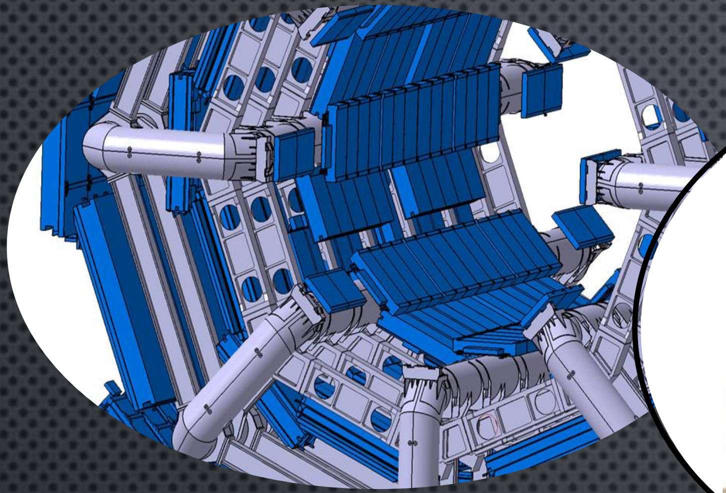
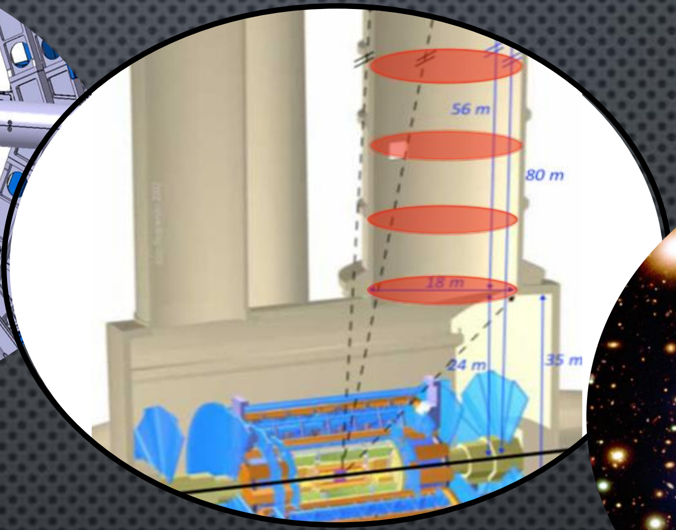




ANUBIS layout and technology

AN Underground Belayed In-Shaft search experiment

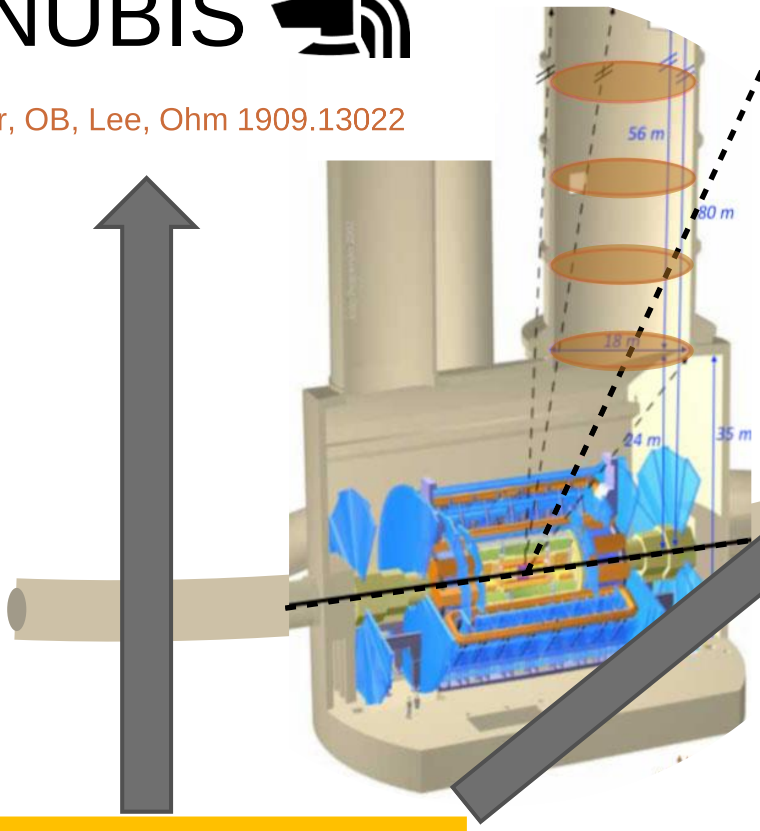
Giulio Aielli • Martin Bauer • Oleg Brandt • Lawrence Lee • Christian Ohm • Bálint Szepfalvi

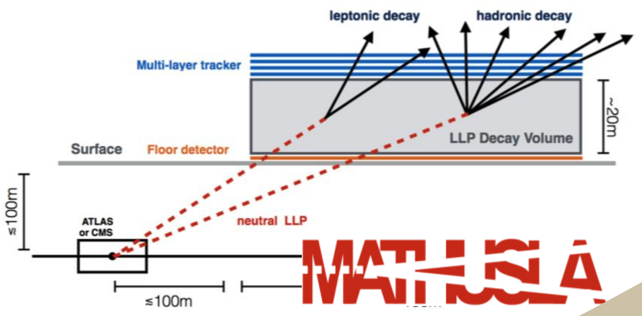
LLP Workshop, 16 Nov 2020

Where to look for long-lived particles?

