MEASUREMENT OF $K^+ \to \pi^+ \nu\bar{\nu}$ DECAY BRANCHING RATIO AT NA62 EXPERIMENT

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SPASIMIR BALEV

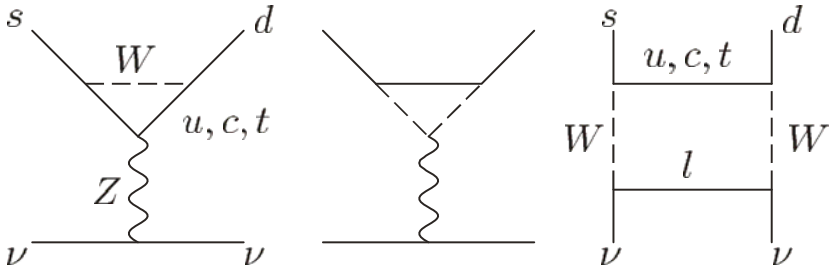
SNS & INFN, PISA

On behalf of NA62 Collaboration:

Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Mainz, Merced, Moscow, Naples, Perugia, Protvino, Pisa, Romel, Rome II, Saclay, San Luis Potosi, Stanford, Sofia, Triumf, Turin

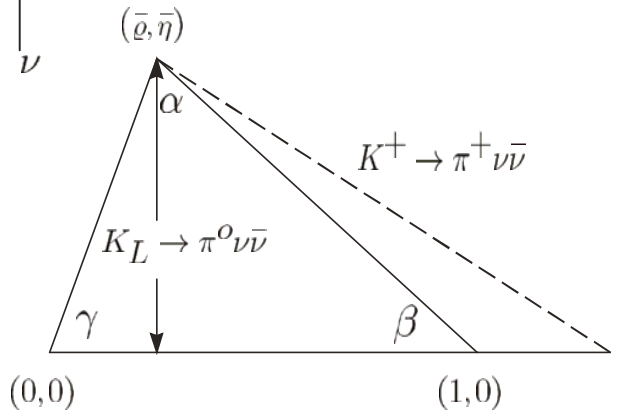
Motivation

- $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ are exceptionally **clean modes**, dominated by short distance dynamics.
- The leading SM contribution to $K \to \pi\bar{\nu}\nu$ is generated by top quark loops and can be computed with **negligible theoretical uncertainty**.
- The **hadronic matrix element** can be extracted with negligible theoretical uncertainty from well measured $K \to \pi e \nu$ rates.



- Predictions within **SM**:

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (1.6 \times 10^{-5}) |V_{cb}|^4 [\sigma\eta^2 + (\rho_c - \rho)^2] = (8.22 \pm 0.84) \times 10^{-11}$$
$$BR(K_L \to \pi^0 \nu\bar{\nu}) = (7.6 \times 10^{-5}) |V_{cb}|^4 \eta^2 = (2.76 \pm 0.40) \times 10^{-11}$$



- Precise measurements of BR($K \to \pi\nu\bar{\nu}$) offer:
  - an independent way of determining the **unitarity triangle**
  - opportunity to make precise test of SM and **search for New Physics**

- **3 events observed by BNL E949 ($BR = 1.47^{+1.30}_{-0.89} \times 10^{-10}$)**

NA62 principle of measurement

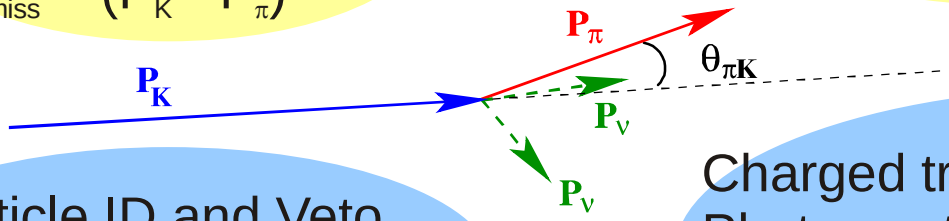
Goal: O(100) events with 10% background

N(K decays) = 10^{13}
14% acceptance

→ Kaon decays in flight technique
400 GeV proton beam from CERN SPS
High energy K^+ beam (P_K=75 GeV/c)

Kinematical rejection
Single track signature
$m^2_{miss} = (P_K - P_\pi)^2$

→ Kaon momentum: beam tracker
Pion momentum: spectrometer



Particle ID and Veto
in addition to kinematical rejection

→ Charged track veto: spectrometer
Photon veto: calorimeters
Beam kaon ID: CEDAR
$\pi/\mu/e$ separation: RICH

Budget limitations

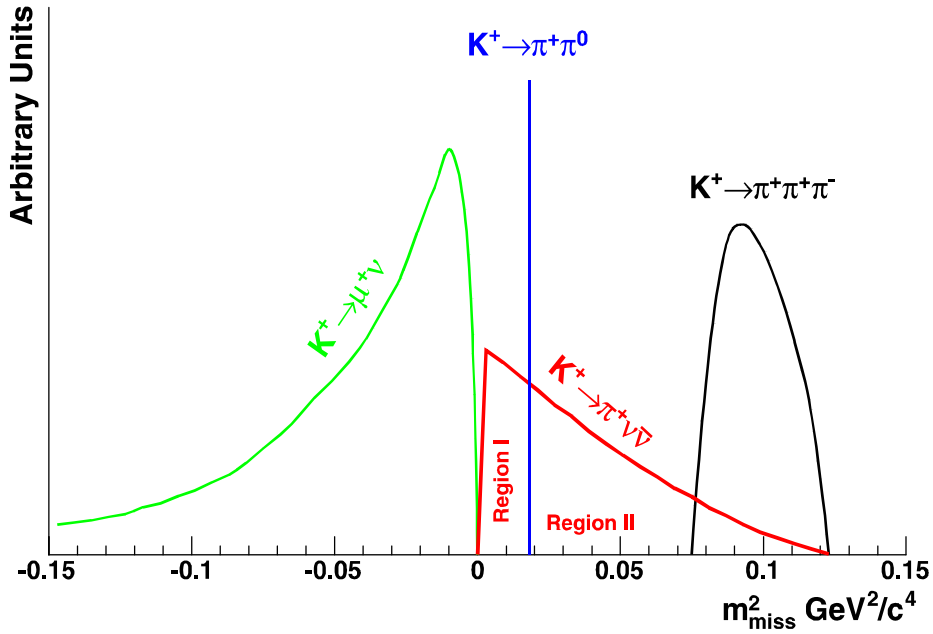
→ Use the existing NA48 infrastructure:
beam line, LKr calorimeter,...

