Measurement of cross sections and couplings of the Higgs Boson using the ATLAS detector
• The Higgs at LHC:
  Production and decay mechanisms at LHC
• Parameterization used:
  Signal strength and k-framework
• Cross section and coupling measurements:
  • Run 1 overview
  • Run 2 measurements at $\sqrt{s}=13$ TeV

$m_H = 125.09 \pm 0.24 (\pm 0.21 \text{ stat.} \pm 0.11 \text{ syst.})$ GeV
The Higgs production at LHC can occur through the following mechanisms:

**ggF:** is the dominant production mode, $\sigma_{\text{ggF}}/\sigma_{\text{TOT}} = 87\% @ 13 \text{ TeV}$. 

**VBF:** whose signature is characterized by H +2jet forward, $\sigma_{\text{VBF}}/\sigma_{\text{TOT}} = 7\% @ 13 \text{ TeV}$. 

**VH:** whose signature is composed by a H associated to a W or a Z boson, $\sigma_{\text{VH}}/\sigma_{\text{TOT}} = 4\% @ 13 \text{ TeV}$. 

**ttH-bbH:** in which the H is associated to $t\bar{t}$-bar / bb-bar pairs, $\sigma_{\text{ttH+bbH}}/\sigma_{\text{TOT}} = 2\% @ 13 \text{ TeV}$.

**Decay channels:**
- $H\rightarrow ZZ^*\rightarrow 4l$: pure channel by very low statistics ($\text{BR}_{H\rightarrow ZZ^*\rightarrow 4l} \sim 2 \times 10^{-4}$)
- $H\rightarrow \gamma\gamma$: “easy” final state but low BR
- $H\rightarrow WW^*$: good sensitivity but low mass resolution
- VH-$bb$-bar & $H\rightarrow \tau\tau$: interesting for the measurements of couplings to fermions (huge bkgs)
- $H\rightarrow Z\gamma$ & $H\rightarrow \mu\mu$: low BR

<table>
<thead>
<tr>
<th>Decay channel</th>
<th>Branching ratio [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H \rightarrow bb$</td>
<td>57.5 ± 1.9</td>
</tr>
<tr>
<td>$H \rightarrow WW$</td>
<td>21.6 ± 0.9</td>
</tr>
<tr>
<td>$H \rightarrow gg$</td>
<td>8.56 ± 0.86</td>
</tr>
<tr>
<td>$H \rightarrow \gamma\gamma$</td>
<td>6.30 ± 0.36</td>
</tr>
<tr>
<td>$H \rightarrow \tau\tau$</td>
<td>2.90 ± 0.35</td>
</tr>
<tr>
<td>$H \rightarrow ZZ$</td>
<td>2.67 ± 0.11</td>
</tr>
<tr>
<td>$H \rightarrow Z\gamma$</td>
<td>0.228 ± 0.011</td>
</tr>
<tr>
<td>$H \rightarrow \mu\mu$</td>
<td>0.155 ± 0.014</td>
</tr>
</tbody>
</table>

Giada Mancini (LNF INFN)
Analyses in RunI have been optimized for the discovery

- The first measurements of the properties have shown that the observed boson was compatible, within the uncertainties, with the Higgs predicted by the SM.

Measurements in terms of:

- **Signal strength**: defined as the ratio of the $\sigma \cdot BR$ with respect to the SM (more model dependent):
  \[ \mu = \frac{(\sigma \cdot BR)_{obs}}{(\sigma \cdot BR)_{SM}} \]

- **Coupling modifiers ($k_j$)**, added as multiplying terms in the Higgs boson couplings to fermions and bosons in the SM Lagrangian, in order to take into account for New Physics (NP) effects that can occur both in production and decay:
  \[ \sigma_i \cdot BR^f = \frac{\sigma_i(\tilde{k}) \cdot \Gamma^f(\tilde{k})}{\Gamma_H} \]
  where \[ \kappa_j^2 = \Gamma_j^j / \Gamma_{SM}^j, \quad \kappa_j^2 = \sigma_j / \sigma_{SM}^j \]
  