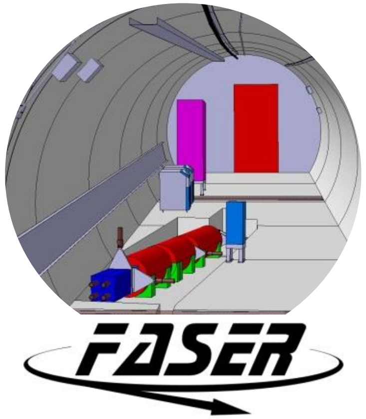
ANUBIS

Bauer, OB, Lee, Ohm 1909.13022

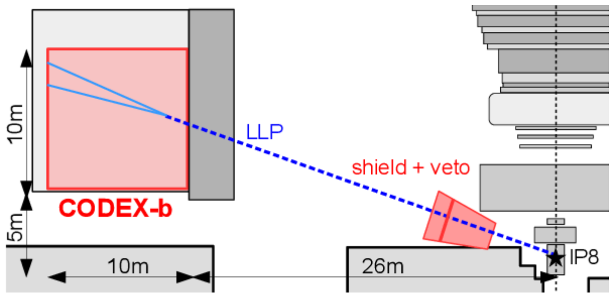




Chou et al 1606.06298



Feng, et al 1710.09387



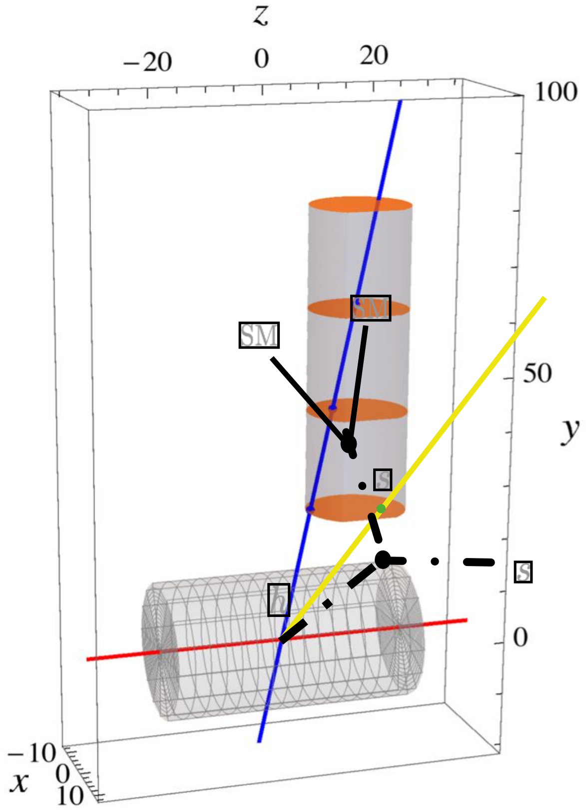
CODEX-b

Gligorov et al 1708.09395

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

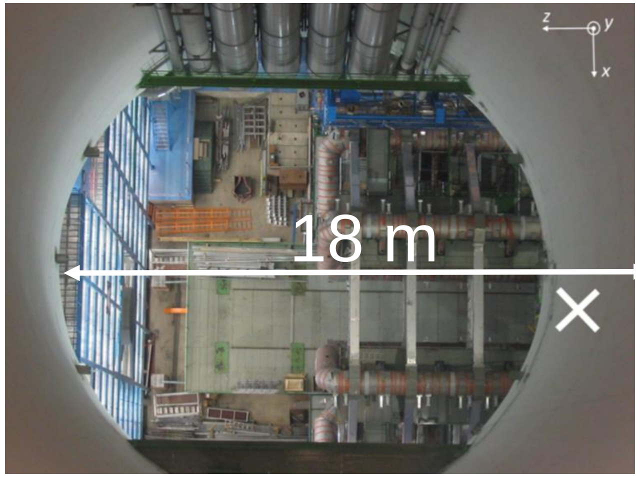
- weakly coupled ***light particles*** with high statistics
- along the beam axis

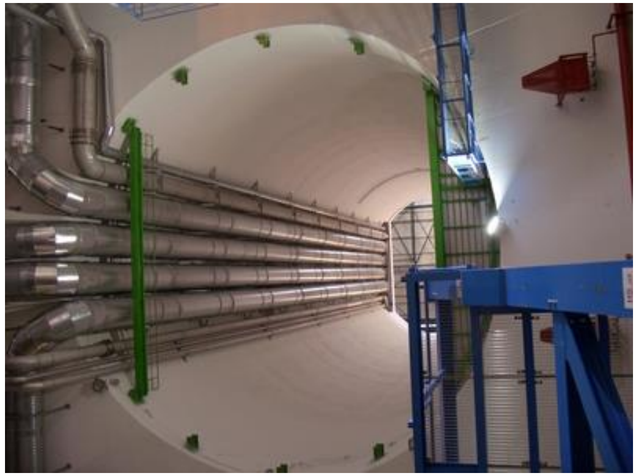
ANUBIS: idea



cranes can support up to 270 t

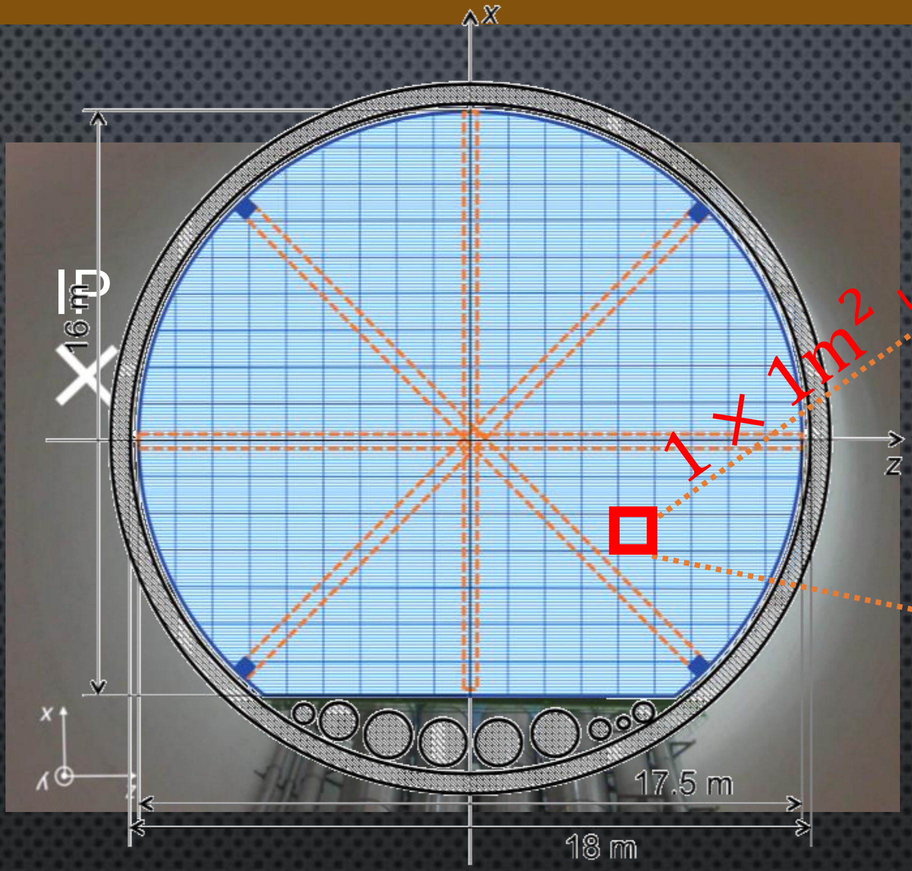
- Existing geometry allows for minimal civil engineering costs
- Projective decay volume optimises acceptance for different lifetimes
- Can be conveniently combined with ATLAS

