I-MCP:
IONIZATION MICRO-CHANNEL PLATES FOR FAST TIMING OF SHOWERS IN HIGH RATE ENVIRONMENTS

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i-MCP plan in one slide

- **R&D program towards a fast detector element based on micro-channel plates (MCP) to sample the ionizing component of electromagnetic showers at HL-LHC**
  - Extensively used in ion time-of-flight mass spectrometers
  - Never exploited in depth to detect the ionizing component of showers
- **The fast time resolution of MCPs exceeds anything that has been previously used in calorimeters**
- **Solution attractive due to recent technological progress in MCP production**
- **Expected outcome:**
  - Proof-of-concept and design of a radiation-hard module (~300 kGy and 10^{16} n/cm^2) with extreme time resolution (<50 ps) to be embedded in a sampling calorimeter or to be added as a standalone timing device (preshower)
  - ***This solution would factorize the quest for precision timing from the technological choice of the full calorimeter***

  - **Approved INFN project for 2014-2015**

Technical approach: (ionization) micro-channel plates

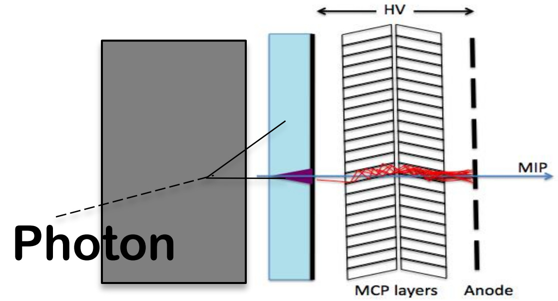
- **One (or more) layer(s) embedded in the calorimeter for fast timing of showers (<50 ps)**
  - *Possibly a preshower*: quest for precise timing decoupled from the choice of the calorimeter technology

- **Exploit MCPs as m.i.p. detector**

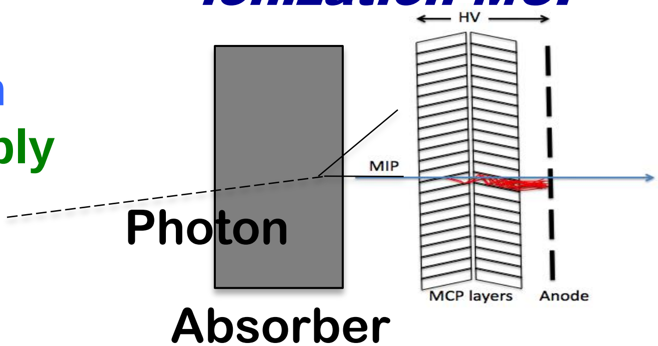
  1. **PMT-MCP**: Very fast (O(10 ps)), high efficiency to m.i.ps through Cerenkov emission in the quartz/glass window
  2. **"Ionization-MCP"**: efficiency to m.i.p.s
     Ɛ > 70% with at least σ_t=75 ps
     - Bondila et al., NIM A 478 (2002) 220

- **Option 2 could be sufficient to sample a shower where m.i.p. multiplicity is high**
  - **No photocathode → robust design / assembly**
  - First proposal for calorimetry (no timing): *A. A. Derevshchikov et al. Preprint IFVE 90-99, Protvino, Russia, 1990.*

