The DIRAC experiment at CERN

Christian Schütz
University of Basel, Switzerland
for the DIRAC Collaboration.

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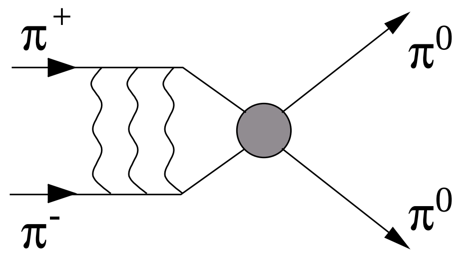
Motivation

- Low energy QCD still not very well understood.
- Pionium ($A_{2\pi}$) atom is an ideal candidate

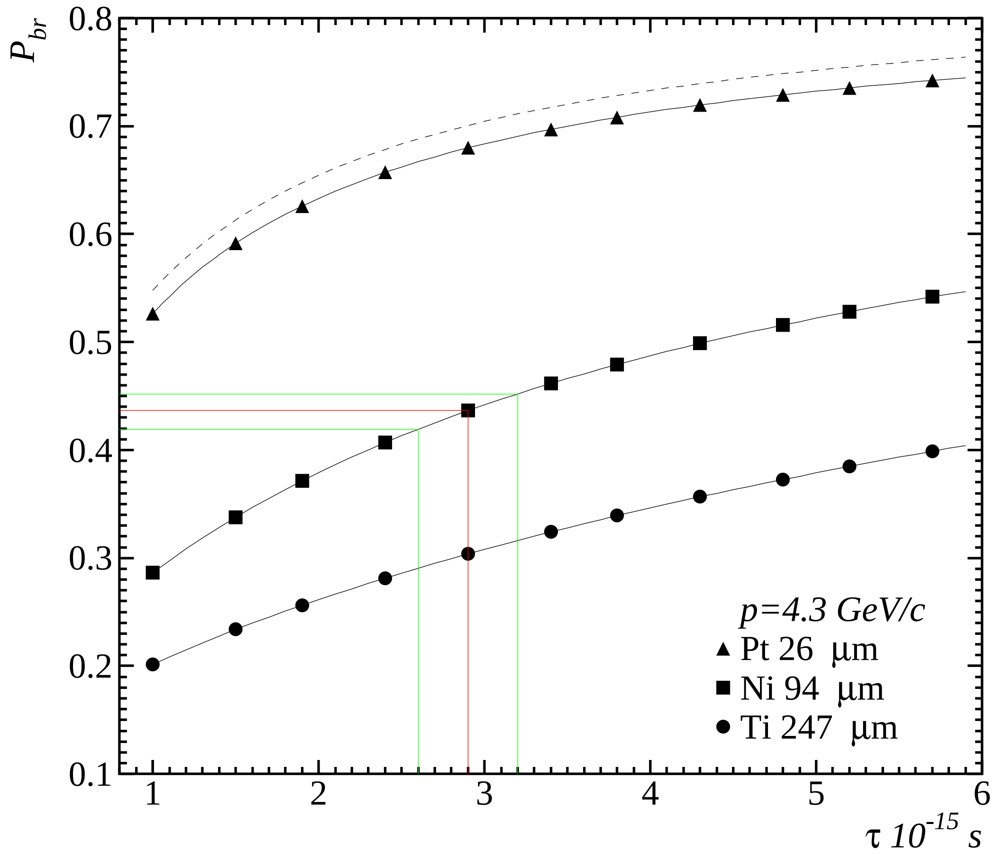


- $1/\tau = \Gamma^{2\pi^0} + \Gamma^{2\gamma}$ (0.36%) $\rightarrow \Gamma^{2\pi^0} \propto |a_0 - a_2|^2 |\psi_s|^2$
- a_I are the S-wave $\pi\pi$ scattering lengths with I=0,2.
- *Colangelo et al* (2001) ChPt:
  $\Delta = |a_0 - a_2| = 0.265 \pm 0.004 \rightarrow \tau = 2.9 \pm 0.1 fs$

Goal: $\delta\tau/\tau = 10\% \quad \Longrightarrow \quad \delta\Delta/\Delta = 5\%$

