOWER LIMIT τ= 0.8 fs

↓

UPPER LIMIT for

$|a_{1/2} - a_{3/2}| < 0.58\ m_{\pi}^{-1}$

predicted τ = (3.7±0.4) fs -> Br.Pr. = 53%

Conclusion

We have presented the first evidence for the production of $K\pi$ atoms

$K\pi$ atoms = 173 ± 54

A lower limit on the mean lifetime is established with CL 90%

τ > 0.8 fs

The ultimate goal of the DIRAC experiment is to measure the lifetime of $K\pi$ atoms with a precision of 20%