  -> $k_j=1$ refers to the Standard Model case (SM)
Signal strength measurements

- Discovery of the Higgs with mass $m_H = 125.09 \pm 0.24 \, (\pm 0.21 \, \text{stat.} \pm 0.11 \, \text{syst.})$ GeV

- Measurements of the couplings to SM particles consistent with the SM within uncertainties

- Combined signal strength:
  \[ \mu = 1.09 \pm 0.07^{\text{stat}} \pm 0.04^{\text{exp.syst.}} \pm 0.03^{\text{th.bkg}} {+0.07}^{-0.06}^{\text{th.sig}} \]

- Results can be expressed in terms of couplings with fermions ($ggF, bbH, ttH$) or vector bosons ($VBF, WH, ZH$)
  \[ \mu_V/\mu_F = 1.06^{+0.35}_{-0.27} \, \text{(assuming no 7-8 TeV dependency)} \]

\begin{tabular}{|l|c|c|}
  \hline
  Production process & Measured significance ($\sigma$) & Expected significance ($\sigma$) \\
  \hline
  VBF & 5.4 & 4.7 \\
  WH & 2.4 & 2.7 \\
  ZH & 2.3 & 2.9 \\
  VH & 3.5 & 4.2 \\
  $ttH$ & 4.4 & 2.0 \\
  \hline
  Decay channel & & \\
  $H \to \tau\tau$ & 5.5 & 5.0 \\
  $H \to bb$ & 2.6 & 3.7 \\
  \hline
\end{tabular}
Interference effects (like in $H \rightarrow \gamma\gamma$) allow to test the relative sign $\kappa_V e \kappa_F$ (universal coupling constant of the Higgs to vector bosons and fermions).

Reduced-$k$ can be defined:

$$ y_{F,i} = k_{F,i} \frac{m_{F,i}}{v} e \quad y_{V,i} = \sqrt{k_{V,i}} \frac{m_{V,i}}{v} $$

where $v$ is the vev of the Higgs field. Built to give qualitatively the consistency with the SM.
RUN2

- Enhance sensitivity to production modes
- Observation of exclusive production modes in each channel splitting the events in more restricted phase
- Better precision on the coupling measurements
H→ZZ*→4l

- two isolated-lepton pairs (SFOS)
- $p_T > 5/7$ GeV for muons/electrons

Events extracted in the mass region $115 < m_{4l} < 130$ GeV are analyzed to extract the fiducial and total cross sections.

- $m_{4l}$ distribution is used as a discriminant to increase the sensitivity to the signal.
- Combining the sub-channels: $\sigma_{\text{fid,comb}}^{4\ell} = 4.54^{+1.02}_{-0.90}$ fb
- Total cross section contains extrapolation factors to the full phase space:
  \[ \sigma_{\text{tot}} = 81^{+18}_{-16} \text{ pb} \quad \sigma_{\text{tot,SM}} = 55.5^{+3.8}_{-4.4} \text{ pb} \]
Categorization to extract the cross section per production mode.

<table>
<thead>
<tr>
<th>Analysis category</th>
<th>ggF + bbH + t\bar{t}H</th>
<th>VBF</th>
<th>WH</th>
<th>ZH</th>
<th>ZZ*</th>
<th>Z + jets, t\bar{t}</th>
<th>Total</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-jet</td>
<td>11.2 ± 1.4</td>
<td>0.120 ± 0.019</td>
<td>0.047 ± 0.007</td>
<td>0.060 ± 0.006</td>
<td>6.2 ± 0.6</td>
<td>0.84 ± 0.12</td>
<td>18.4 ± 1.6</td>
<td>21</td>
</tr>
<tr>
<td>1-jet</td>
<td>5.7 ± 2.4</td>
<td>0.59 ± 0.05</td>
<td>0.137 ± 0.012</td>
<td>0.091 ± 0.008</td>
<td>1.62 ± 0.21</td>
<td>0.44 ± 0.07</td>
<td>8.5 ± 2.4</td>
<td>12</td>
</tr>
<tr>
<td>2-jet VBF enriched</td>
<td>1.9 ± 0.9</td>
<td>0.92 ± 0.07</td>
<td>0.074 ± 0.007</td>
<td>0.052 ± 0.005</td>
<td>0.22 ± 0.05</td>
<td>0.24 ± 0.11</td>
<td>3.4 ± 0.9</td>
<td>9</td>
</tr>
<tr>
<td>2-jet VH enriched</td>
<td>1.1 ± 0.5</td>
<td>0.084 ± 0.009</td>
<td>0.143 ± 0.012</td>
<td>0.101 ± 0.009</td>
<td>0.166 ± 0.035</td>
<td>0.088 ± 0.011</td>
<td>1.6 ± 0.5</td>
<td>2</td>
</tr>
<tr>
<td>VH-leptonic</td>
<td>0.055 ± 0.004</td>
<td>&lt; 0.01</td>
<td>0.067 ± 0.004</td>
<td>0.011 ± 0.001</td>
<td>0.016 ± 0.002</td>
<td>0.012 ± 0.010</td>
<td>0.16 ± 0.01</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>20 ± 4</td>
<td>1.71 ± 0.14</td>
<td>0.47 ± 0.04</td>
<td>0.315 ± 0.027</td>
<td>8.2 ± 0.9</td>
<td>1.62 ± 0.07</td>
<td>32 ± 4</td>
<td>44</td>
</tr>
</tbody>
</table>