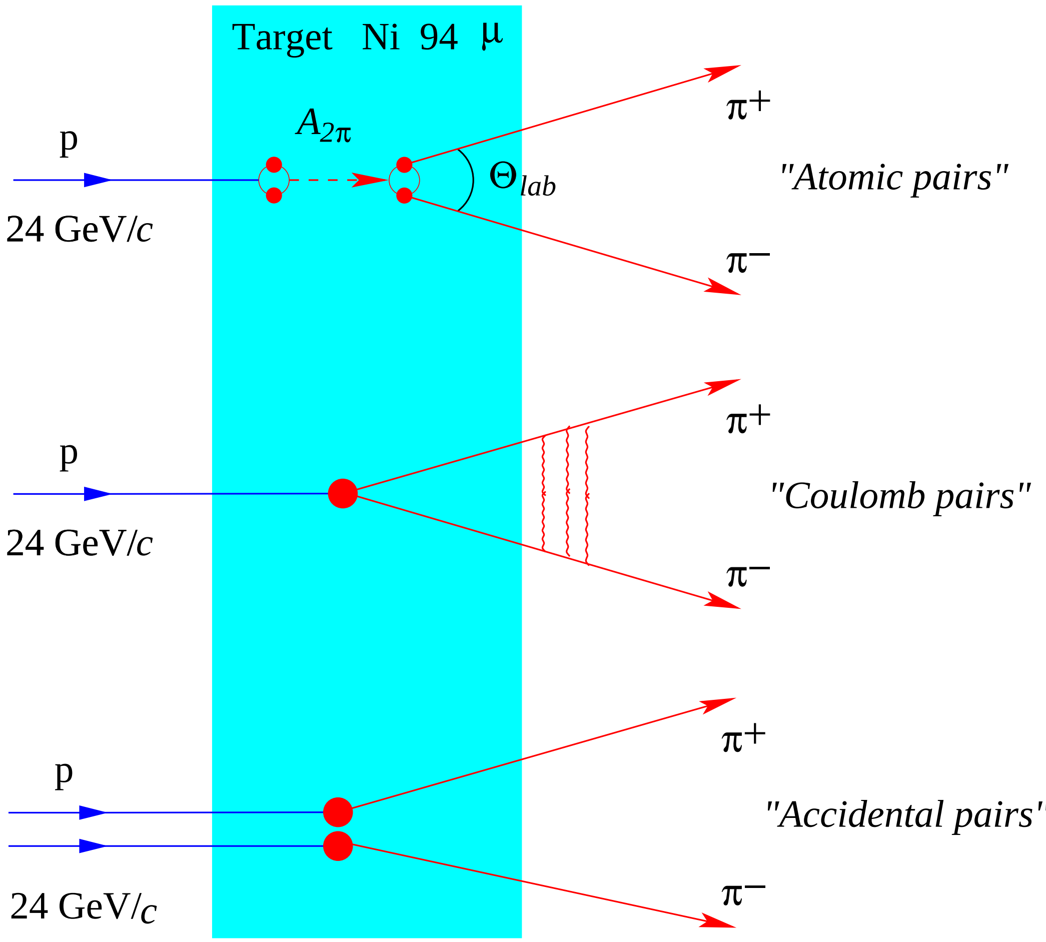
$A_{2\pi}$ life time measurement

- The Break-up probability of Pionium in the target $P_{br} = \frac{n_A}{N_A}$



$\delta\tau = 10\%$ corresponds to $\delta P_{\mathrm{br}} \approx 4\%$

$A_{2\pi}$ Production



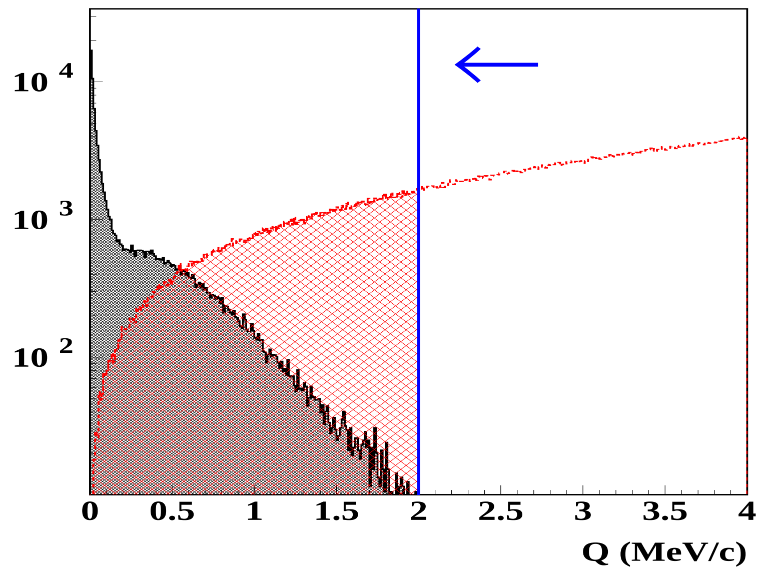
Atomic pairs:

$$Q < 3\ \mathrm{MeV}/c \ : \quad \vec{p}_+ \approx \vec{p}_- \quad \Theta_{lab} < 2.5\ \mathrm{mrad}$$