NA62 schedule

- September 2005: presented at CERN SPSC
- December 2005: R&D endorsed by CERN Research Board
- Start of the Gigatracker project
- Start of test beams at CERN in 2006
- 2007: prototypes construction and test at CERN and Frascati beams
- 2008 – 2010: Technical design and construction
- 2011: Start of data taking

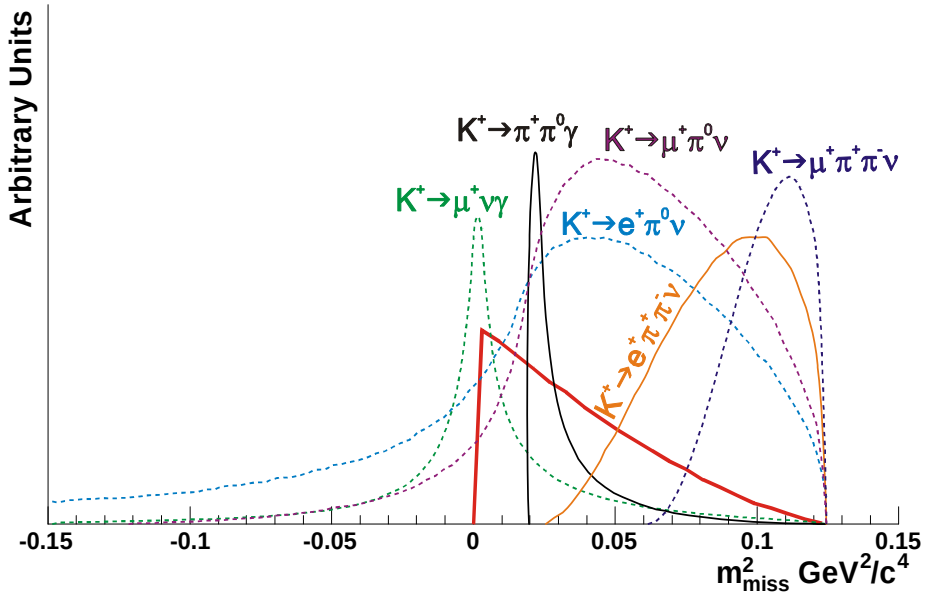
Background

Kinematically constrained background
(92% of total backfround)



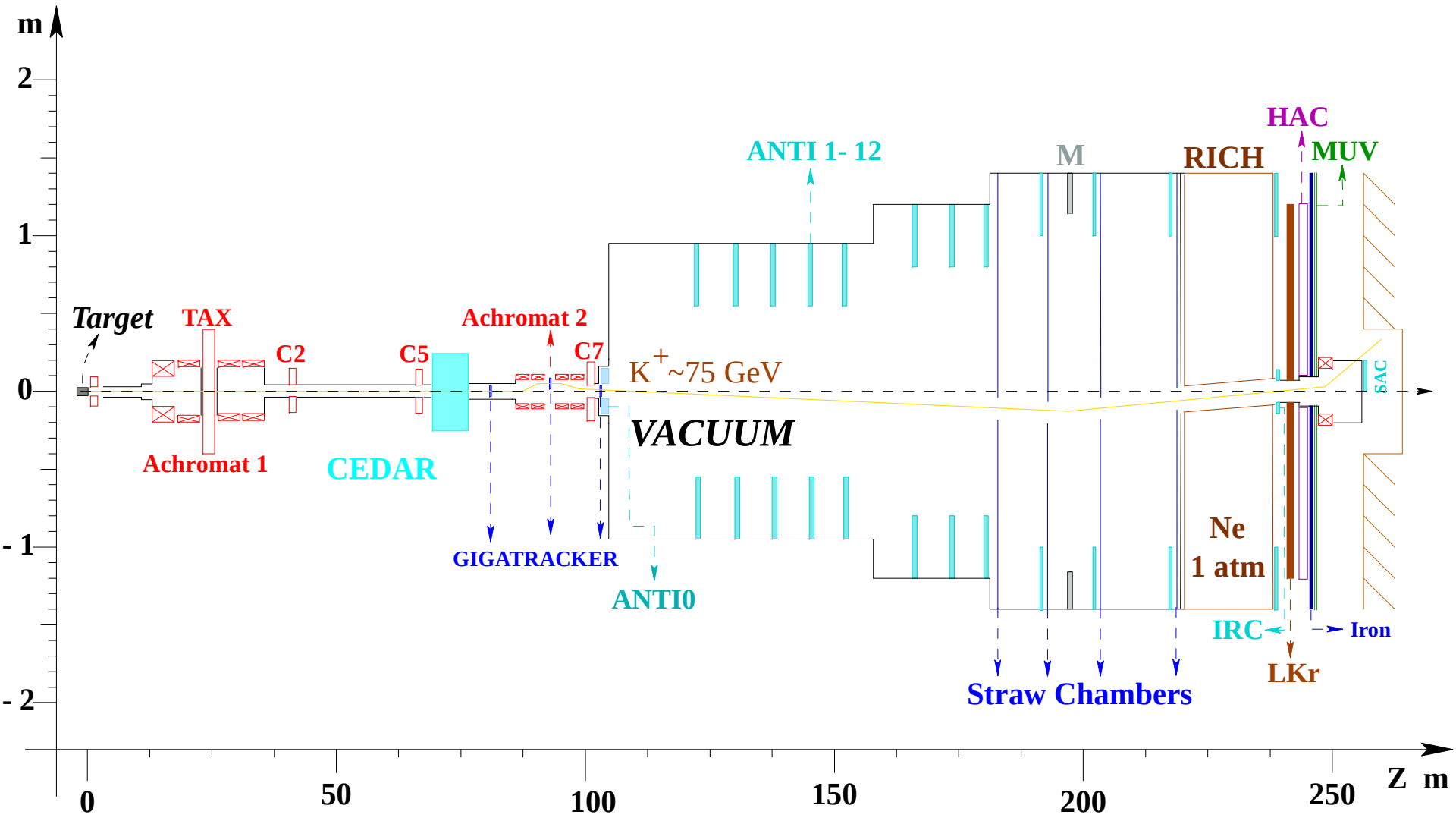
Define signal region
$K^+ \to \pi^+\pi^0$ forces to split in two parts
Region I and II

Background not constrained kinematically
(8% of total background)



Span across the signal region
Lower branching fractions
Rejection relies on vetoes/ID