Giada Mancini (LNF INFN)
**Signal extraction:** Likelihood fit to the BDT discriminants distributions in each category

**Compatibility with the SM:**
- $\sigma_{ggF+bbH+tH} B(H\rightarrow ZZ^*) @ 1.1\sigma$
- $\sigma_{VBF} B(H\rightarrow ZZ^*) @ 1.4\sigma$

**Cross section per production mode compared to the SM prediction:**

**Observed:**
- $\sigma_{ggF+bbH+tH} \cdot B(H\rightarrow ZZ^*) = 1.80^{+0.49}_{-0.44}$ pb
- $\sigma_{VBF} \cdot B(H\rightarrow ZZ^*) = 0.37^{+0.28}_{-0.21}$ pb
- $\sigma_{VH} \cdot B(H\rightarrow ZZ^*) = 0^{+0.15}_{-0.15}$ pb

**Expected:**
- $\sigma_{SM,ggF+bbH+tH} \cdot B(H\rightarrow ZZ^*) = 1.31 \pm 0.07$ pb
- $\sigma_{SM,VBF} \cdot B(H\rightarrow ZZ^*) = 0.100 \pm 0.003$ pb
- $\sigma_{SM,VH} \cdot B(H\rightarrow ZZ^*) = 0.059 \pm 0.002$ pb

**Results can be expressed within the k framework**
- $k_F$ for the prod. modes mediated by fermions
- $k_V$ for those mediated by vector bosons

Giada Mancini (LNF INFN)
**H->γγ**

- two isolated photons
- $E_T / m_{γγ} > 0.35$ (0.25)
- Unbinned maximum likelihood fit on the $m_{γγ}$ spectrum
- Categorization aiming for production modes separation and event kinematics and topology