$$\sigma^{Coul} = Ac(Q) \cdot \sigma^{Acc},\ Ac(Q) : \text{Sakharov factor}$$

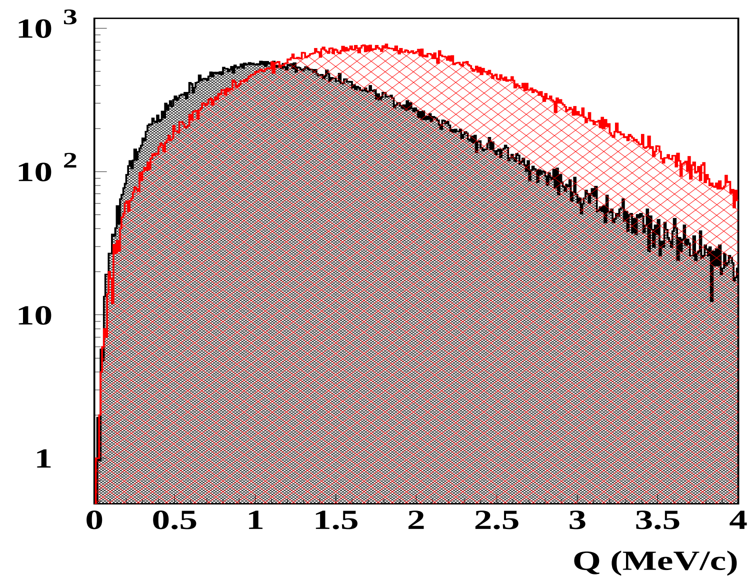
Normalisation

At Production



$$\frac{N_A}{N_{Coul}}(Q < 2) = 0.615$$