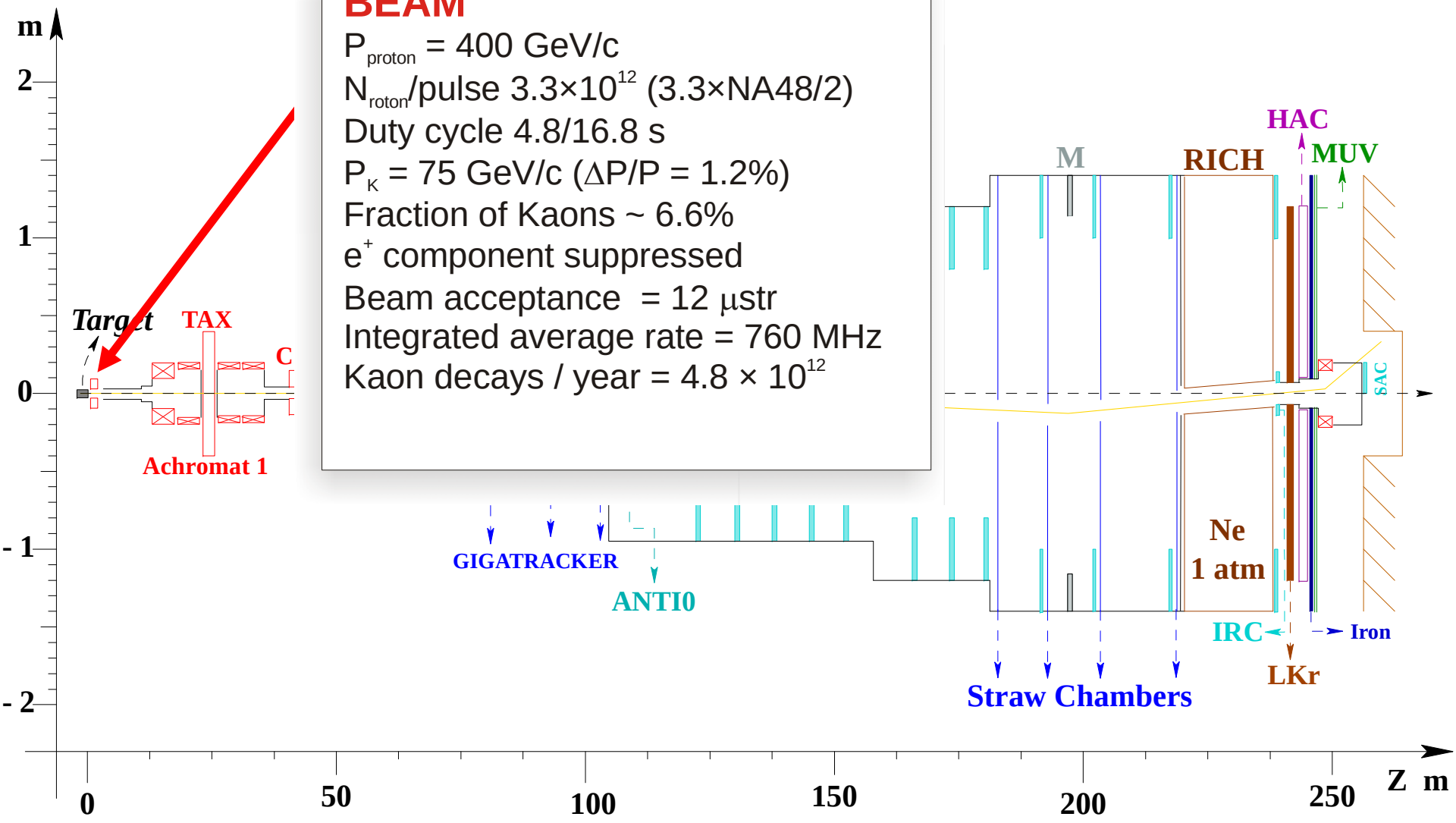
Experimental layout



Experimental layout

BEAM

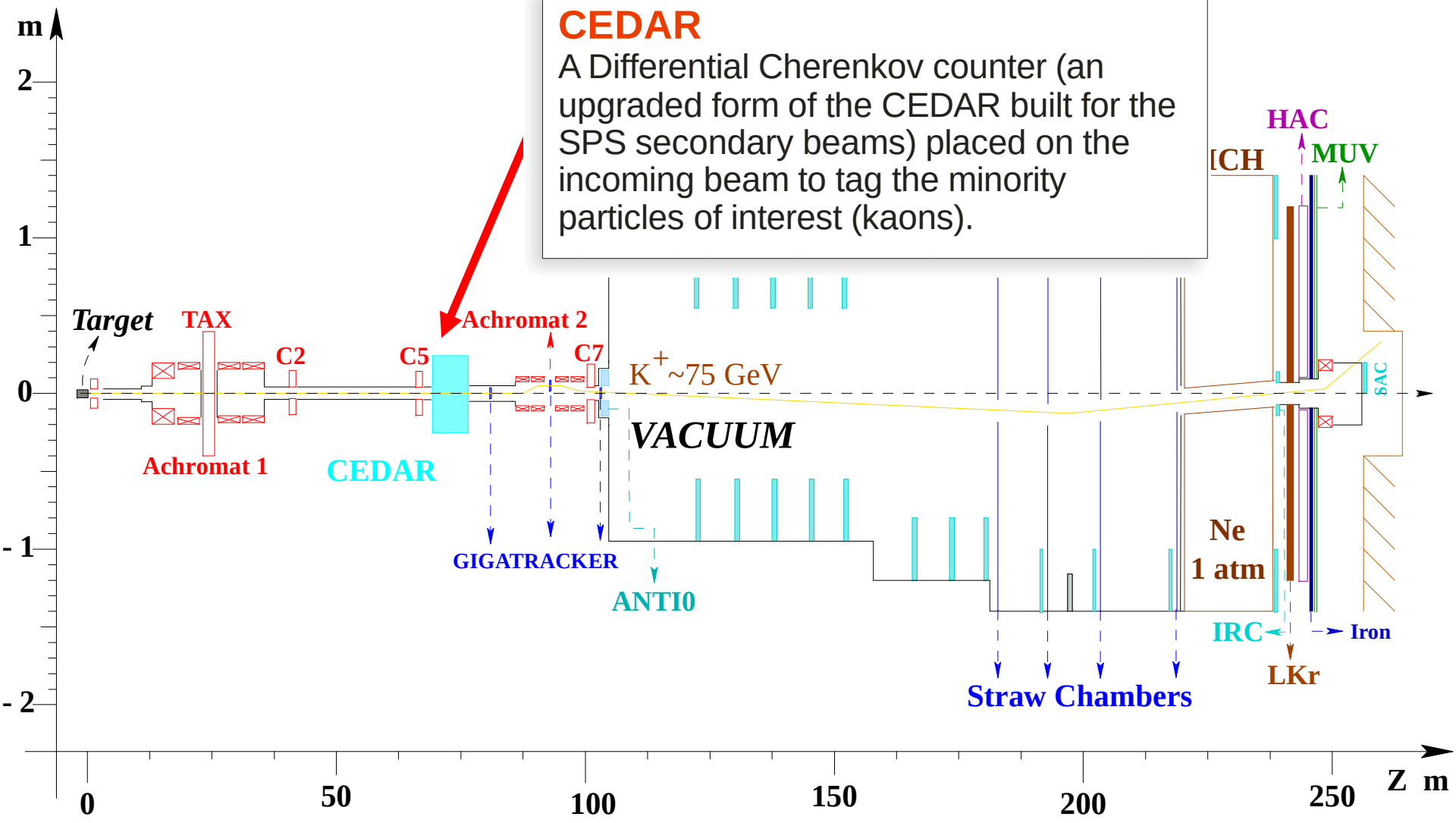
P_{proton} = 400 GeV/c
N_{roton}/pulse 3.3×10^{12} (3.3×NA48/2)
Duty cycle 4.8/16.8 s
P_K = 75 GeV/c ($\Delta P/P$ = 1.2%)
Fraction of Kaons ~ 6.6%
e^+ component suppressed
Beam acceptance = 12 μstr
Integrated average rate = 760 MHz
Kaon decays / year = 4.8×10^{12}



Experimental layout

CEDAR

A Differential Cherenkov counter (an upgraded form of the CEDAR built for the SPS secondary beams) placed on the incoming beam to tag the minority particles of interest (kaons).



