



# How do Large Collaborations Work? Why?

## LHC-ATLAS as an Example

**Austrian Chamber of Commerce Workshop**

**October 18, 2022**

**Markus Nordberg, Head of Resources Development**

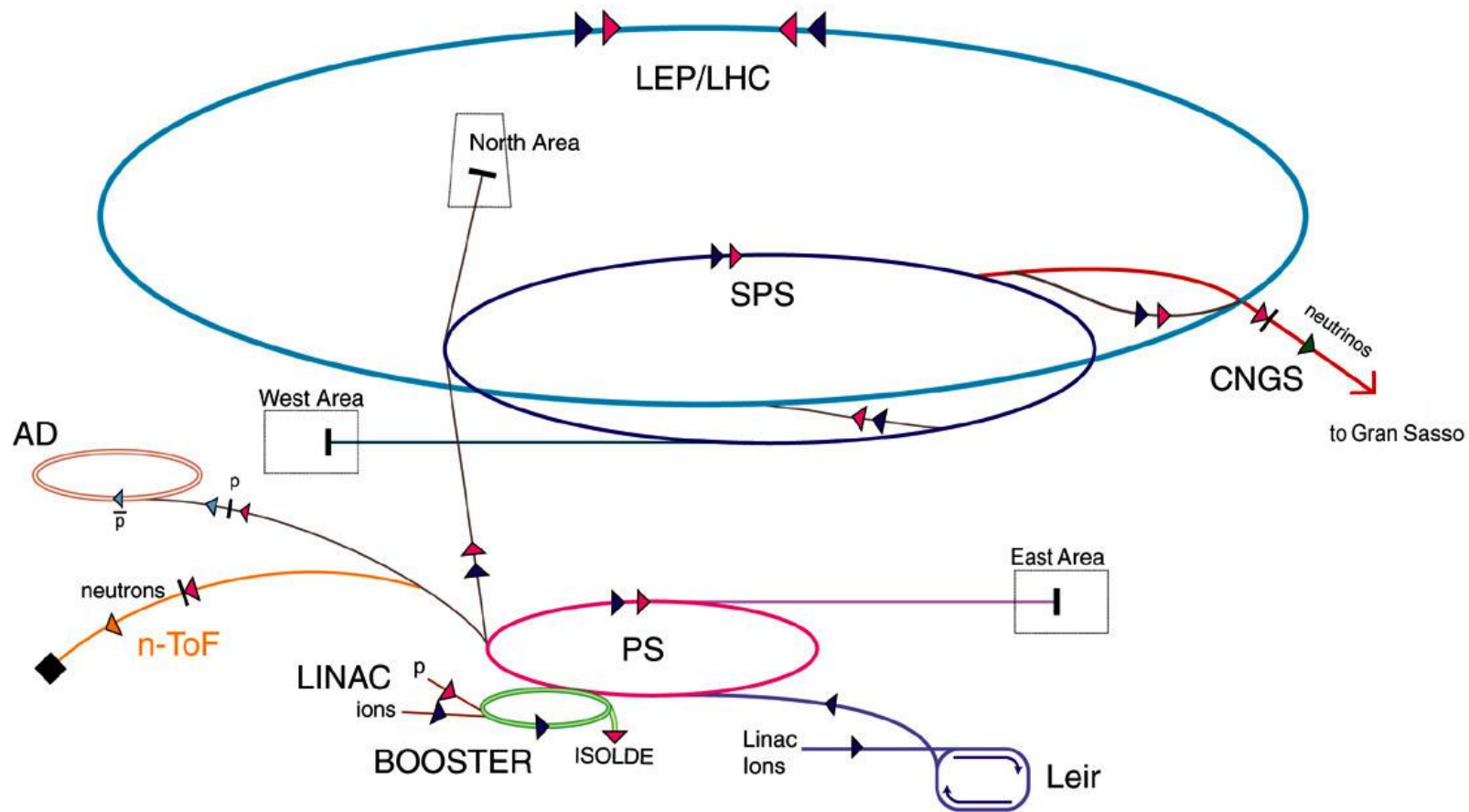
**Development and Innovation Unit (IPT-DI)**