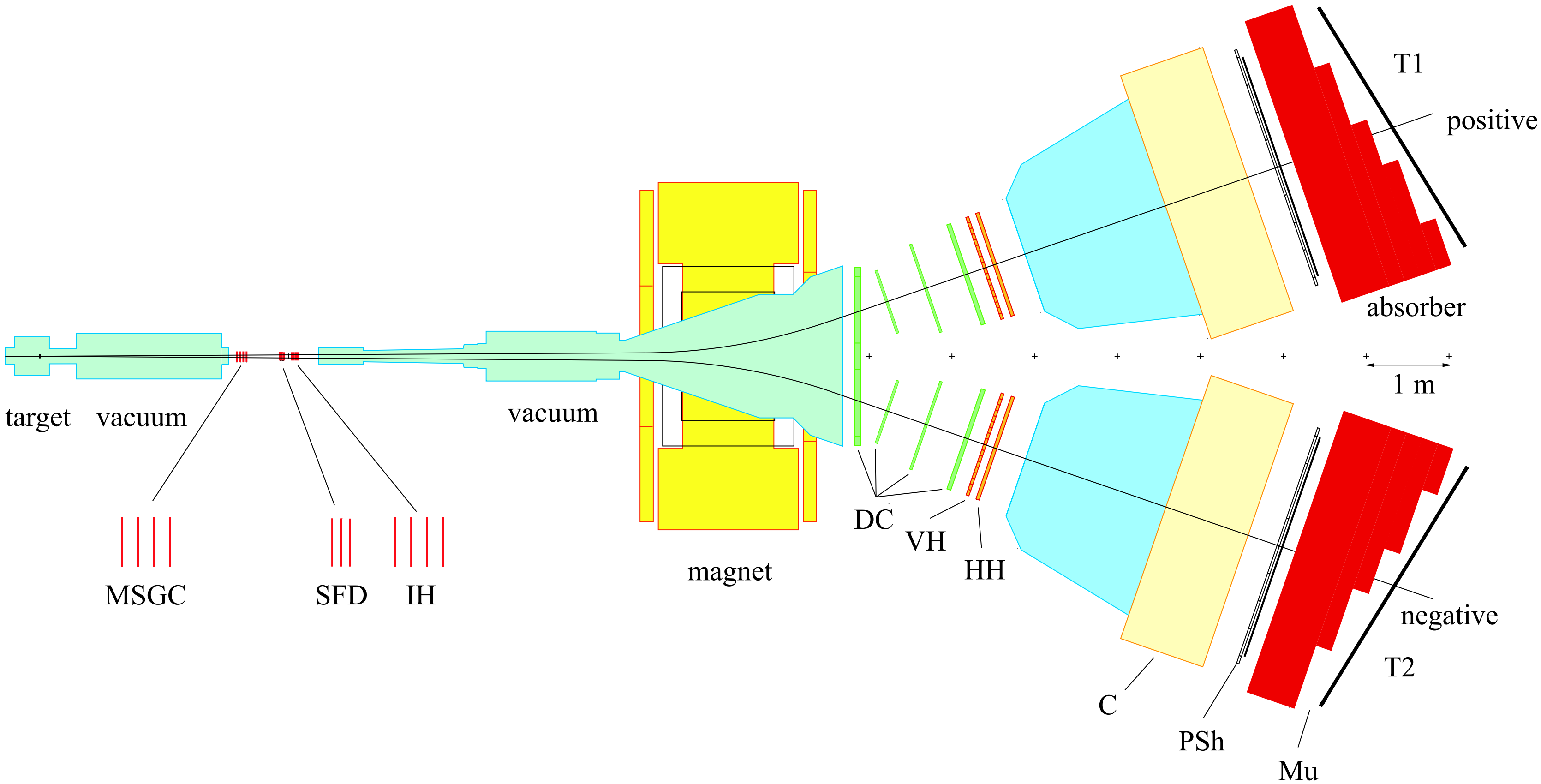
After target



$$\frac{N_A}{N_{Coul}}(Q_R < 2) = ??$$

- ...We need a high resolution spectrometer with $\sigma_Q < 0.5$ MeV/c
- ...We need to know the MS very precise for the normalisation