Classical PMT-MCP+Absorber

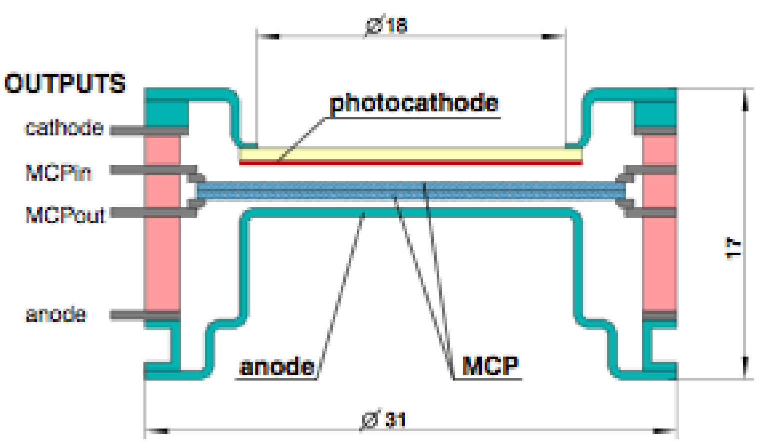


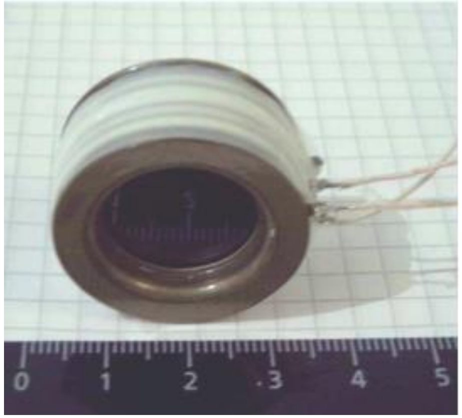
"ionization-MCP"

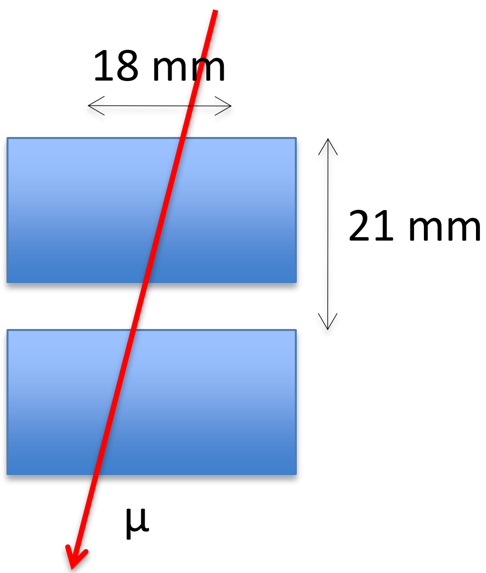


Preliminary tests with cosmic muons

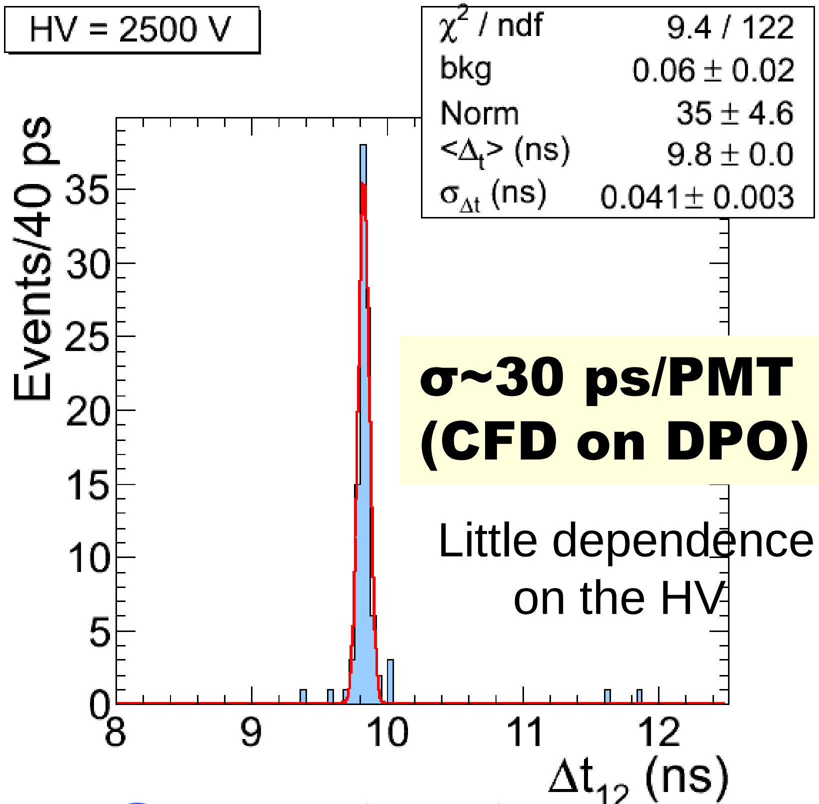
- **Test of ‘classical’ PMT-MCP with cosmic rays**
  - Two PMT-MCPs 1.8 cm diameter in coincidence (courtesy of M.Barnyakov, *BINP, Novosibirsk)*
    - ***Two MCP layers per tube in ‘chevron’ configuration – 10 μm pores***
    - *More properties: Lehman et al. NIM A595 (2008) 173; Barnyakov et al. A598 (2009) 160*
  - Time resolution from ***Δt*** spread of events in coincidence
    - ***Expected coincidence rate ~ 0.25 min^{-1} = 15 / hour***
  - Readout: basic circuit with finite components + DSO for trigger and timing