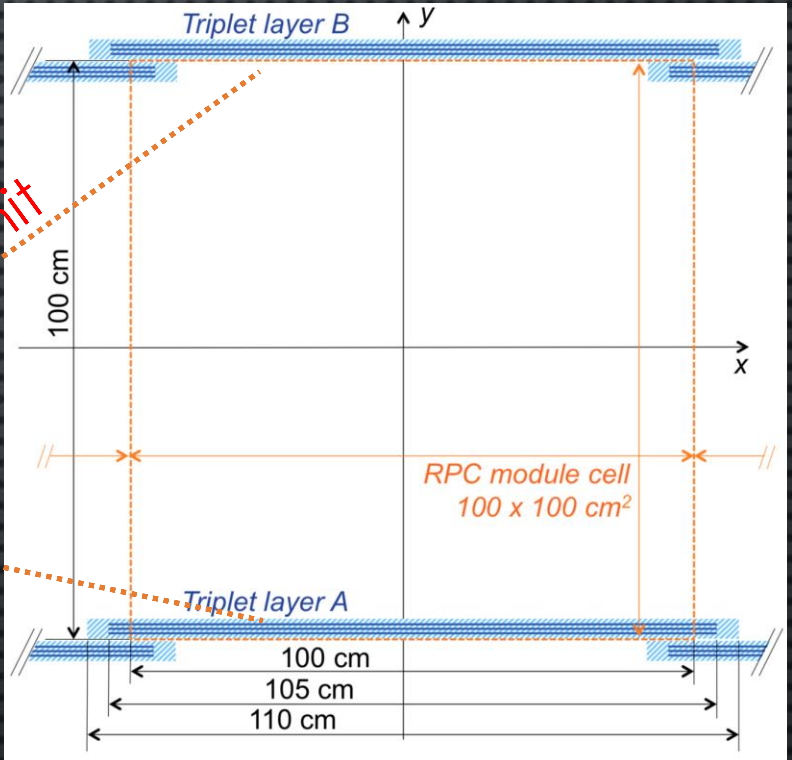




ANUBIS DETECTOR INITIAL PROPOSAL

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

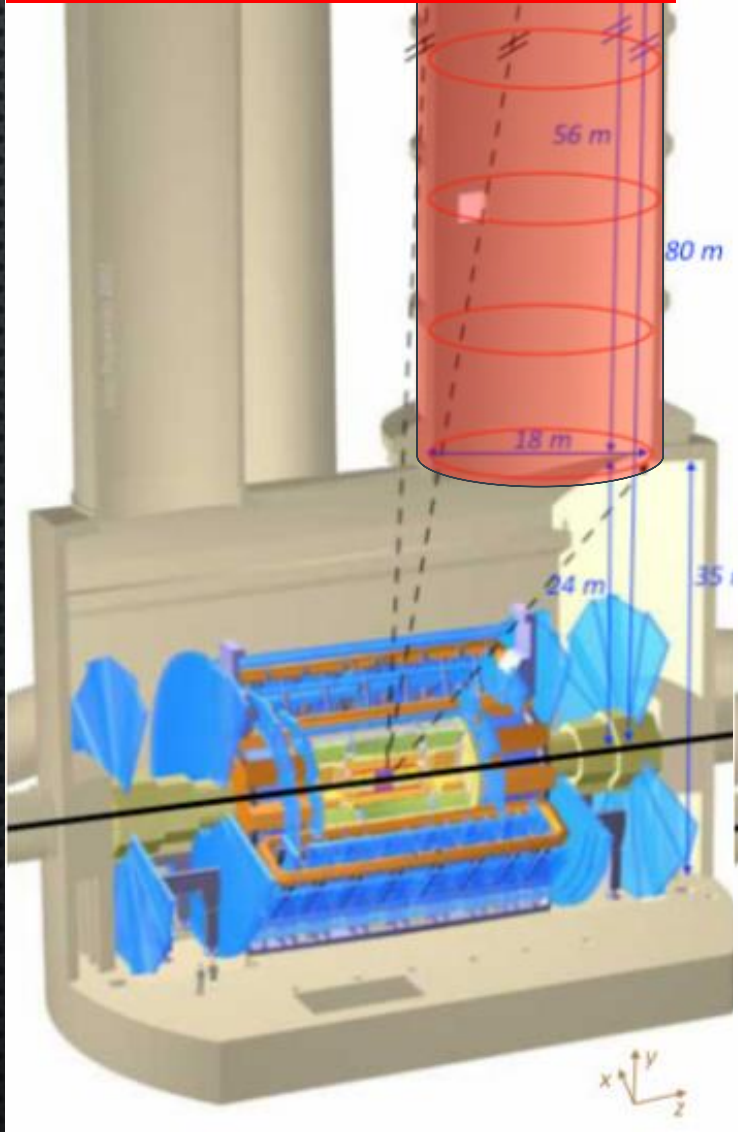




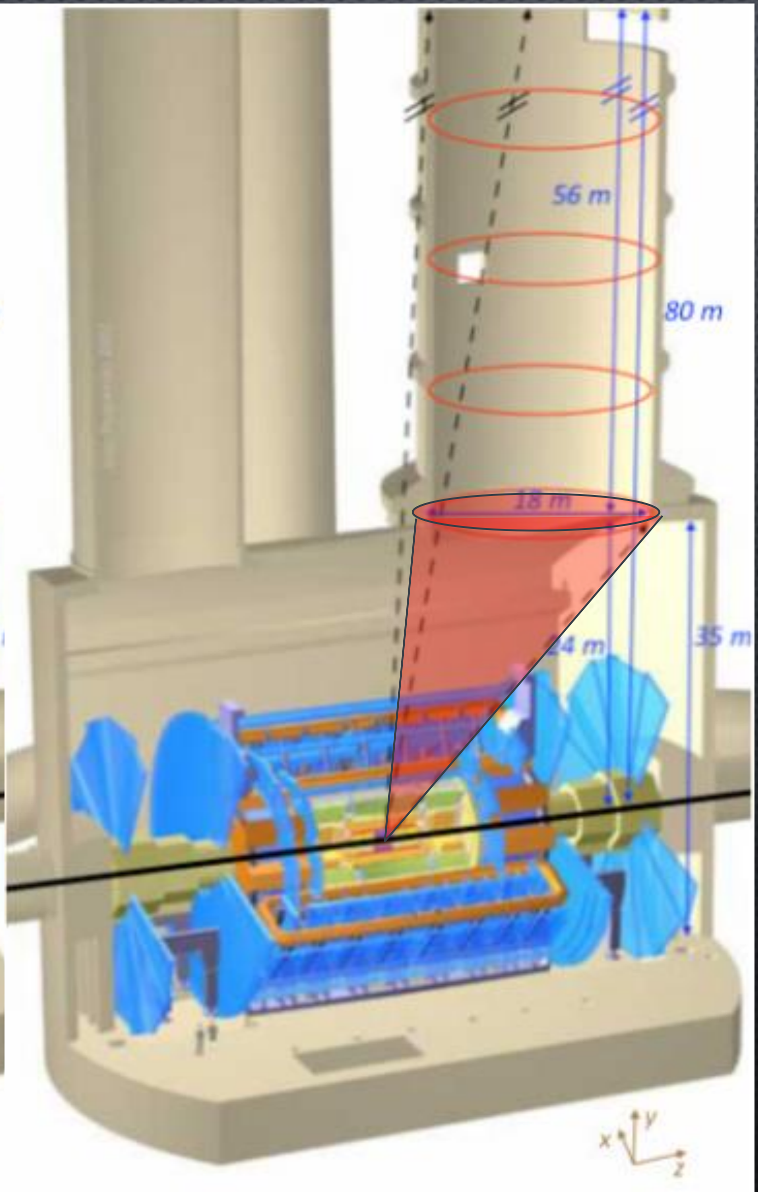
Parameter	Specification
Time resolution	$\delta t \lesssim 0.5$ ns
Angular resolution	$\delta\alpha \lesssim 0.01$ rad
Spatial resolution	$\delta x, \delta z \lesssim 0.5$ cm
Per-layer hit efficiency	$\varepsilon \gtrsim 98\%$