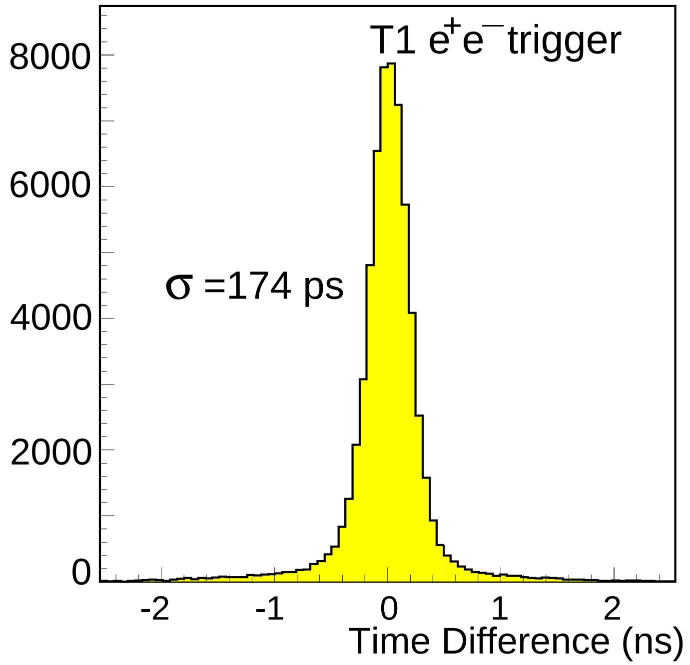
The Detector



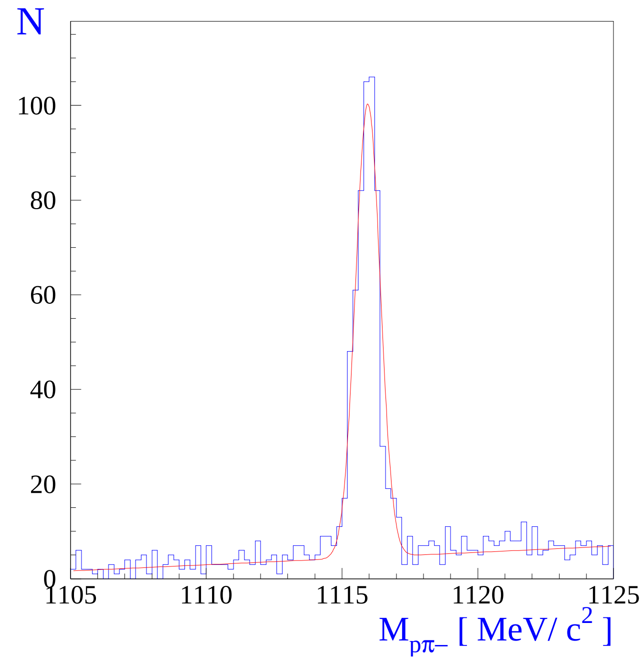
Momentum range: $1.2 \leq p_\pi \leq 7$ GeV/c

Resolution: $\sigma_{Qx} = \sigma_{Qy}$ =0.4 MeV/c, σ_{Ql} = 0.6 MeV/c

Calibration Measurements

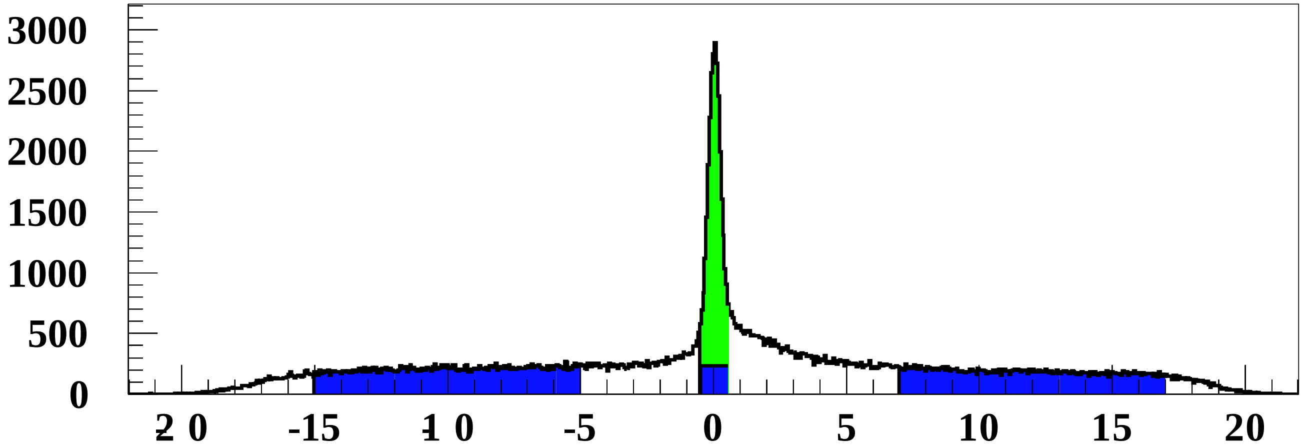


VH time difference spectrum for electron-positron T1 trigger



Mass distribution for $p\pi^-$ pairs from Λ decay at $4.7 < p_\Lambda < 6.5$ GeV/c; $\sigma_\Lambda = 0.43$ MeV/c^2.