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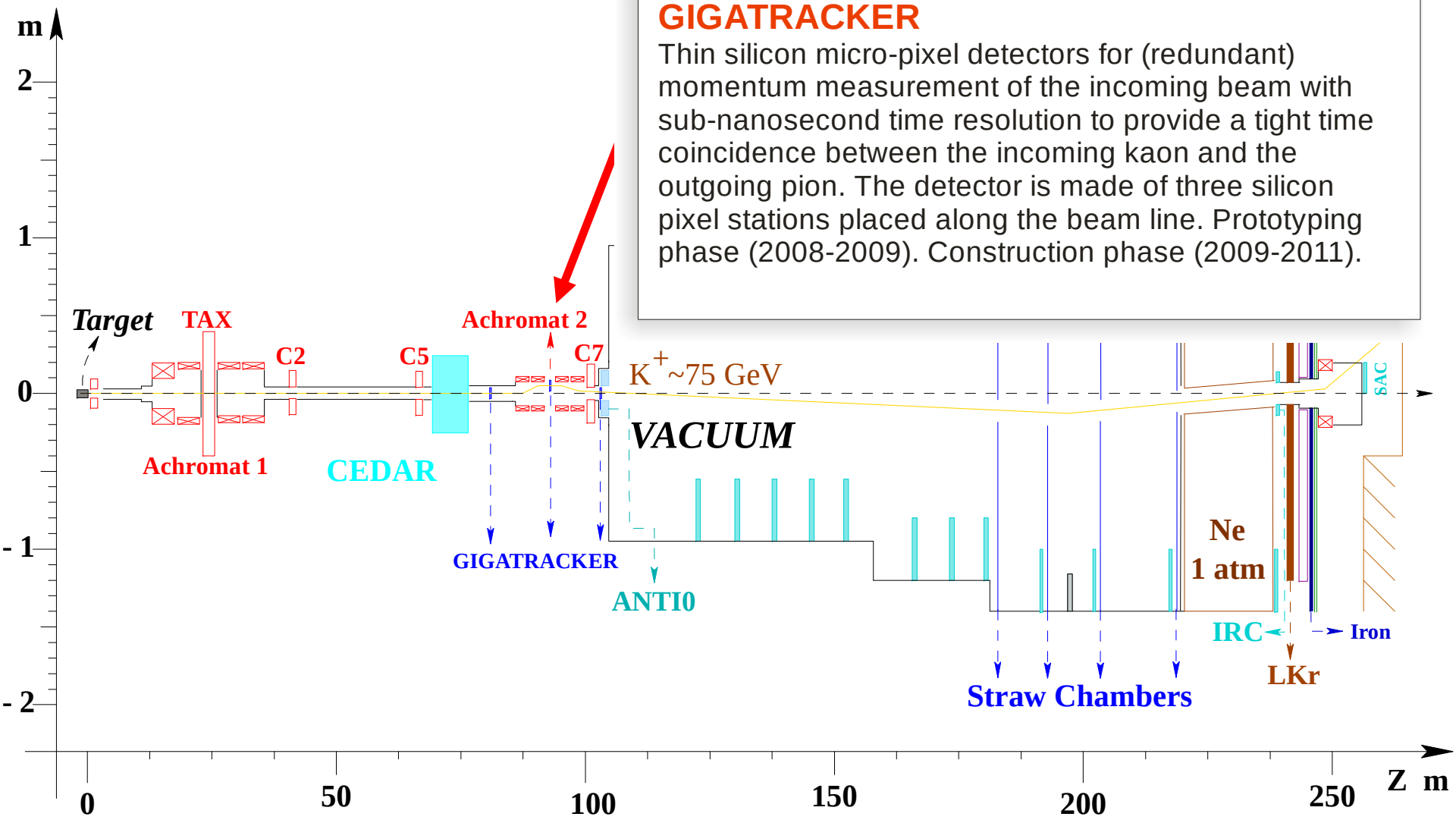
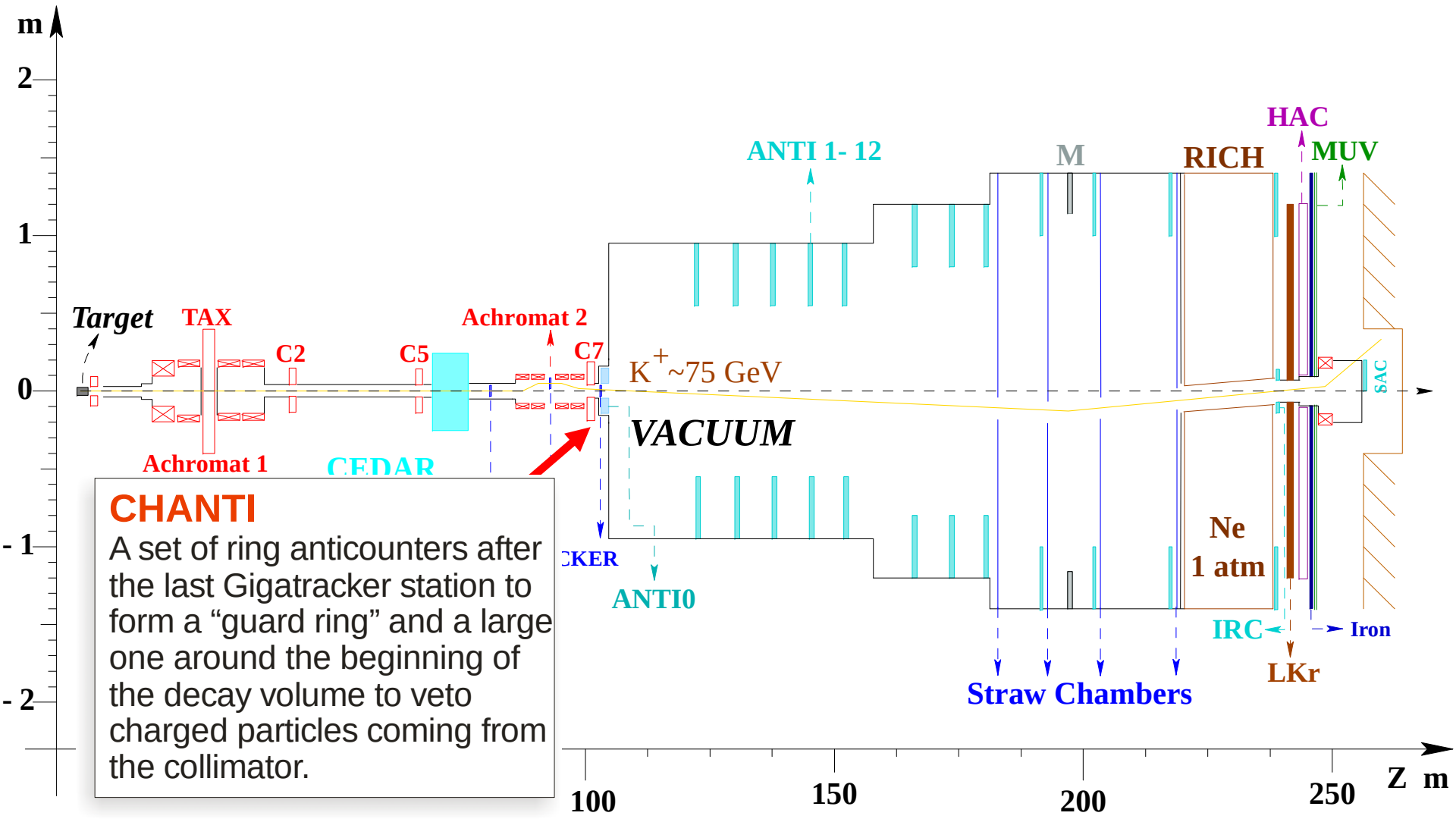


GIGATRACKER

Thin silicon micro-pixel detectors for (redundant) momentum measurement of the incoming beam with sub-nanosecond time resolution to provide a tight time coincidence between the incoming kaon and the outgoing pion. The detector is made of three silicon pixel stations placed along the beam line. Prototyping phase (2008-2009). Construction phase (2009-2011).