<table>
<thead>
<tr>
<th>Category</th>
<th>Events</th>
<th>$B_{90}$</th>
<th>$S_{90}$</th>
<th>$f_{90}$</th>
<th>$Z_{90}$</th>
<th>$S_{fit}^{90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central low-$p_{Tγ}$</td>
<td>31907</td>
<td>3500</td>
<td>180</td>
<td>0.05</td>
<td>3.04</td>
<td>120</td>
</tr>
<tr>
<td>Central high-$p_{Tγ}$</td>
<td>1319</td>
<td>140</td>
<td>20</td>
<td>0.13</td>
<td>1.66</td>
<td>15</td>
</tr>
<tr>
<td>Forward low-$p_{Tγ}$</td>
<td>85129</td>
<td>13000</td>
<td>310</td>
<td>0.02</td>
<td>2.73</td>
<td>200</td>
</tr>
<tr>
<td>Forward high-$p_{Tγ}$</td>
<td>3977</td>
<td>540</td>
<td>33</td>
<td>0.06</td>
<td>1.38</td>
<td>25</td>
</tr>
<tr>
<td>VBF loose</td>
<td>604</td>
<td>76</td>
<td>15</td>
<td>0.16</td>
<td>1.62</td>
<td>21</td>
</tr>
<tr>
<td>VBF tight</td>
<td>76</td>
<td>8.8</td>
<td>7.3</td>
<td>0.45</td>
<td>2.19</td>
<td>13</td>
</tr>
<tr>
<td>VH hadronic loose</td>
<td>937</td>
<td>120</td>
<td>8.9</td>
<td>0.07</td>
<td>0.81</td>
<td>4.7</td>
</tr>
<tr>
<td>VH hadronic tight</td>
<td>66</td>
<td>6.7</td>
<td>2.3</td>
<td>0.26</td>
<td>0.86</td>
<td>1.0</td>
</tr>
<tr>
<td>VH $E_{Tmiss}$</td>
<td>20</td>
<td>2.4</td>
<td>0.81</td>
<td>0.26</td>
<td>0.50</td>
<td>0.18</td>
</tr>
<tr>
<td>VH one-lepton</td>
<td>8</td>
<td>1.0</td>
<td>0.57</td>
<td>0.37</td>
<td>0.53</td>
<td>0.12</td>
</tr>
<tr>
<td>VH dilepton</td>
<td>3</td>
<td>0.4</td>
<td>0.30</td>
<td>0.43</td>
<td>0.43</td>
<td>0.07</td>
</tr>
<tr>
<td>$t\bar{t}H$ hadronic</td>
<td>72</td>
<td>8.1</td>
<td>1.8</td>
<td>0.18</td>
<td>0.60</td>
<td>-0.23</td>
</tr>
<tr>
<td>$t\bar{t}H$ leptonic</td>
<td>19</td>
<td>2.3</td>
<td>1.3</td>
<td>0.36</td>
<td>0.78</td>
<td>-0.18</td>
</tr>
</tbody>
</table>

\[ Z_{90} = \sqrt{2((S_{90} + B_{90})ln(1 + S_{90}/B_{90}) - S_{90})} \]
\[ f_{90} = S_{90}/(S_{90} + B_{90}) \]

Giada Mancini (LNF INFN)

ATLAS Preliminary

VBF-enhanced

$\sqrt{s} = 13$ TeV, 13.3 fb$^{-1}$

$H\rightarrow\gamma\gamma$, $m_H = 125.09$ GeV

**13.3 fb$^{-1}$ at 13 TeV**
- Fiducial XS measured in phase space regions sensitive to the inclusive Higgs boson production, the VBF and the H production in association with a charged lepton.

- Exclusive event categories enriched in specific production processes, as for the signal strength measurements
  - VH production cross sections determined using the WH and ZH SM ratios

\[
\begin{align*}
\sigma_{ggH} \times \mathcal{B}(H \rightarrow \gamma\gamma) &= 65^{+32}_{-31} \text{ fb} \\
\sigma_{VBF} \times \mathcal{B}(H \rightarrow \gamma\gamma) &= 19.2^{+6.8}_{-6.1} \text{ fb} \\
\sigma_{VH} \times \mathcal{B}(H \rightarrow \gamma\gamma) &= 1.2^{+6.5}_{-5.4} \text{ fb} \\
\sigma_{t\bar{t}H} \times \mathcal{B}(H \rightarrow \gamma\gamma) &= -0.3^{+1.4}_{-1.1} \text{ fb}
\end{align*}
\]
Combination of the 13 TeV results in terms of XSs per production mode