POSSIBLE IMPLEMENTATIONS OF ANUBIS CONCEPT

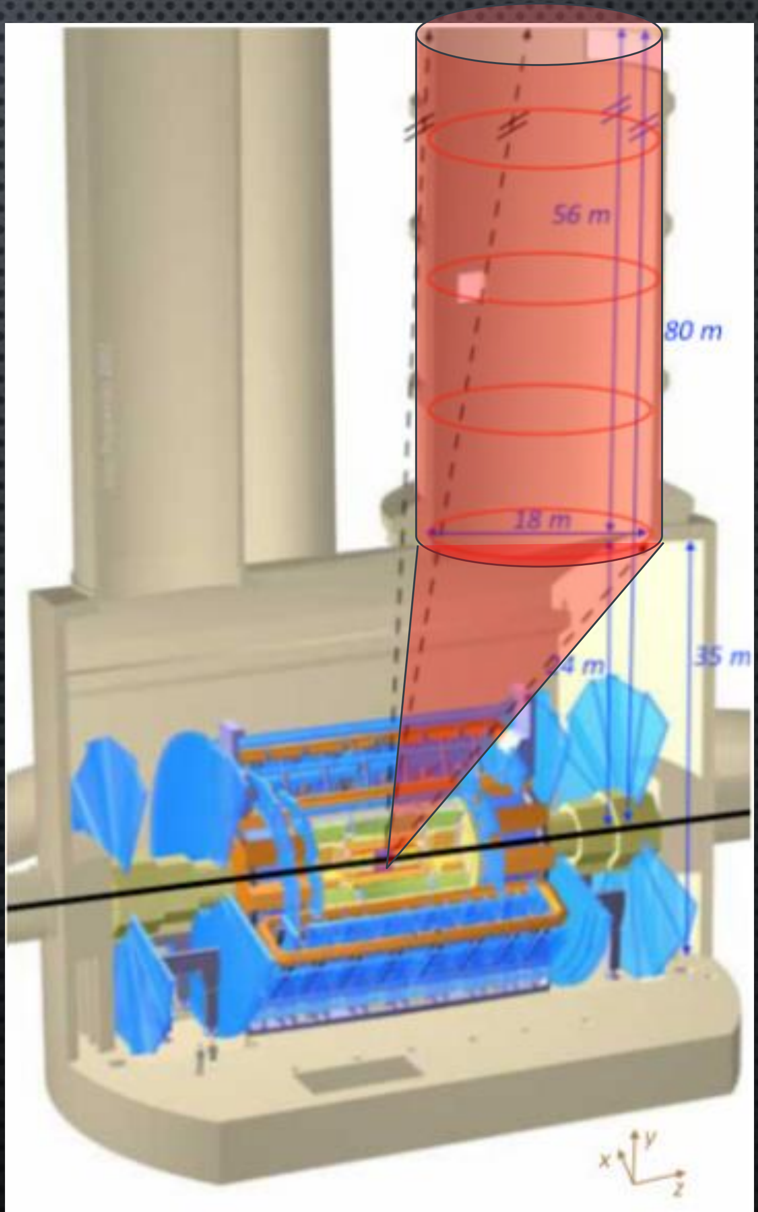
Standard (conservative) scenario



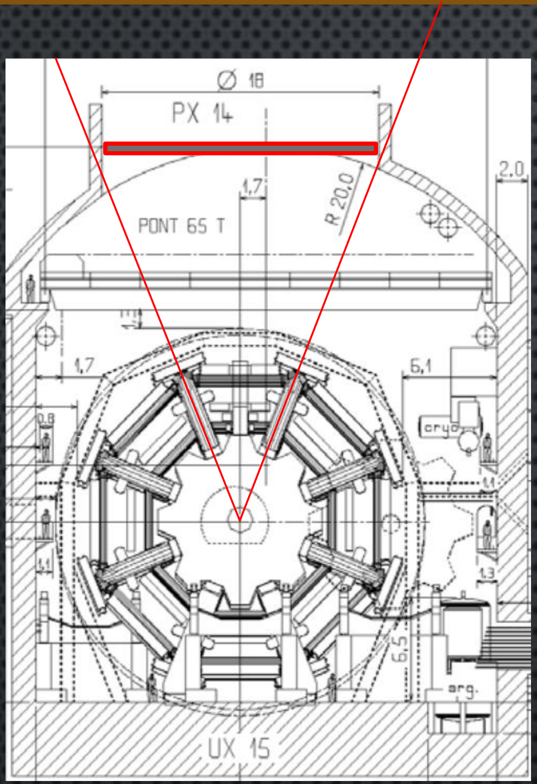
1 ring scenario

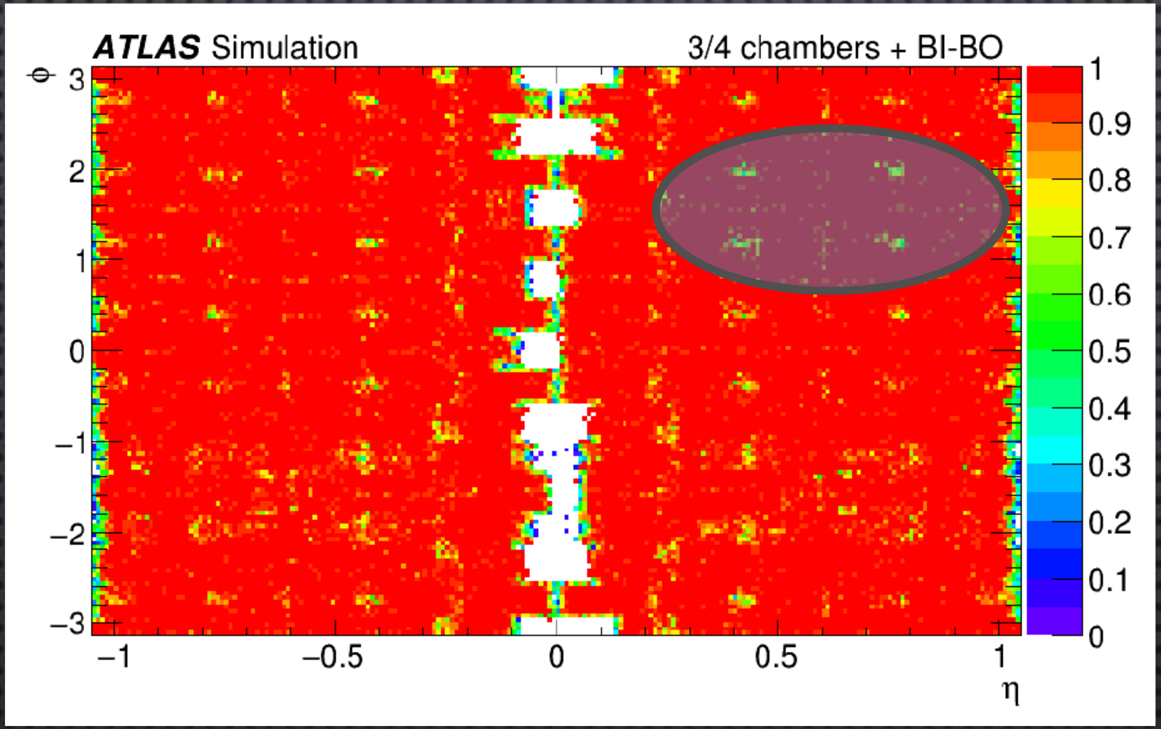


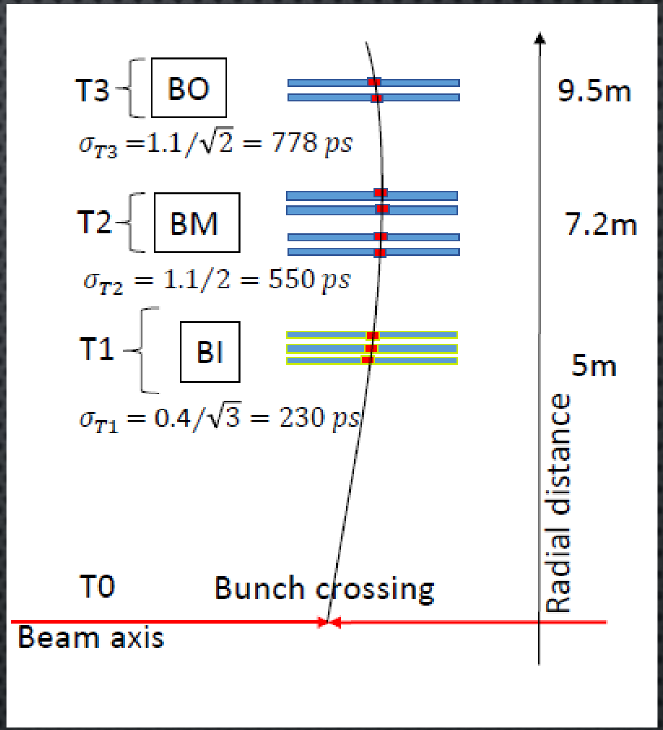
Extended scenario



PERFORMANCE OF THE ATLAS MUON SYSTEM