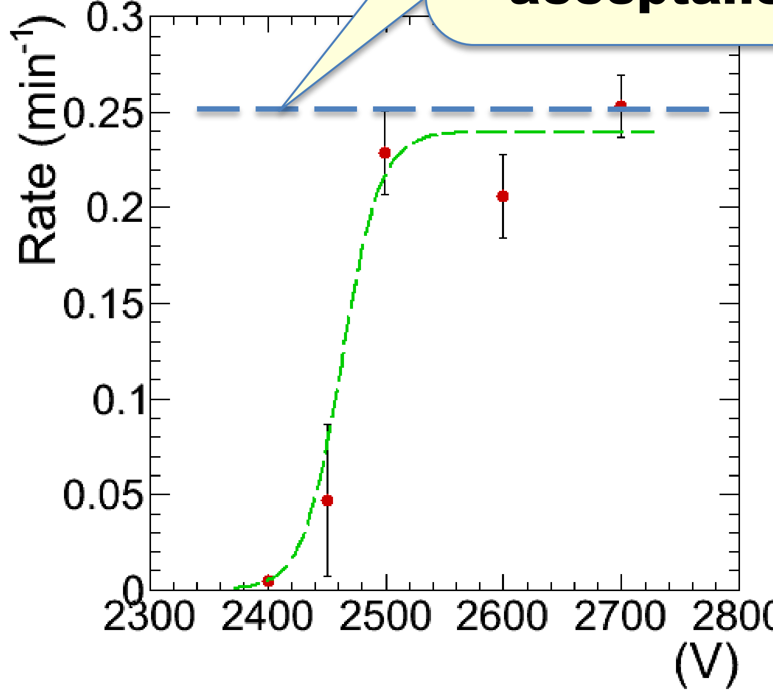
Exploitation of C emission



σ~30 ps/PMT (CFD on DPO)