Method of $A_{2\pi}$ Observation

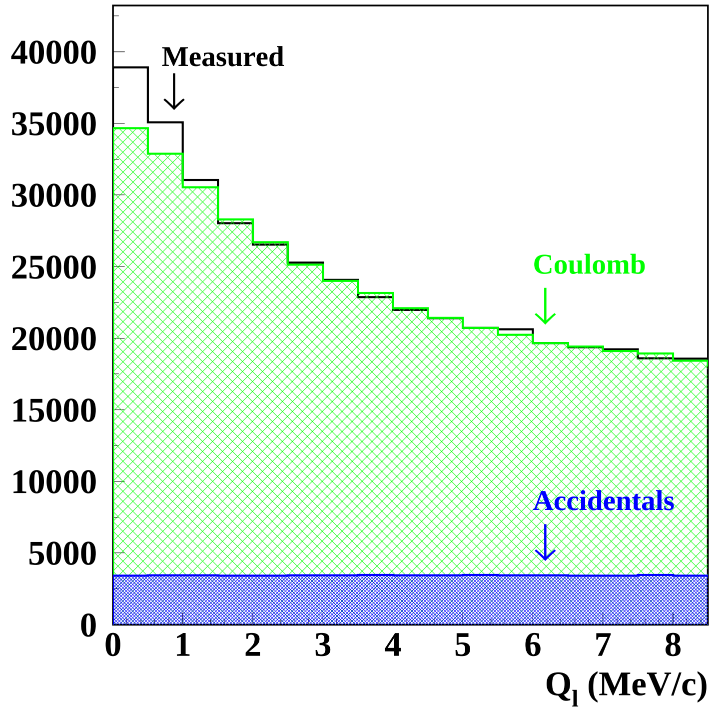


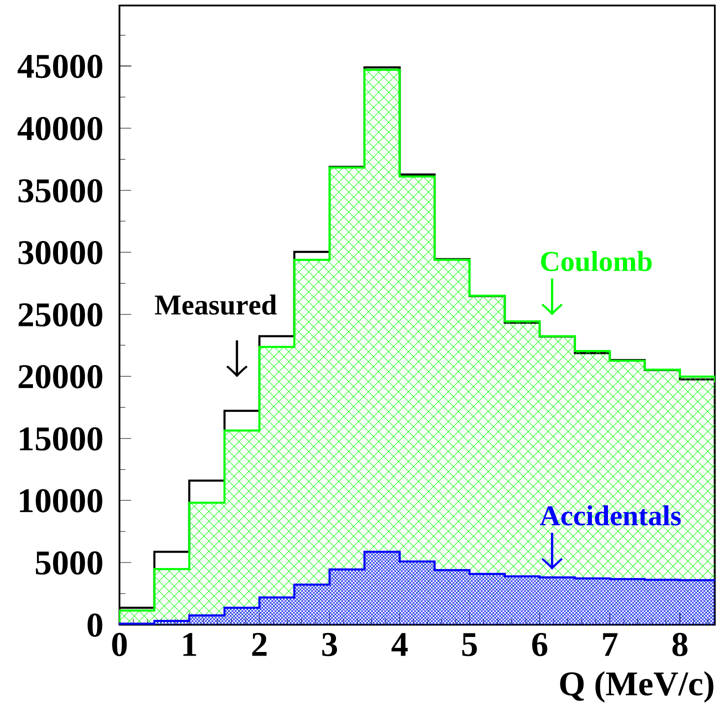
Atomic pairs Coulomb pairs Accidentals

$$\frac{dN_{\mathrm{corr}}}{dQ} = \frac{dN_{\mathrm{A}_{2\pi}}}{dQ} + \frac{dN_{\mathrm{Coul}}}{dQ} + \frac{dN_{\mathrm{Acc}}}{dQ}$$