<table>
<thead>
<tr>
<th>Decay mode</th>
<th>ggF</th>
<th>VBF</th>
<th>VHhad</th>
<th>VH1ep</th>
<th>top</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H \rightarrow \gamma \gamma$</td>
<td>$(\sigma \cdot B)_{ggF}^{\gamma \gamma}$</td>
<td>$(\sigma \cdot B)_{VBF}^{\gamma \gamma}$</td>
<td>$(\sigma \cdot B)_{VH\text{had}}^{\gamma \gamma}$</td>
<td>$(\sigma \cdot B)_{VH\text{lep}}^{\gamma \gamma}$</td>
<td>$(\sigma \cdot B)_{\text{top}}^{\gamma \gamma}$</td>
</tr>
<tr>
<td>$H \rightarrow ZZ^*$</td>
<td>$(\sigma \cdot B)_{ggF}^{ZZ}$</td>
<td>$(\sigma \cdot B)_{VBF}^{ZZ}$</td>
<td>fixed to SM</td>
<td>fixed to SM</td>
<td>fixed to SM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Best fit value (pb)</th>
<th>SM prediction (pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_{ggF}$</td>
<td>47.8 $^{+9.8}_{-9.4}$</td>
</tr>
<tr>
<td>$\sigma_{VBF}$</td>
<td>7.9 $^{+2.8}_{-2.4}$</td>
</tr>
<tr>
<td>$\sigma_{VH\text{had}}$</td>
<td>$-2.5^{+2.9}_{-2.6}$</td>
</tr>
<tr>
<td>$\sigma_{VH\text{lep}}$</td>
<td>0.32 $^{+1.07}_{-0.79}$</td>
</tr>
<tr>
<td>$\sigma_{\text{top}}$</td>
<td>$-0.11^{+0.67}_{-0.54}$</td>
</tr>
</tbody>
</table>

- BRs assumed from SM
- Evidence for the VBF with a local significance of 4.0 $\sigma$ (1.9 $\sigma$ exp.)
- Total signal strength $\mu = 1.13^{+0.18}_{-0.17}$ (p-value = 43%)

Giada Mancini (LNF INFN)
Total cross section measurements

**ATLAS Preliminary**

- $\sqrt{s} = 7$ TeV, 4.5 fb$^{-1}$
- $\sqrt{s} = 8$ TeV, 20.3 fb$^{-1}$
- $\sqrt{s} = 13$ TeV, 13.3 fb$^{-1}$ ($\gamma\gamma$), 14.8 fb$^{-1}$ (ZZ*)

<table>
<thead>
<tr>
<th>Decay channel</th>
<th>Total cross section ($pp\to H + X$)</th>
<th>$\sqrt{s} = 7$ TeV</th>
<th>$\sqrt{s} = 8$ TeV</th>
<th>$\sqrt{s} = 13$ TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H\to\gamma\gamma$</td>
<td>$\sqrt{s} = 7$ TeV</td>
<td>$35^{+13}_{-12}$ pb</td>
<td>$30.5^{+7.5}_{-7.4}$ pb</td>
<td>$37^{+14}_{-13}$ pb</td>
</tr>
<tr>
<td>$H\to ZZ^* \to 4\ell$</td>
<td>$\sqrt{s} = 7$ TeV</td>
<td>$33^{+21}_{-16}$ pb</td>
<td>$37^{+9}_{-8}$ pb</td>
<td>$81^{+18}_{-16}$ pb</td>
</tr>
<tr>
<td>Combination</td>
<td>$\sqrt{s} = 7$ TeV</td>
<td>$34 \pm 10$ (stat.) $^{+4}_{-2}$ (syst.) pb</td>
<td>$33.3^{+5.5}<em>{-5.3}$ (stat.) $^{+1.7}</em>{-1.3}$ (syst.) pb</td>
<td>$59.0^{+9.7}<em>{-9.2}$ (stat.) $^{+4.4}</em>{-3.5}$ (syst.) pb</td>
</tr>
<tr>
<td>SM predictions [7]</td>
<td>$\sqrt{s} = 7$ TeV</td>
<td>$19.2 \pm 0.9$ pb</td>
<td>$24.5 \pm 1.1$ pb</td>
<td>$55.5^{+2.4}_{-3.4}$ pb</td>
</tr>
</tbody>
</table>

Giada Mancini (LNF INFN)
H->WW* (VBF and WH)

- VBF analysis: 2 leptons and >=2 jets (large DY background Z→ee/μμ, only eμ/μe final states are taken into account)
- WH analysis: events with 3 leptons of a total electric charge of ±e, in the presence of missing transverse momentum

5.8 fb⁻¹ @ 13 TeV

\[ \sigma_{\text{VBF}} \cdot \mathcal{B}_{H\rightarrow WW^*} = 1.4^{+0.8}_{-0.6}(\text{stat})^{+0.5}_{-0.4}(\text{sys}) \text{ pb} \]

\[ \sigma_{\text{WH}} \cdot \mathcal{B}_{H\rightarrow WW^*} = 0.9^{+1.1}_{-0.9}(\text{stat})^{+0.7}_{-0.8}(\text{sys}) \text{ pb} \]