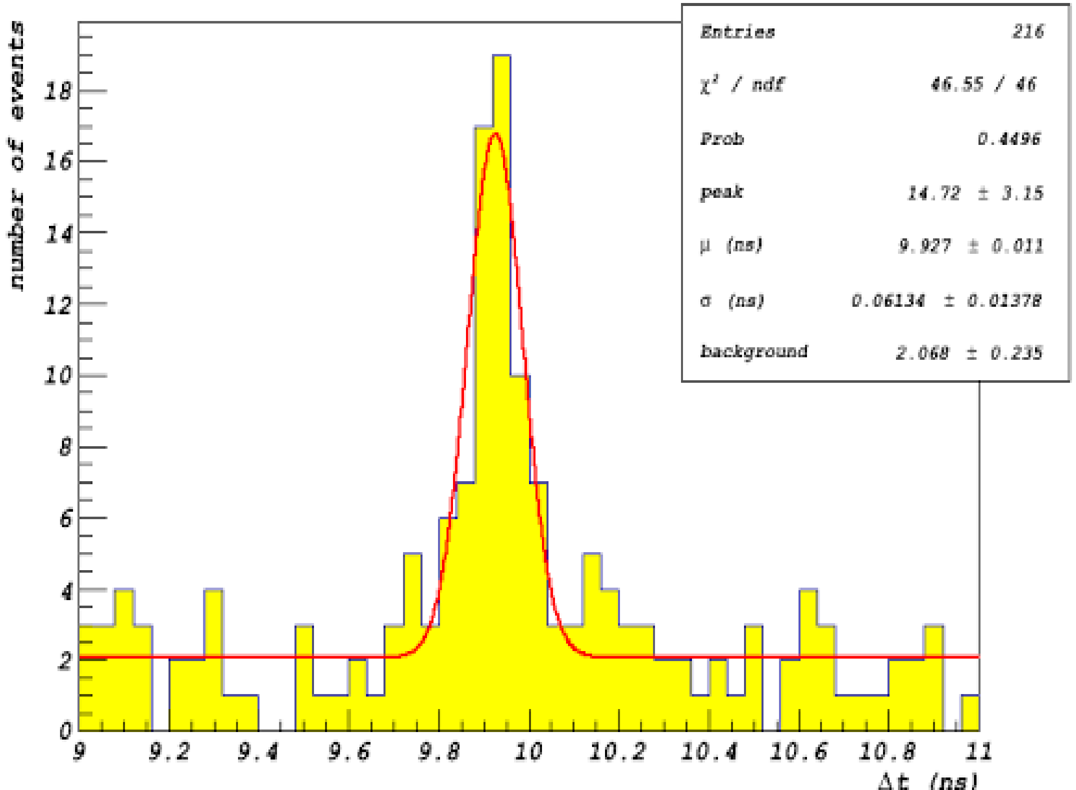
Little dependence on the HV

Rough expectation from μ flux and acceptance



- **Current setup:**
  - Exploit the optical window as **Cerenkov** radiator
  - <p.e.>~4 (1.2 mm with n=1.56; Q.E~10%, ΔE~1 eV)
- **Time resolution:**
  - 40 ps on the difference → ~30 ps (40 ps/√2) per PMT

Preliminary test in 'iMCP' mode



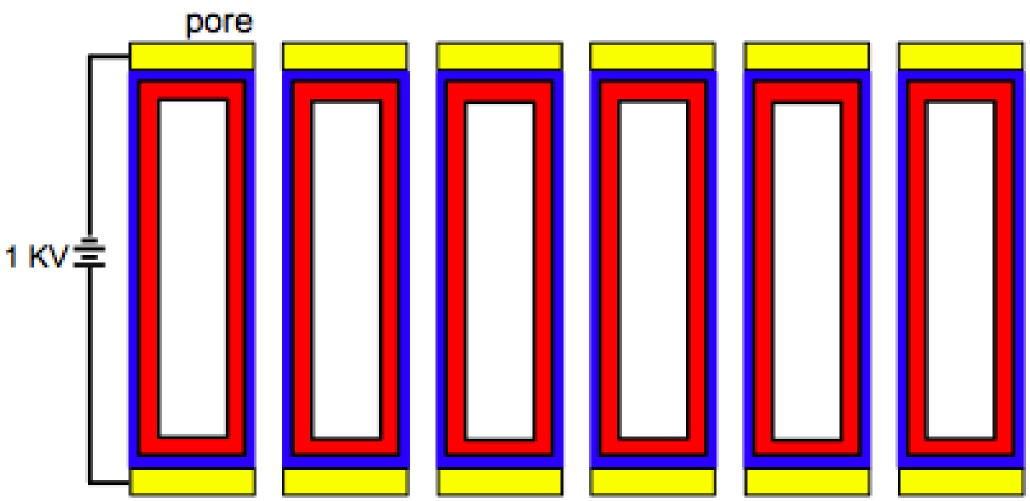
σ ~ 50 ps for the iMPC

Efficiency ~ 20%

- **Direct secondary emission from MCP surface**
  - *Collection of photoelectrons from photocathode inhibited in **one of the two** MCPs via positive bias relative to the MCP input*
- **Time resolution:**
  - 60 ps on the difference → ~ 50 ps on the i-MPC
    [assuming 30 ps from the PMT-MCP (see previous slide)]

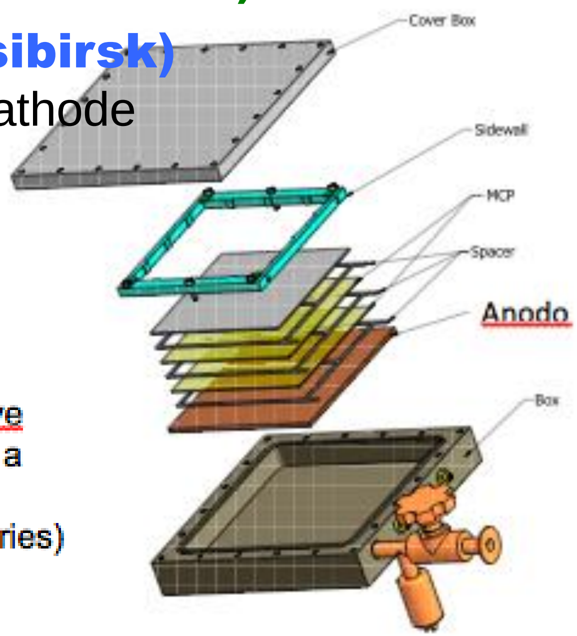
Ongoing R&D (two-year timescale):

