ANUBIS layout and technology

AN Underground Belayed In-Shaft search experiment

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Where to look for long-lived particles?

- LLPs from the decays of **heavy states** (e.g. the Higgs)
- at large angle, off axis

- weakly coupled **light particles** with high statistics
- along the beam axis
ANUBIS: idea

- Existing geometry allows for minimal civil engineering costs
- Projective decay volume optimises acceptance for different lifetimes
- Can be conveniently combined with ATLAS

Cranes can support up to 270 t
ANUBIS DETECTOR INITIAL PROPOSAL

- **Proposed ATLAS Phase-2 upgrade RPCs as baseline technology**
- **2D readout triplet chambers made of 3 independent singlets**
- **2.3 km² total instrumented area**
- **Each tracking station weighs 230 m² x 51 kg/m² ~ 30 tons (OK)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Time resolution</td>
<td>$\delta t \lesssim 0.5$ ns</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>$\delta \alpha \lesssim 0.01$ rad</td>
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<tr>
<td>Spatial resolution</td>
<td>$\delta x, \delta z \lesssim 0.5$ cm</td>
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<tr>
<td>Per-layer hit efficiency</td>
<td>$\epsilon \gtrsim 98%$</td>
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POSSIBLE IMPLEMENTATIONS OF ANUBIS CONCEPT

Standard (conservative) scenario

1 ring scenario

Extended scenario
PERFORMANCE OF THE ATLAS MUON SYSTEM

- New RPC layer in the inner barrel
- Same RPC technology baseline for ANUBIS
- High efficiency projective to the access shaft
- Can be improved with ID combined tracking

- Time of flight performance
- 9 tracking layers
- 5 m independent lever arm
- 0.5% resolution on $\beta$
For a given decay volume length

- More solid angle if closer to the IP
- Number of decays higher if closer to the IP (for shorter decay lengths)

DETECTOR REQUIREMENTS

- Enclose large volumes → Low cost per unit surface
- Discriminate external SM particles → Efficient, hermetic & time resolved
- Tracking charged particles → Good 2D tracking ability
- Resolving 2 (or more) tracks at small angle → Multi-hit resolution
- Measure particle β → Time of flight capability
- Identify particles → Pre-shower layers embedded
- Veto → Active: close by experiments integrating DAQ with the host
- Short time scale → HL-LHC little residual time for design and construction

This applies also to CODEX-B which is preparing a large demonstrator using the same technology (See Vladimir talk)

WHY ATLAS RPCs?

Turn key solution → new generation RPCs designed for HL-LHC and construction can start in time

- Industrially produced on large scale → Low unit cost
- Thinner gas gap → Higher time resolution
- Built-in high sensitivity front end → High efficiency with thin gas gaps
- 50 ps embedded TDC and serializer → High performance low cost, easy to readout
- Stand-alone singlet structure → Can be combined in sandwich with high Z layers for particle ID
GAS GAP VS. ELECTRONICS

THINNER GAS GAP
- \( \rightarrow \text{higher E field} \rightarrow \text{higher charge density} \)
- \( \rightarrow \text{same saturation with less charge} \)
- \( \rightarrow \text{faster peaking time} \)

HIGHER ELECTRONICS PERFORMANCE
- Can exploit thinner gas gap small & fast signals
- Can work at lower gas gain
- Compatible with eco-friendly gases
A singlet is made of:

- A RPC gas gap
- Two readout strip panels
  - Strip PCB facing the gap
  - Low $\varepsilon_r$ dielectric filler
  - Reference ground plane
  - Front end electronics
  - Matching resistors
- Ground reference interconnections
- A singlet is a independent Faraday cage insensitive to the external world
- A number of singlets can be boxed freely and interleaved with other materials

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STATE OF THE ART PERFORMANCE WITH 1 MM GAS GAP

- 95% of efficiency at 5.6 kV for each singlet
- Measurement over all surface with CR → a few percent of missing acceptance
- Inactive area 1% for the spacers

Efficiency curve all over the singlet surface

- Time resolution of a single 1 mm gas gap measured through TOF between identical detectors
- About 350 ps with time walk correction
- About 200 ps for a triplet of gas gaps

η layer
Φ layer
AND η-Φ
OR η-Φ
CUTTING COSTS AND SIMPLIFY LAYOUT: DIGITIZATION INSIDE

- **An upgraded readout chip in preparation for the ATLAS RPC Phase2 upgrade:**
  - Same as present amplifier
  - Same as present fast discriminator
  - 70 ps low power TDC
  - Data encoder with serializer
- **Daisy chain option foreseen for the low rate experiment as ANUBIS**
  - Greatly compress the readout cost
- **Standard 2D readout for squared chamber**
- **1D readout convenient for rectangular formats**
  - Less channels and less dead area
  - Second coordinate from time difference at strip ends

\[
\Delta x_1 = \frac{v}{\sqrt{2}} \Delta t \approx 1 \text{ cm}
\]

See “5D tracking concept” in RPC2016
**Station Structure**

- Each station is a multi singlet interleaved with high Z material layers acting as pre-showers
- 2D readout with mean timer functions
- Embedded 50 ps TDC

**RPC Discharge Cells are ~0.1x0.1mm^2 small**

- RPC elementary cells respond independently on each other till to very high particle density
- Signal amplitude proportional to the number of tracks
- Ideal after a pre-shower
- Several stations can perform some calorimetry

Take home message:
- Gamma discrimination is possible!
- Montecarlo studies needed
CONCLUSIONS

- ANUBIS combined with ATLAS has a competitive LLP search potential
- New generation RPCs is a promising technology to build the detector
- A technical collaboration with ATLAS RPC upgrade started
- Prototypes can be readily installed by cloning ATLAS phase-1 chambers
- Base technology for the final detector can be taken from the ATLAS phase-2 chambers
- Specific layout for ANUBIS to be defined basing on final performance requirements
- One of the main difficulties is to organize such a big production in time
- Other LLP search experiments are based on the same technology
- CERN should create a local pool for RPC based detector construction