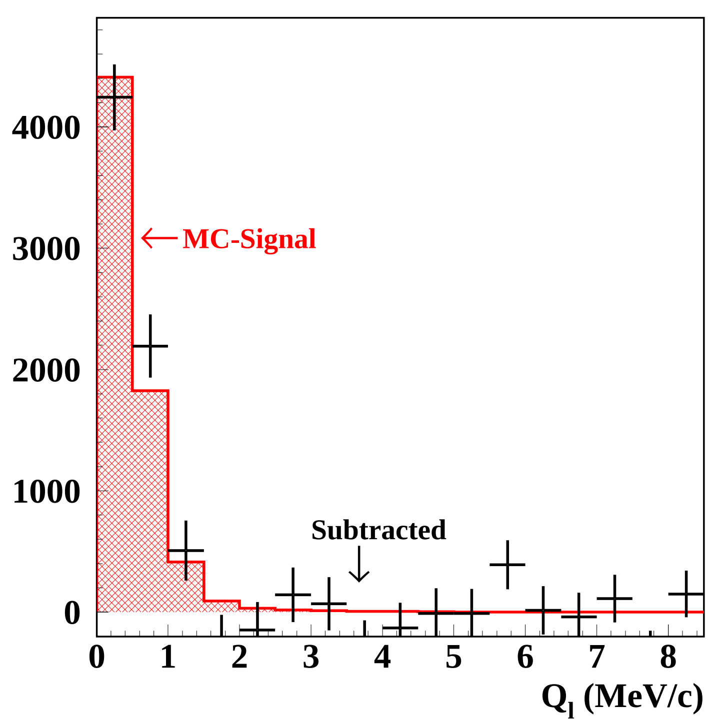
Background determination

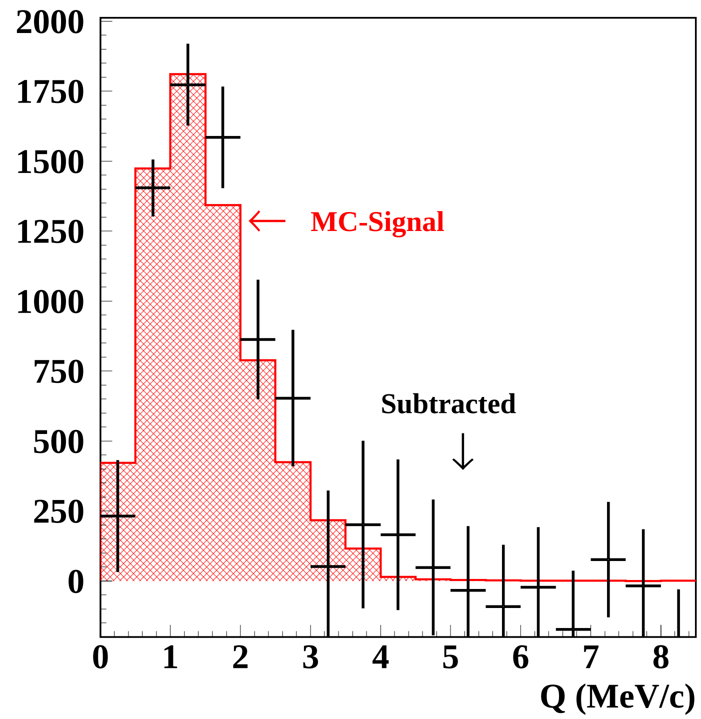
$$\frac{dN_{\rm Acc}}{dQ} \propto Q^2 \qquad \frac{dN_{\rm Coul}}{dQ} \propto Ac(Q)\cdot Q^2 \Longrightarrow \text{GEANT(MC) Reconstruction} \Longrightarrow \frac{dN_{\rm Acc}}{dQ}^{Rec} \qquad \frac{dN_{\rm Coul}}{dQ}^{Rec}$$





Signal extraction - 2001





$$n_{A_{2\pi}}(Ni - 2001) = 6800 \pm 300(stat)$$

From the signal to the life time

- From the number of measured Coulombs N_{Coul}, we can estimate the number of produced atoms N_A using the normalisation $\frac{N_A}{N_{Coul}}$.
- The ratio of measured atoms n_A to produced ones defines the break-up probability P_{br}...
- ...which is connected to the life time τ

$$N_{Coul} \rightarrow N_A \rightarrow P_{br} = \frac{n_A}{N_A} \rightarrow \tau = f(P_{br})$$

The normalisation is crucial to obtain the life time..... which depends strongly on the MS after the measurement.

Conclusions

- The DIRAC experiment is running and collecting data.
- The detector has a very good relative momentum resolution, which allows to detect $\pi^+\pi^-$ pairs coming from $A_{2\pi}$ atoms.
- The extracted signal and the background is consistent with MC simulation
- To obtain the life time from the signal, we have to know the background in the signal region very accurate. Dedicated measurements are planned in 2003 for this purpose.