Experimental layout



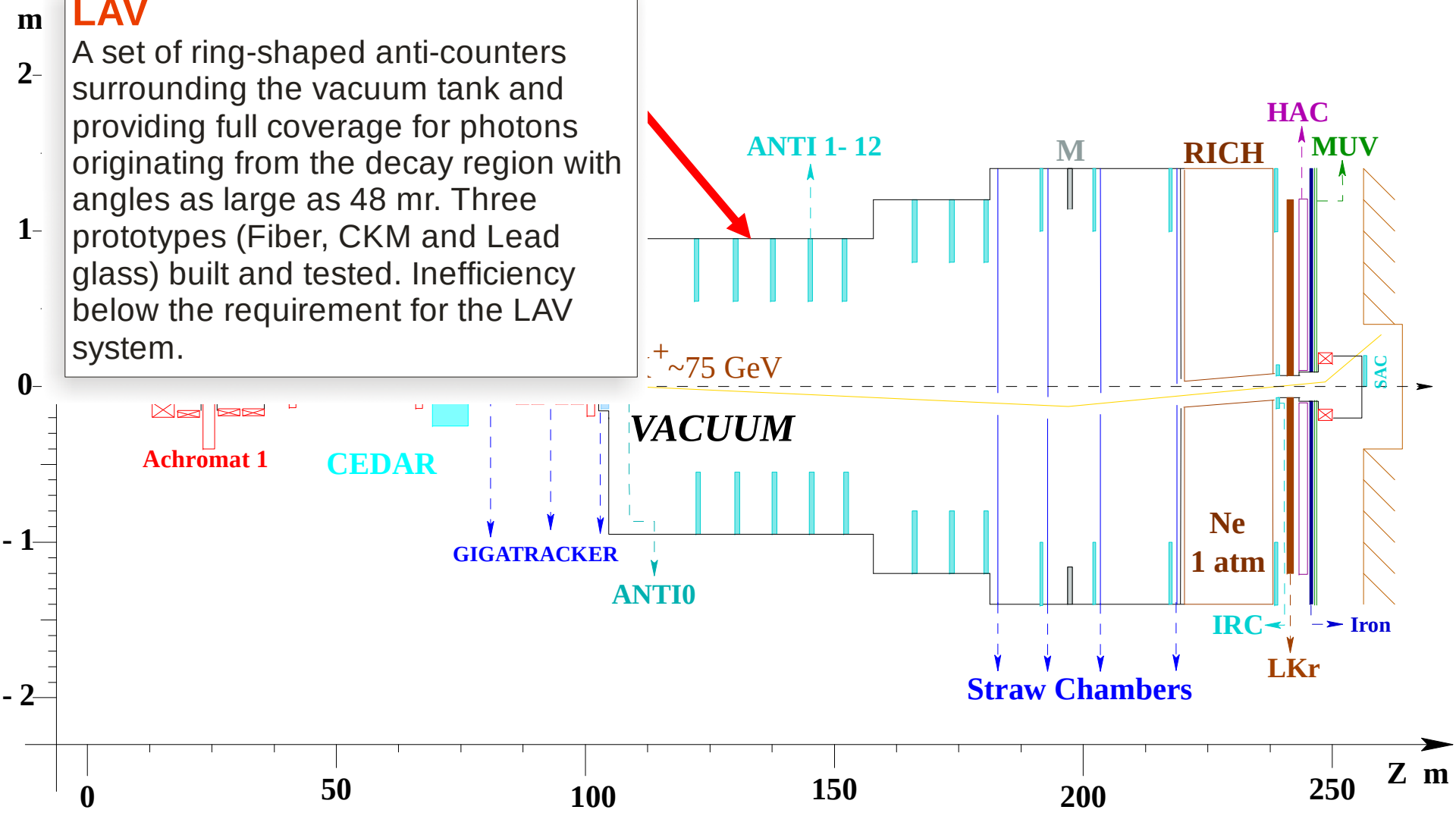
CHANTI

A set of ring anticounters after the last Gigatracker station to form a “guard ring” and a large one around the beginning of the decay volume to veto charged particles coming from the collimator.

Experimental layout

LAV

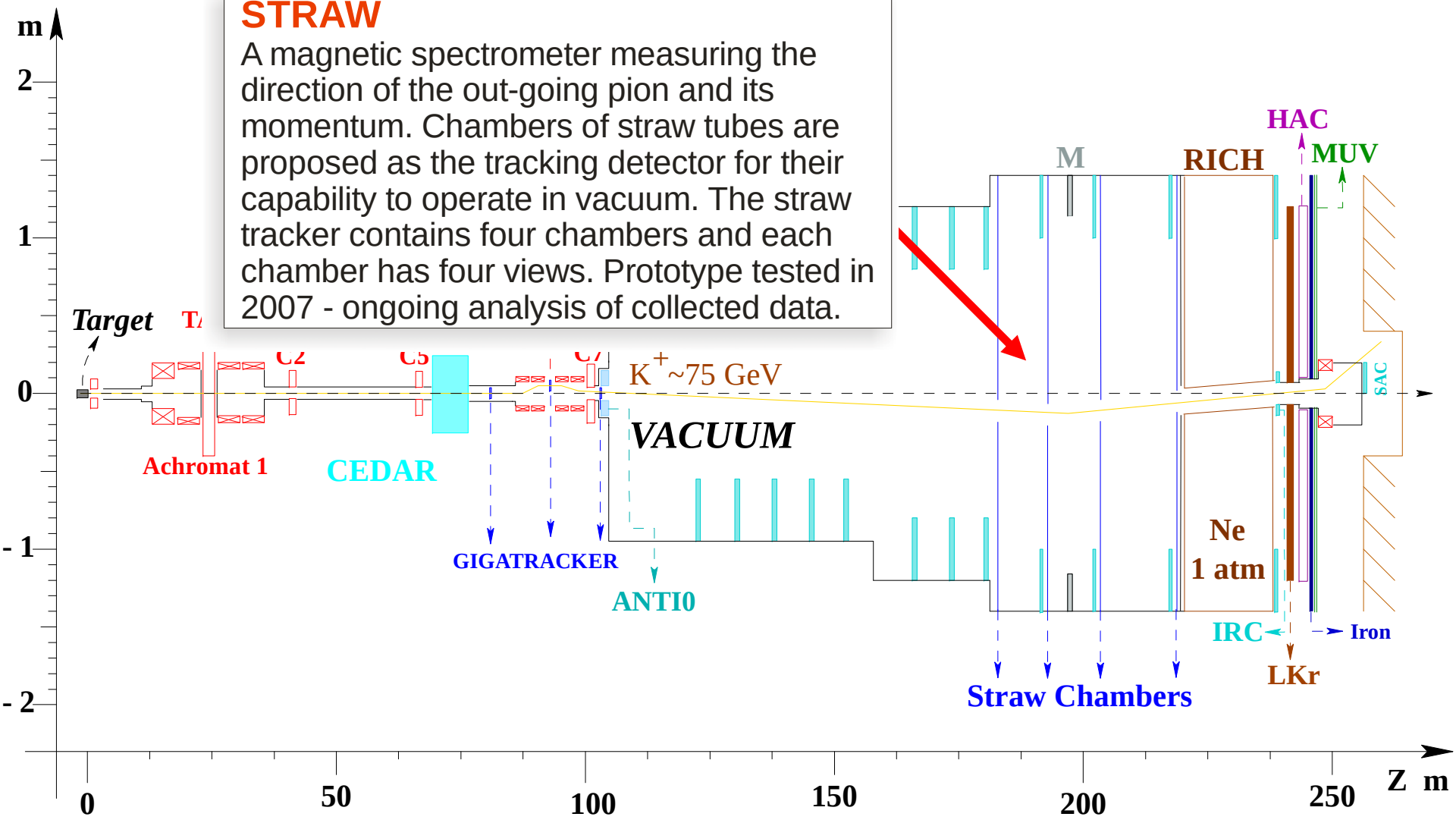
A set of ring-shaped anti-counters surrounding the vacuum tank and providing full coverage for photons originating from the decay region with angles as large as 48 mr. Three prototypes (Fiber, CKM and Lead glass) built and tested. Inefficiency below the requirement for the LAV system.