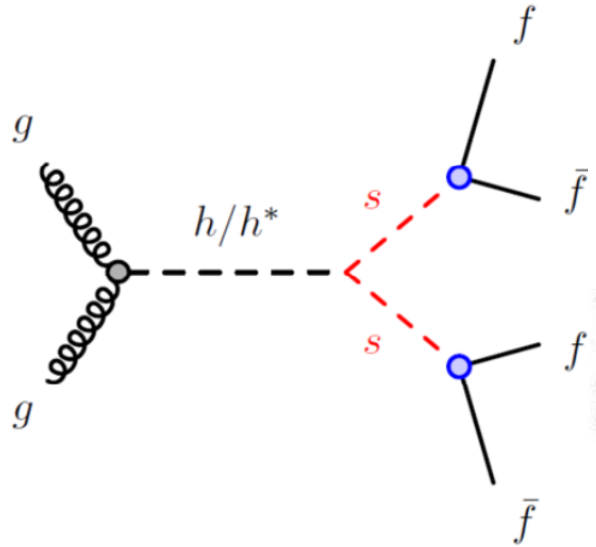


- NEW RPC LAYER IN THE INNER BARREL
- SAME RPC TECHNOLOGY BASELINE FOR ANUBIS
- HIGH EFFICIENCY PROJECTIVE TO THE ACCESS SHAFT
- CAN BE IMPROVED WITH ID COMBINED TRACKING

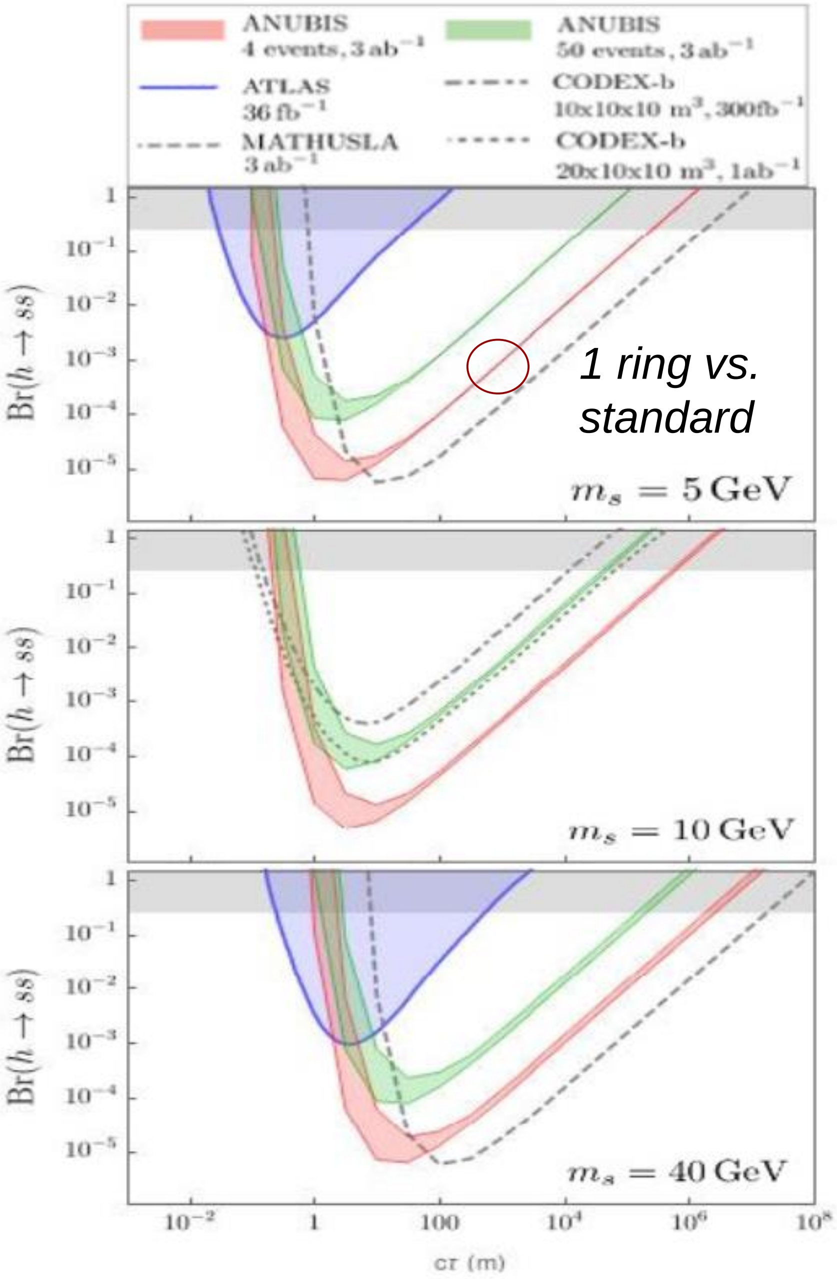
- TIME OF FLIGHT PERFORMANCE
- 9 TRACKING LAYERS
- 5 M INDEPENDENT LEVER ARM
- 0.5% RESOLUTION ON β