- **Additional tests on existing devices ongoing:**
  - Planacon (Photonis) 5x5 cm^2 64 pixels: tests with (inhibited) photocathode
- **Test of Incom Ltd. glass+ALD wafers (developed by/with LAPPD):**
    - First purchase order placed for 5x5 cm^2 wafers
    - ***Goals: define geometry / emissive coatings***
  - **Full test of the i-MCP concept with cosmic rays**
  - **Characterization with EM showers at LNF-BTF (700 MeV e-)**
    - **Test beams this spring and in fall**
  - **Radiation hardness qualification (various sources)**
- **Contacts for collaboration with BINP (Novosibirsk)**
  - Test of additional emissive layer instead of photocathode
  - Test of alternate MCP wafers



- Resistive
- Emissive
- Conductiive

coatings on a glass wafer (with capillaries)



ALD = Atomic layer deposition

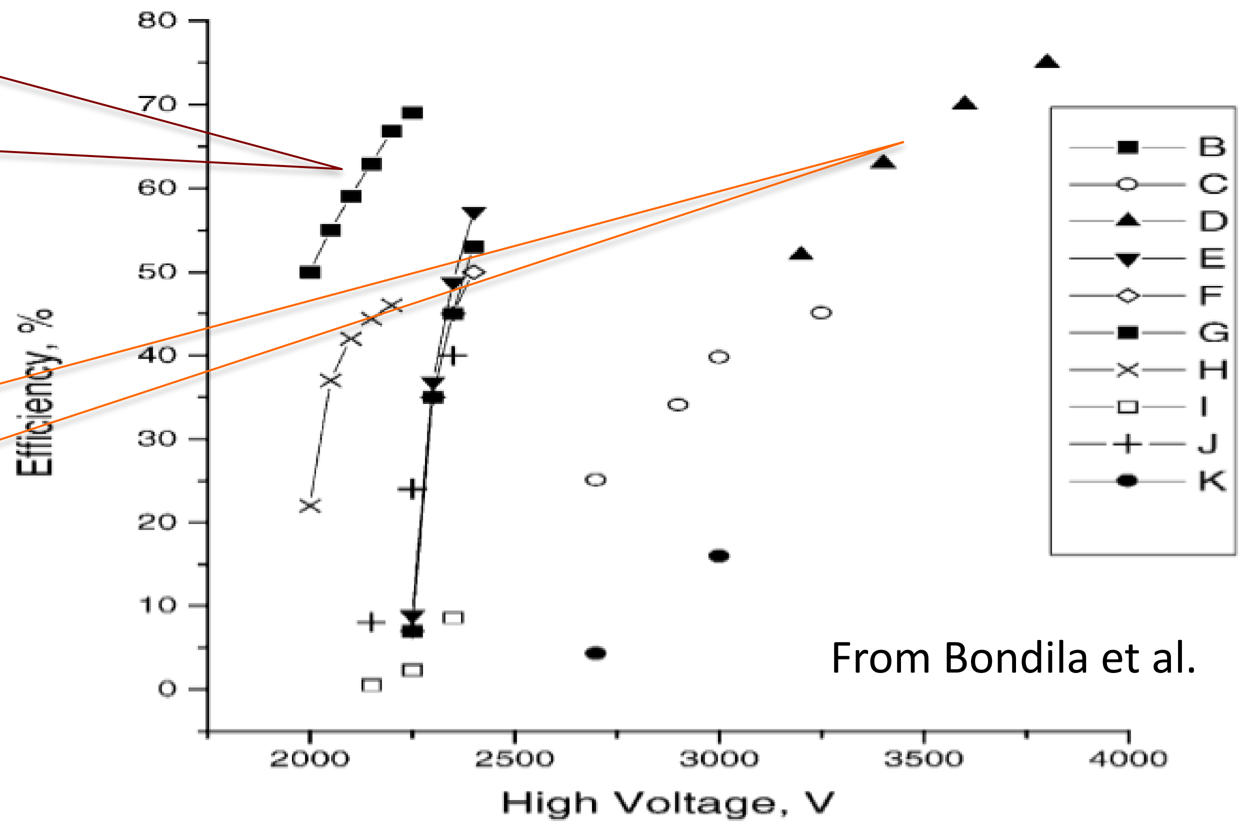
Effects of MCP parameters (I)