Experimental layout

STRAW

A magnetic spectrometer measuring the direction of the out-going pion and its momentum. Chambers of straw tubes are proposed as the tracking detector for their capability to operate in vacuum. The straw tracker contains four chambers and each chamber has four views. Prototype tested in 2007 - ongoing analysis of collected data.



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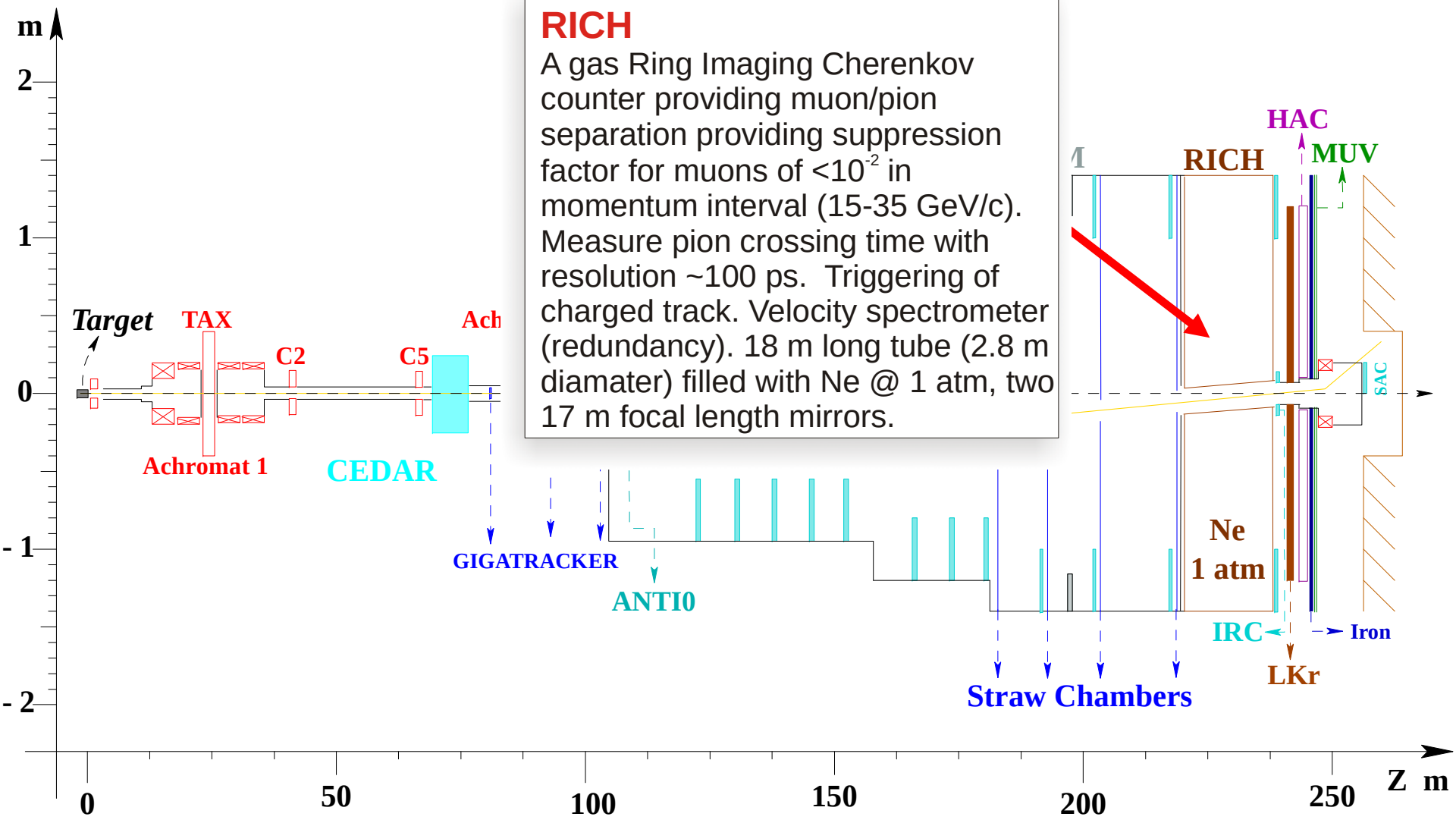