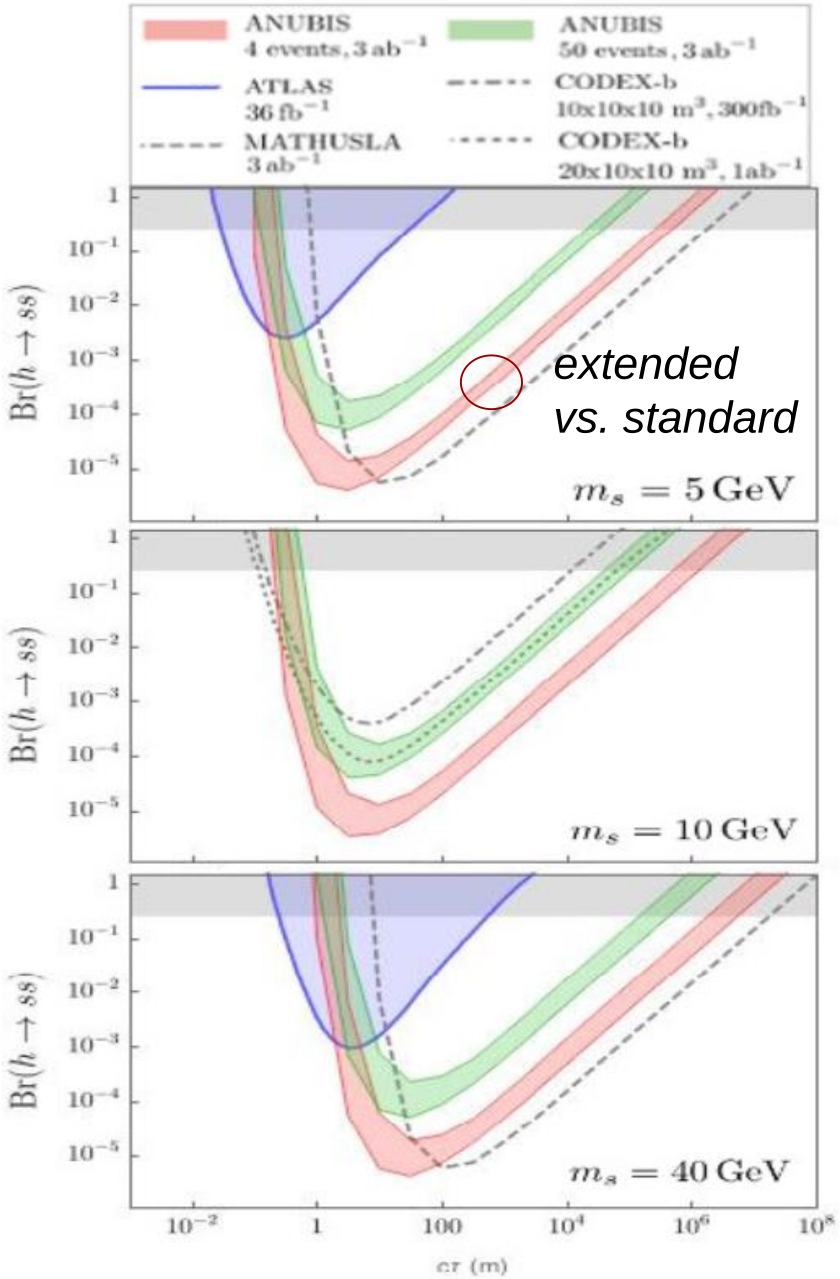
ANUBIS layout comparison

https://arxiv.org/pdf/1909.13022.pdf



- 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**

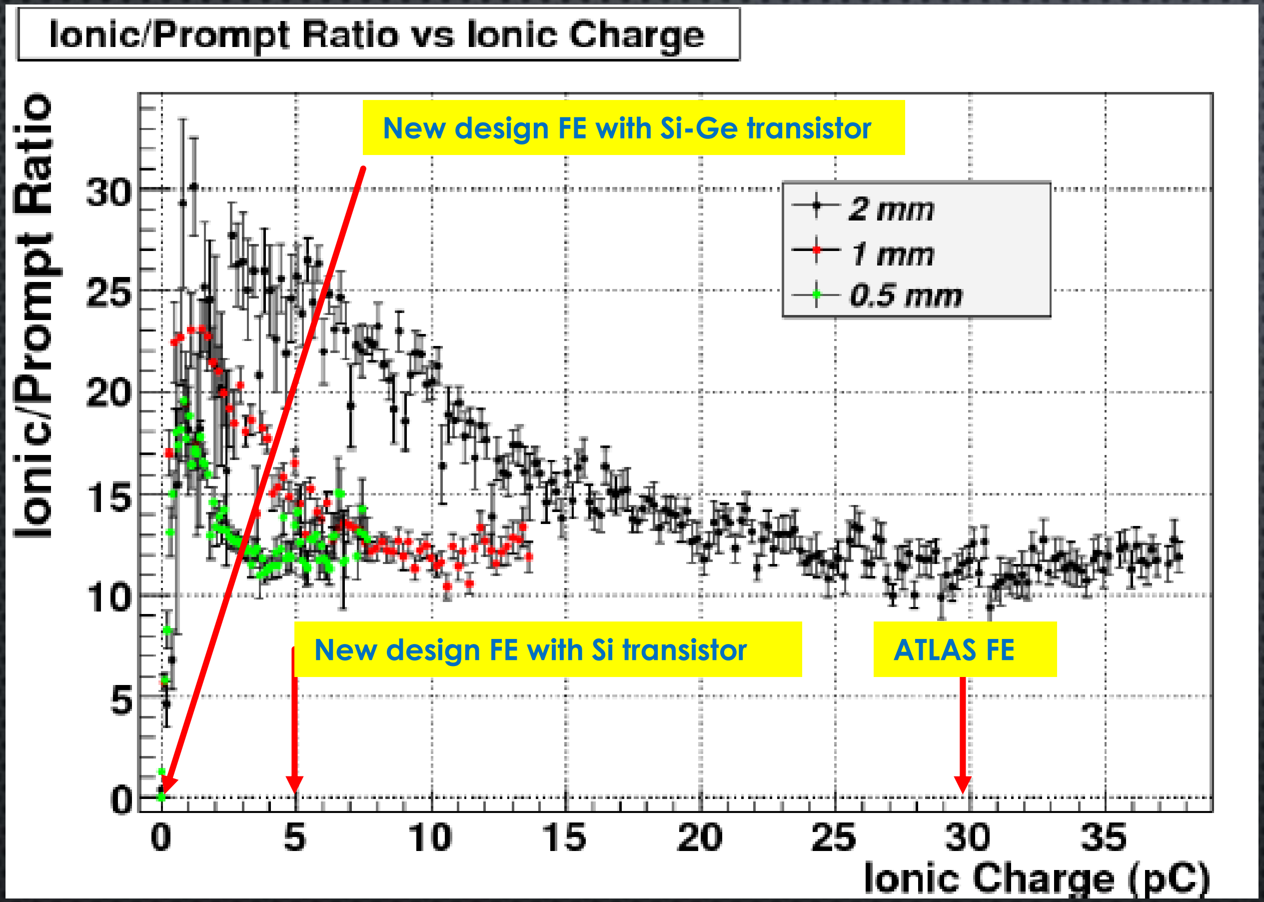
This applies also to CODEX-B which is preparing a large demonstrator using the same technology (See Vladimir talk)

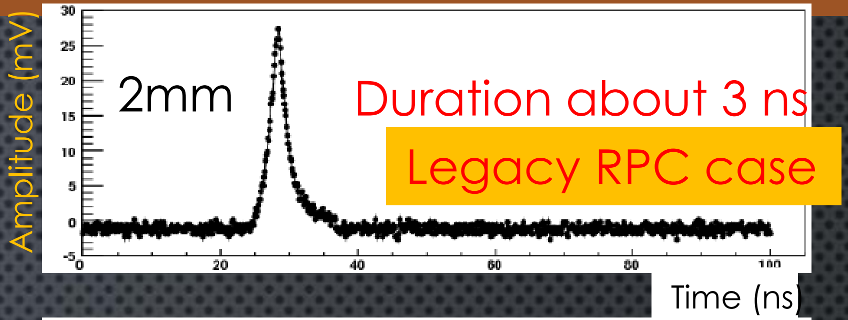
WHY ATLAS RPCs?

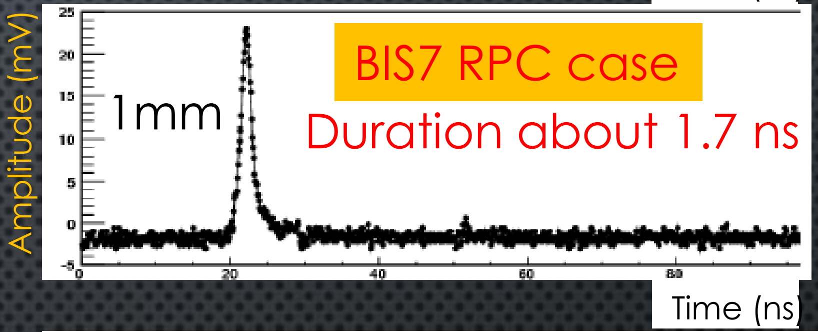
Turn key solution → **new generation RPCs designed for HL-LHC and construction can start in time**