- The observed (expected) signal significance (@ m_H=125.0 GeV) is 1.9σ (1.2σ) for VBF and 0.77σ (0.24σ) for WH
- 95% CL upper limits on the (σ B)_{VBF} at 3.0 pb and on the (σ B)_{WH} at 3.3 pb
H\rightarrow bb \quad 13.2 \text{ fb}^{-1} @ 13 \text{ TeV}

- Huge bkg from multi-jet -> incl. search challenging
- Look at VH leptonic decays (lower XS than ggH)
- Event selection: 2 high-\pT b-tagged jets together with 0 (Z → \nu\nu), 1 (W → l\nu) or 2 (Z → ll) charged leptons (e,\mu)
- Categories built using N_{jets}
- multivariate discriminants based on kinematics observables are used in each category

\[ \mu = 0.21^{+0.36}_{-0.35} \text{(stat.)} \pm 0.36 \text{(syst)} \]

Observed combined limit on the ratio of the (\sigma B) wrt the SM for m_H = 125 GeV:

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Limit Exp.</th>
<th>Limit Obs.</th>
<th>(p_0) Exp.</th>
<th>(p_0) Obs.</th>
<th>Significance Exp.</th>
<th>Significance Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-lepton</td>
<td>1.4^{+0.6}_{-0.4}</td>
<td>2.0</td>
<td>0.07</td>
<td>0.15</td>
<td>1.45</td>
<td>1.02</td>
</tr>
<tr>
<td>1-lepton</td>
<td>2.0^{+0.8}_{-0.6}</td>
<td>2.1</td>
<td>0.15</td>
<td>0.46</td>
<td>1.04</td>
<td>0.10</td>
</tr>
<tr>
<td>2-lepton</td>
<td>1.8^{+0.7}_{-0.5}</td>
<td>1.7</td>
<td>0.13</td>
<td>0.57</td>
<td>1.14</td>
<td>-0.17</td>
</tr>
<tr>
<td>Combined</td>
<td>1.0^{+0.4}_{-0.3}</td>
<td>1.2</td>
<td>0.03</td>
<td>0.34</td>
<td>1.94</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Giada Mancini (LNF INFN)
H→μμ

• Clean final state signature
• Irreducible DY bkg Z/γ* →μμ
• VBF and ggH enriched categories further splitted based on the event topology and kinematics
• BDT trained for the >=2jet categories:
  VBF\text{t}ight (BDT score > 0.9),
  VBF\text{l}oose (0.7 < BDT score < 0.9)

The observed (expected) upper limit on μ at 95% is found to be 3.0 (3.1) for m_H = 125 GeV. Combined with the ATLAS Run 1 data, the observed (expected) upper limit is 2.8 (2.9) at the 95% CL.
tfH production in the γγ, multilepton, and b¯b decay channels

- σ_{ttH} o(10^{-2}σ_{ggH})
- Combination to test the presence of a signal (m_H=125 GeV)

The combined signal strength is:

$$\mu_{ttH} = 1.8 \, ^{+0.4}_{-0.4} \, \text{(stat.)} \, ^{+0.6}_{-0.5} \, \text{(syst.)} = 1.8 \, ^{+0.7}_{-0.7}$$

which corresponds to an observed significance of 2.8 σ.

The sensitivity of this combination exceeds the Run-1 ttH expected significance of 1.5 σ. All three analyses are within 1.5 σ of the central value.

Giada Mancini (LNF INFN)
Conclusions

- **Overview of the Run1** measurements presented
- Measurements of the cross sections and couplings of SM particles with the Higgs boson have been performed with 13 TeV p-p collisions
- **High resolution channels** ($H \rightarrow \gamma \gamma$ and $H \rightarrow ZZ^* \rightarrow 4l$) are ideal to measure the Higgs properties
- No significant deviations wrt the SM predictions has been observed
- Measurements are statistically limited

--> More than $100 \text{ fb}^{-1}$ expected by the end of Run2!

Looking forward for more data!
Thanks for your attention!
Backup