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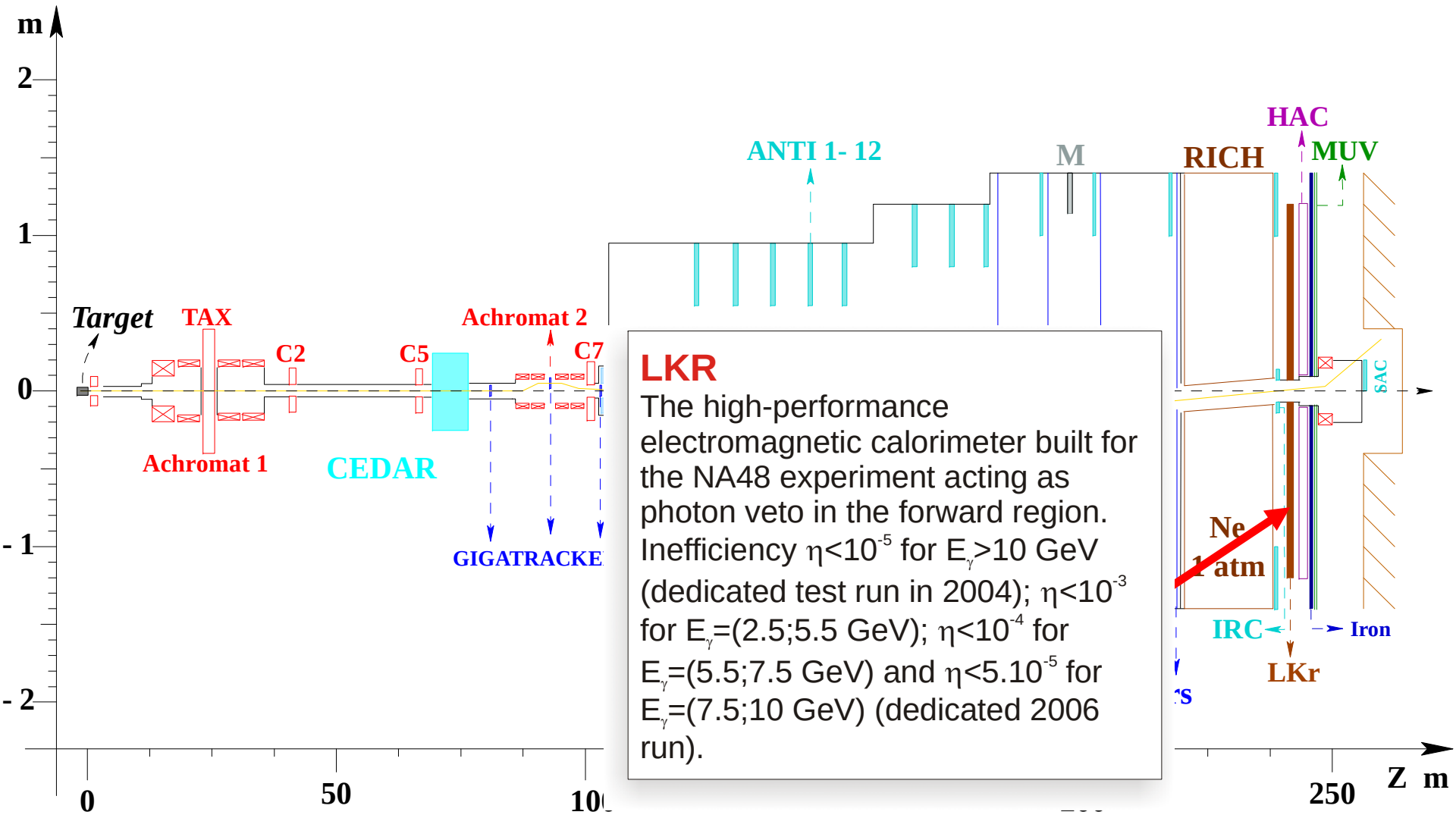
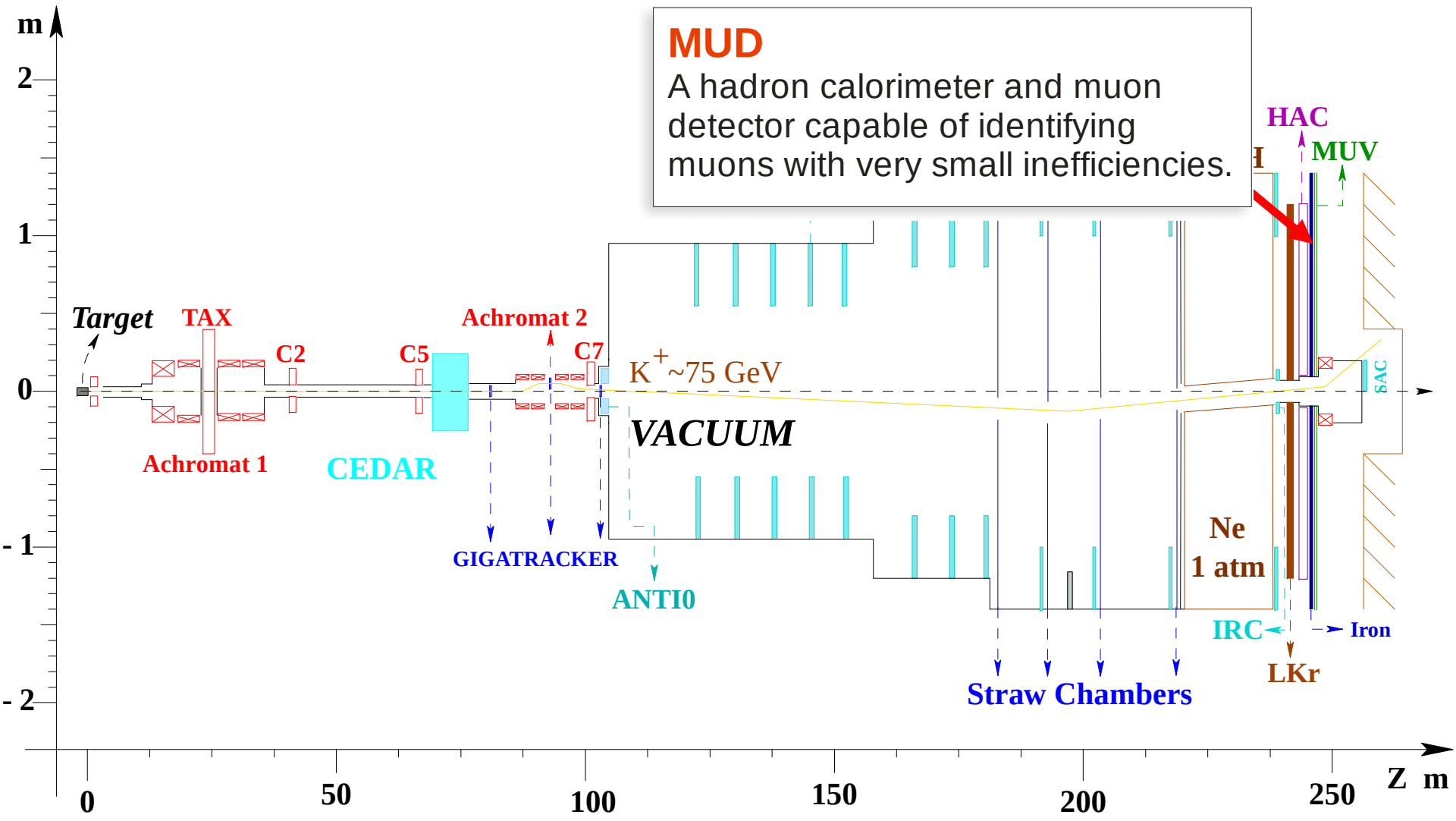