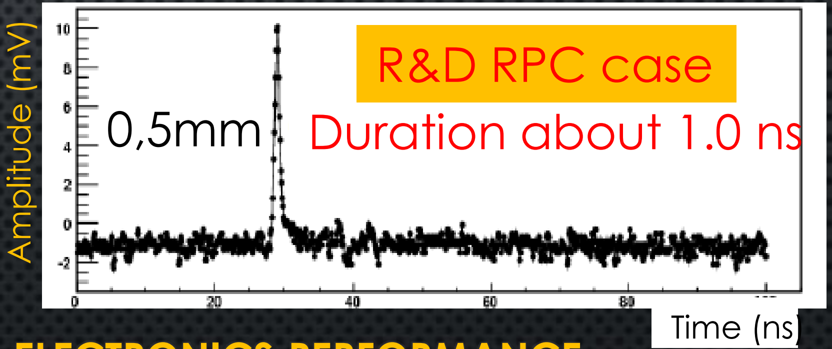
- INDUSTRIALLY PRODUCED ON LARGE SCALE → **LOW UNIT COST**
- THINNER GAS GAP → **HIGHER TIME RESOLUTION**
- BUILT-IN HIGH SENSITIVITY FRONT END → **HIGH EFFICIENCY WITH THIN GAS GAPS**
- 50 PS EMBEDDED TDC AND SERIALIZER→ **HIGH PERFORMANCE LOW COST, EASY TO READOUT**
- STAND-ALONE SINGLET STRUCTURE → **CAN BE COMBINED IN SANDWICH WITH HIGH Z LAYERS FOR PARTICLE ID**

GAS GAP VS. ELECTRONICS









Thinner gas gap

- → higher E field → higher charge density
- → same saturation with less charge
- → faster peaking time

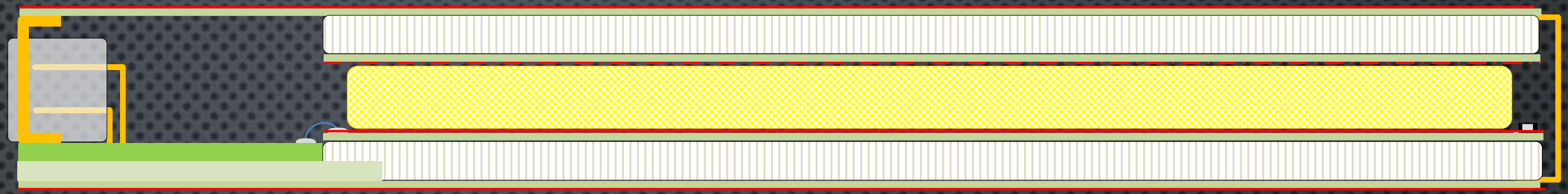
Higher electronics performance

- Can exploit thinner gas gap small & fast signals
- Can work at lower gas gain
- Compatible with eco-friendly gases

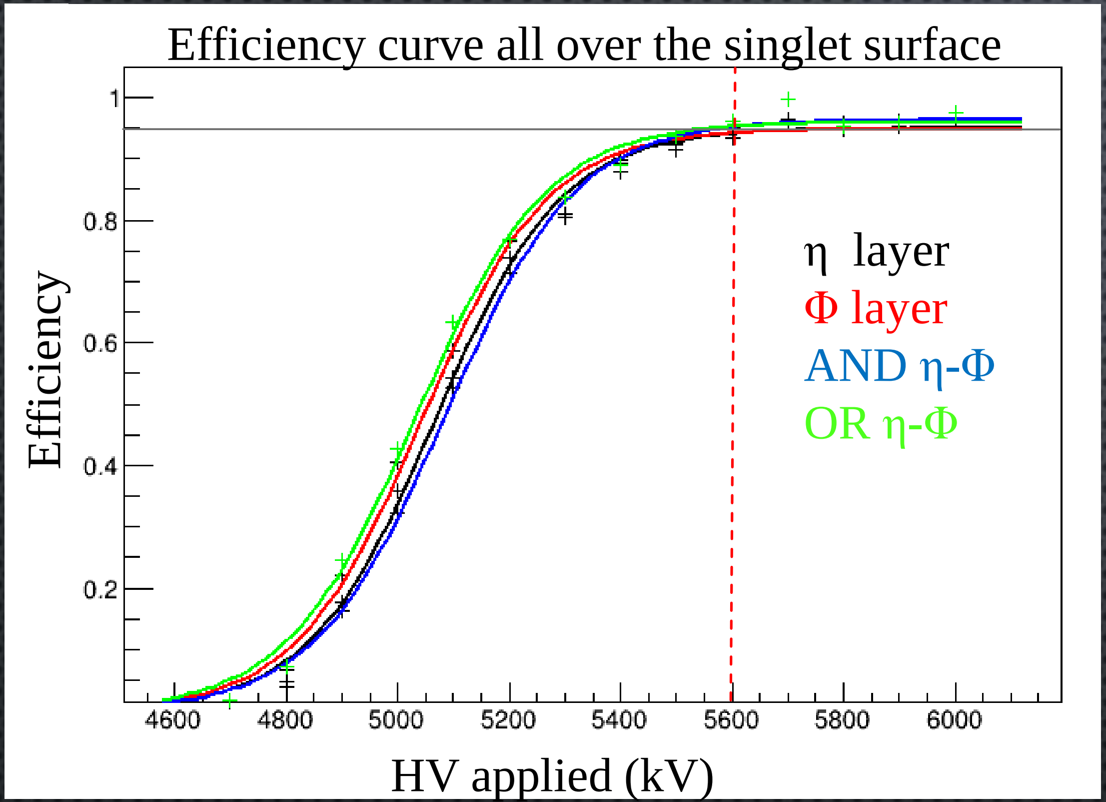
SINGLET STRUCTURE

A singlet is made of

- A RPC gas gap
- Two readout strip panels
  - Strip PCB facing the gap
  - Low ε_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