(*) Smaller pores and high thickness enhance MIP efficiency, according to Bondila et al., NIM A478 (2002) 220 (the only available test of the i-MCP concept with MIPs)

(**) Dependence on coating material and thickness (Al_2O_3 and MgO available, others on request)

Two MCPs Chevron Config. 12 µm / 0.8 mm High Gain

Three MCPs Z-stack Config. 25 µm / ?? mm

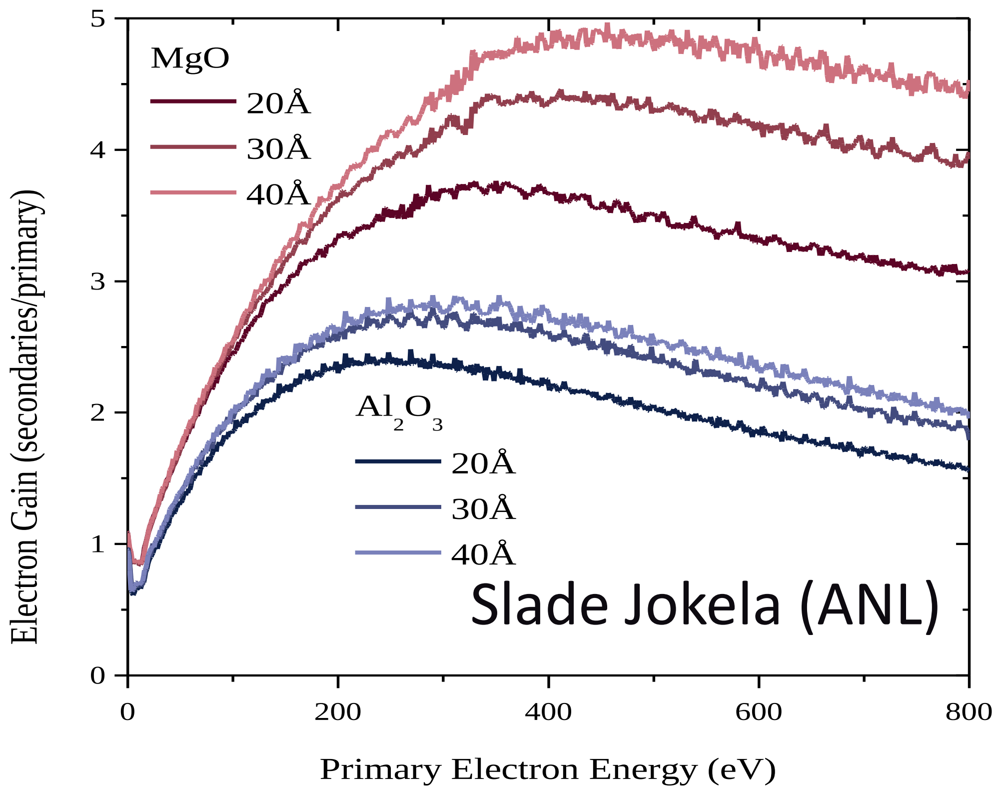


Effects of MCP parameters (II)

(*) Smaller pores and high thickness enhance MIP efficiency, according to Bondila et al., NIM A478 (2002) 220 (the only available test of the i-MCP concept with m.i.p.s)

(**) Dependence on coating material and thickness (Al_2O_3 and MgO available, others on request)

Note : this is far from m.i.p. regime (~3 MeV for electrons)



Instead of a summary

- **Expected outcome of the R&D:**
  - **Proof-of-concept and design of i-MCP prototypes for fast timing of EM showers**
    - ***Contingency***: MIP efficiency could be enhanced though Cerenkov emission in an optical window (photocathode may add complexity)
- **Application to CMS:**
  - Viability of the option with simulation
  - Integration in a calorimeter concept (preshower?)
  - Electronics and clock distribution
    - Not addressed in the R&D, but solutions of O(10) ps exists

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