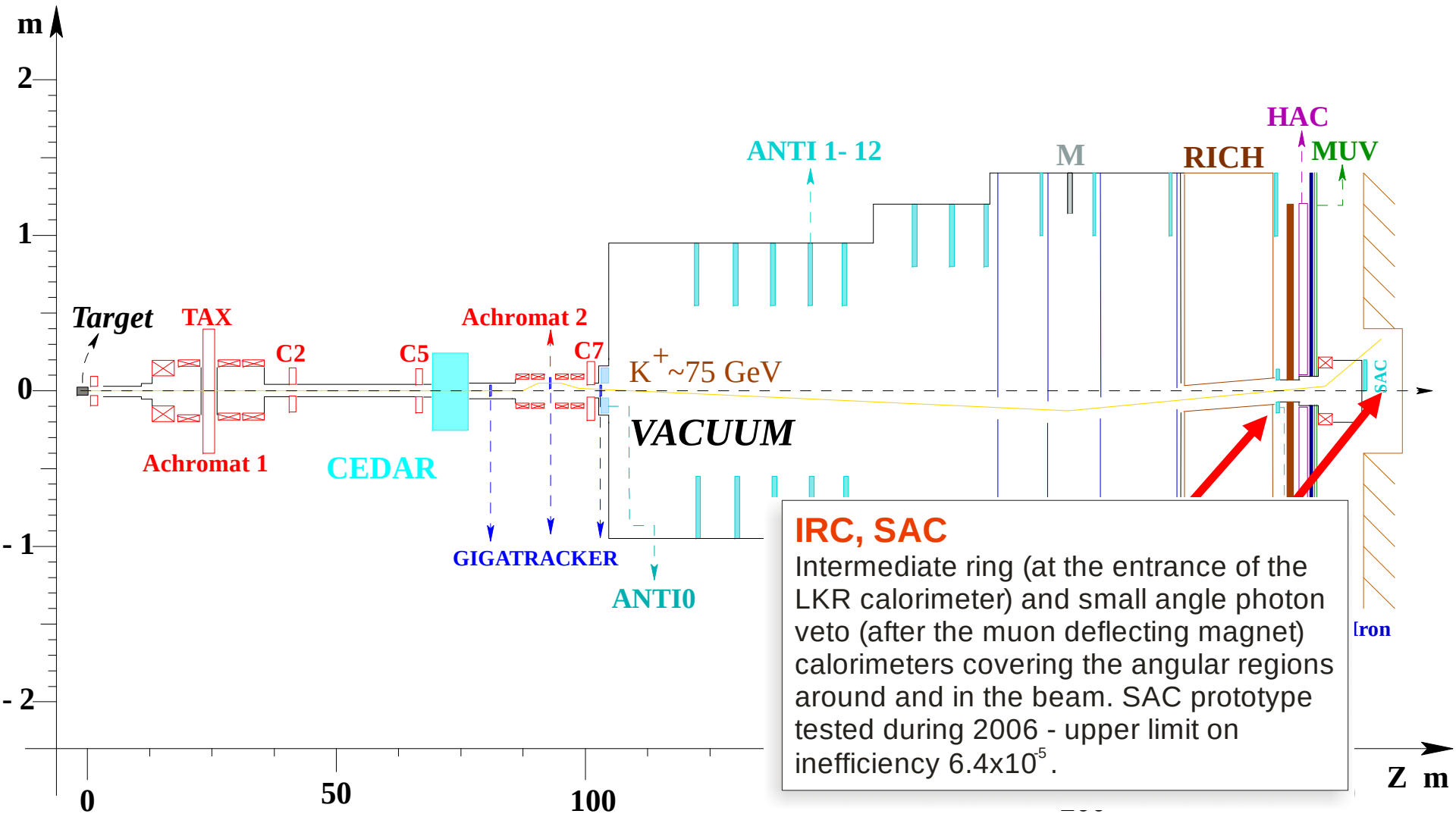
LKR

The high-performance electromagnetic calorimeter built for the NA48 experiment acting as photon veto in the forward region. Inefficiency $\eta<10^{-5}$ for $E_\gamma>10$ GeV (dedicated test run in 2004); $\eta<10^{-3}$ for $E_\gamma=(2.5;5.5$ GeV); $\eta<10^{-4}$ for $E_\gamma=(5.5;7.5$ GeV) and $\eta<5.10^{-5}$ for $E_\gamma=(7.5;10$ GeV) (dedicated 2006 run).

Experimental layout



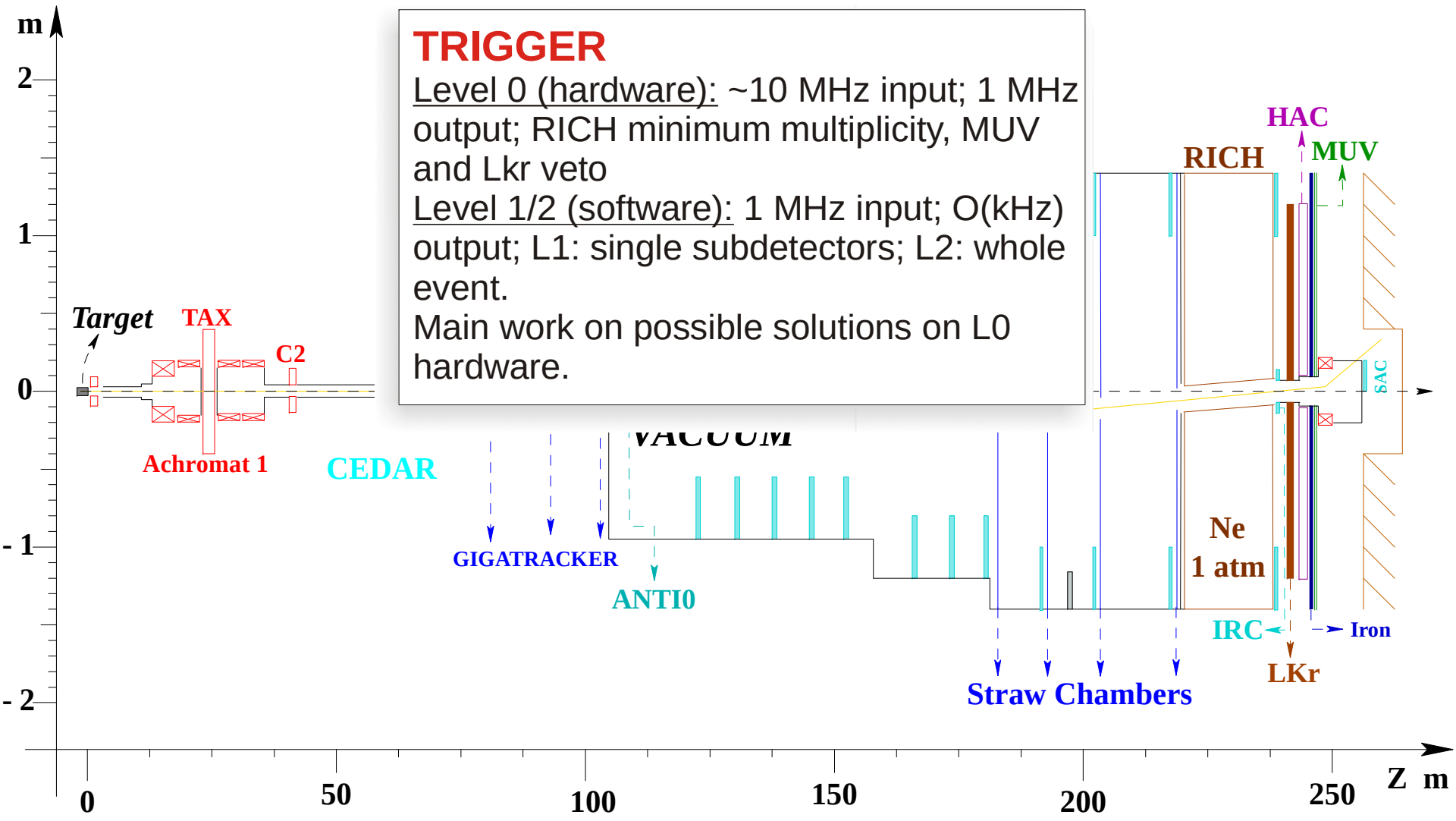
Experimental layout



IRC, SAC

Intermediate ring (at the entrance of the LKR calorimeter) and small angle photon veto (after the muon deflecting magnet) calorimeters covering the angular regions around and in the beam. SAC prototype tested during 2006 - upper limit on inefficiency 6.4×10^{-5}.

Experimental layout



Background estimations

Signal (acc=14.4% flux = 4.8×10^{12} evts/year)	55 events/year
$K^+ \to \pi^+ \pi^0$	4.3%
$K^+ \to \mu^+ \nu$	2.2%
$K^+ \to e^+ \pi^+ \pi^- \nu$	~3%
Other 3 – track decays	~1.5%
$K^+ \to \pi^+ \pi^0 \gamma$	~2%
$K^+ \to \mu^+ \nu \gamma$	~0.7%
$K^+ \to e^+(\mu^+) \pi^0 \nu$, others	negligible
Total bckg.	~13.5%

Conclusions

- The experiment NA62 is proposed to search for new physics by measuring the **BR($K^+ \to \pi^+ \nu\nu$) with 10% accuracy**.
- **Other physics opportunities** part of the experimental program (lepton universality, LFV, search for new low mass particles…)
- **General design is mostly defined.** Overall simulation and performances are under review.
- The **R&D program is well advanced**: construction of detector prototypes and tests are in progress (in some cases completed).
- The new experiment should be able to reach **sensitivity ~10^{-12} per event** using the existing infrastructure at CERN.