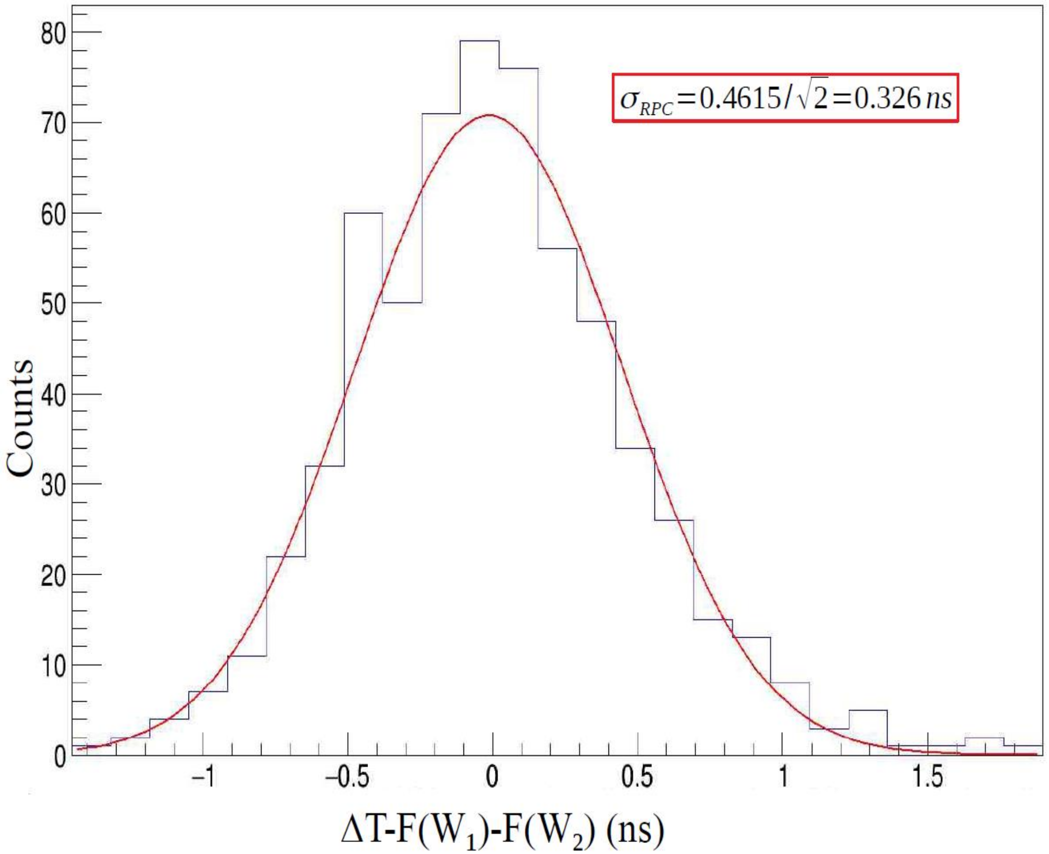


STATE OF THE ART PERFORMANCE WITH 1 MM GAS GAP



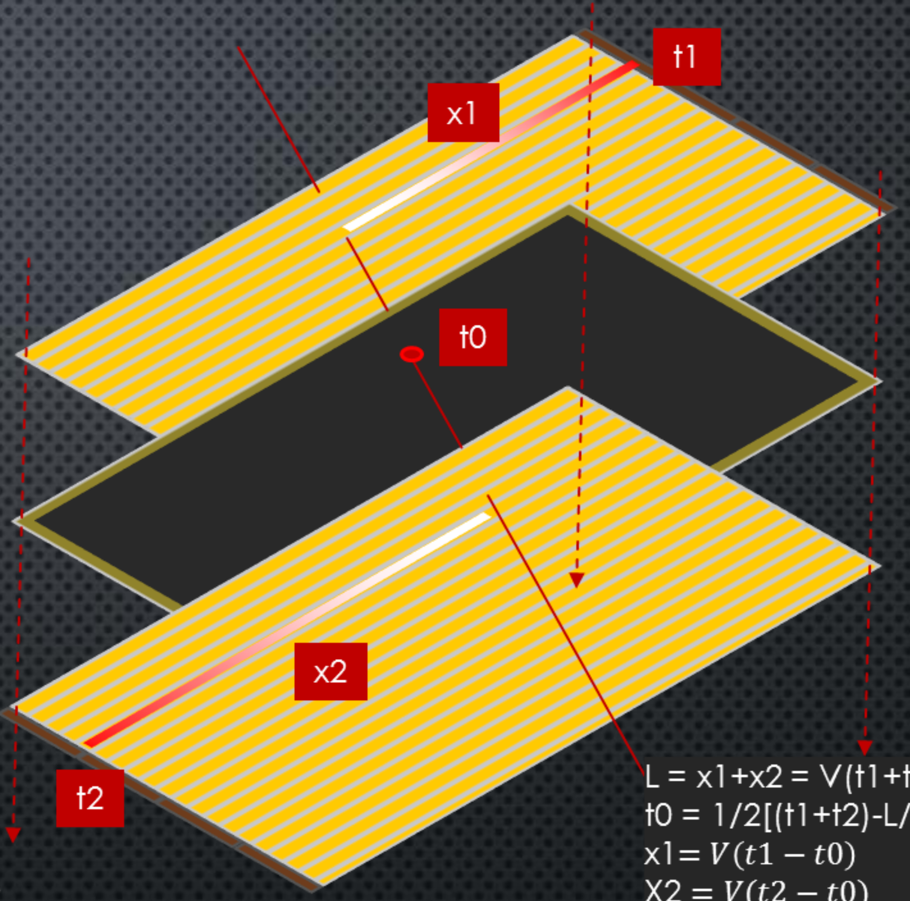
- 95% of efficiency at 5,6kV for each singlet
- Measurement over all surface with CR → a few percent of missing acceptance
- Inactive area 1% for the spacers

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



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



L = x1+x2 = V(t1+t2-2t0)
t0 = 1/2[(t1+t2)-L/v]
x1= $V(t1-t0)$
X2 = $V(t2-t0)$

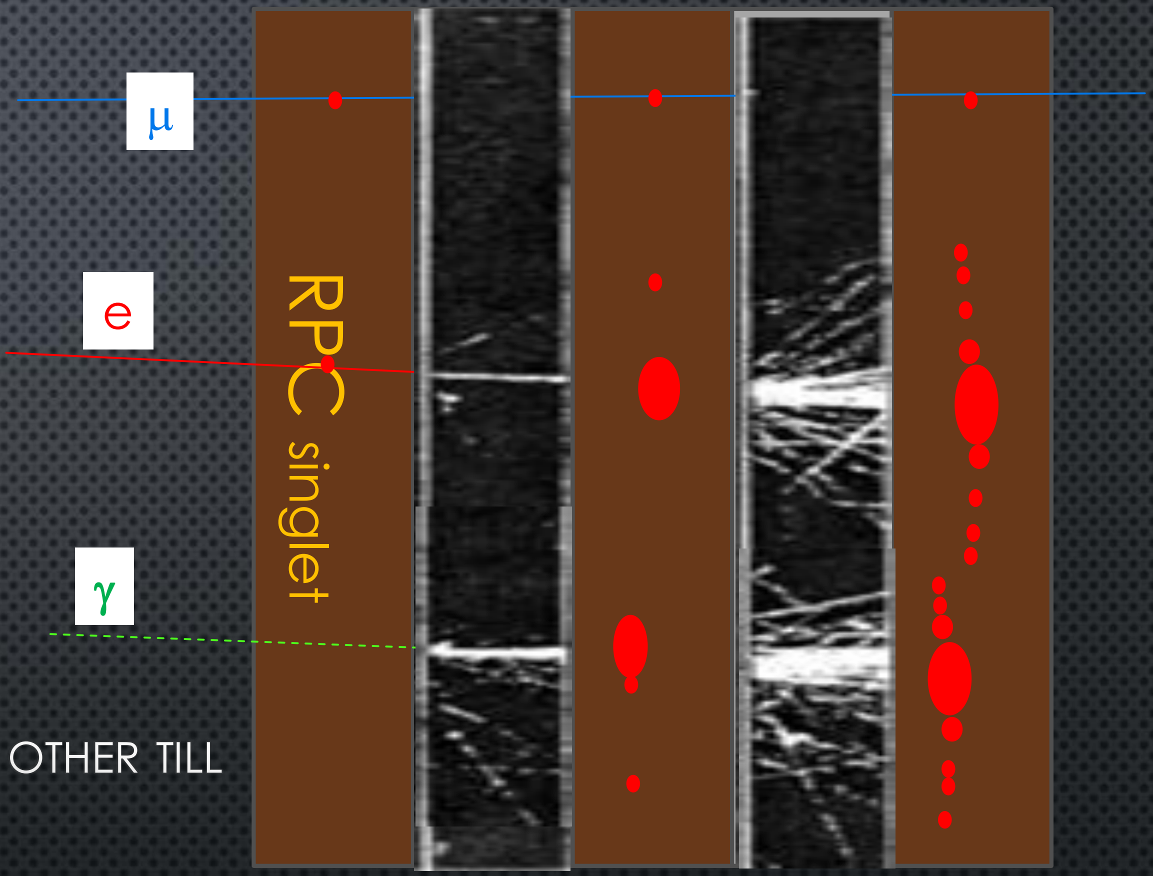
$\Delta x_1 = v/\sqrt{2}\,\Delta t \approx$ 1cm

See "5D tracking concept" in RPC2016

INITIAL DETECTOR DESIGN PROPOSAL

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 BUILT 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**