# Accelerator chain at CERN, a complex business

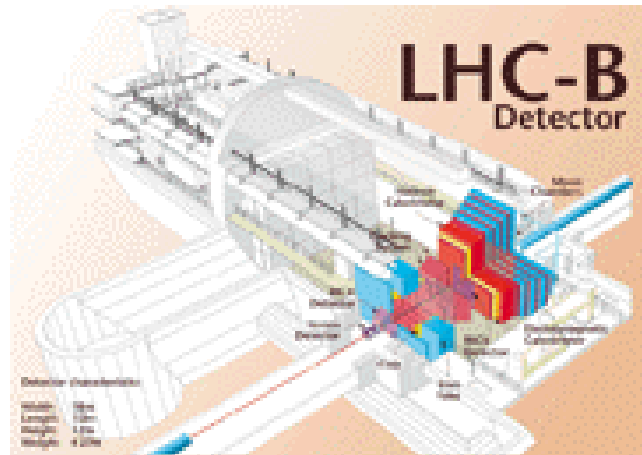
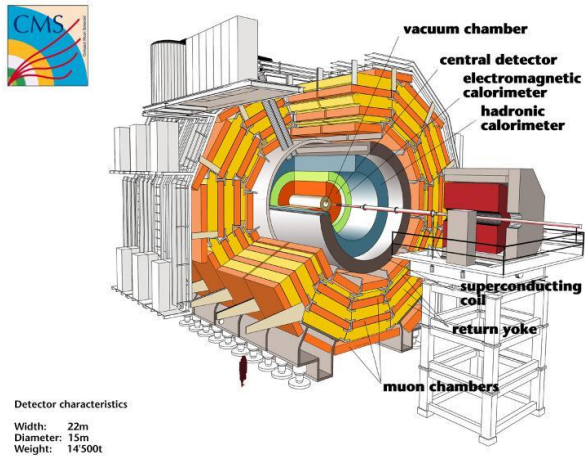
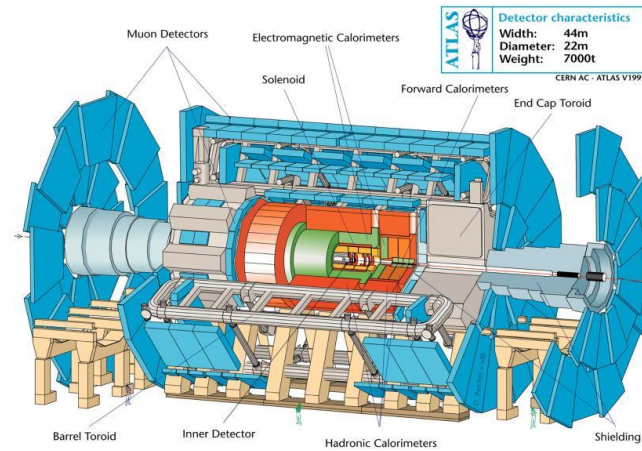
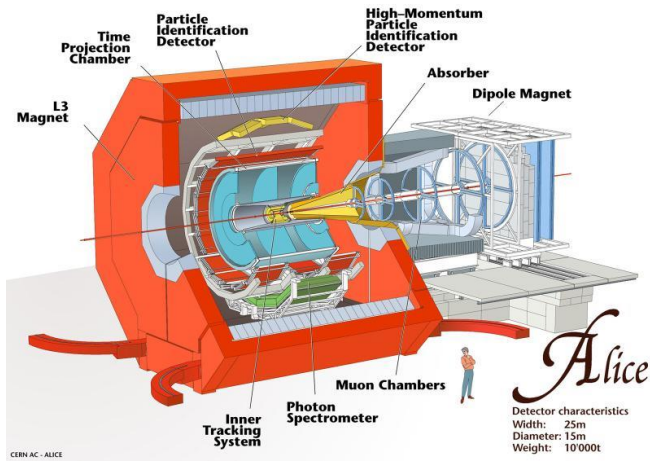


- ▶ p (proton)
- ▶ ion
- ▶ neutron
- ▶  $\bar{p}$  (antiproton)
- ▶ proton/antiproton conversion
- ▶ neutrino

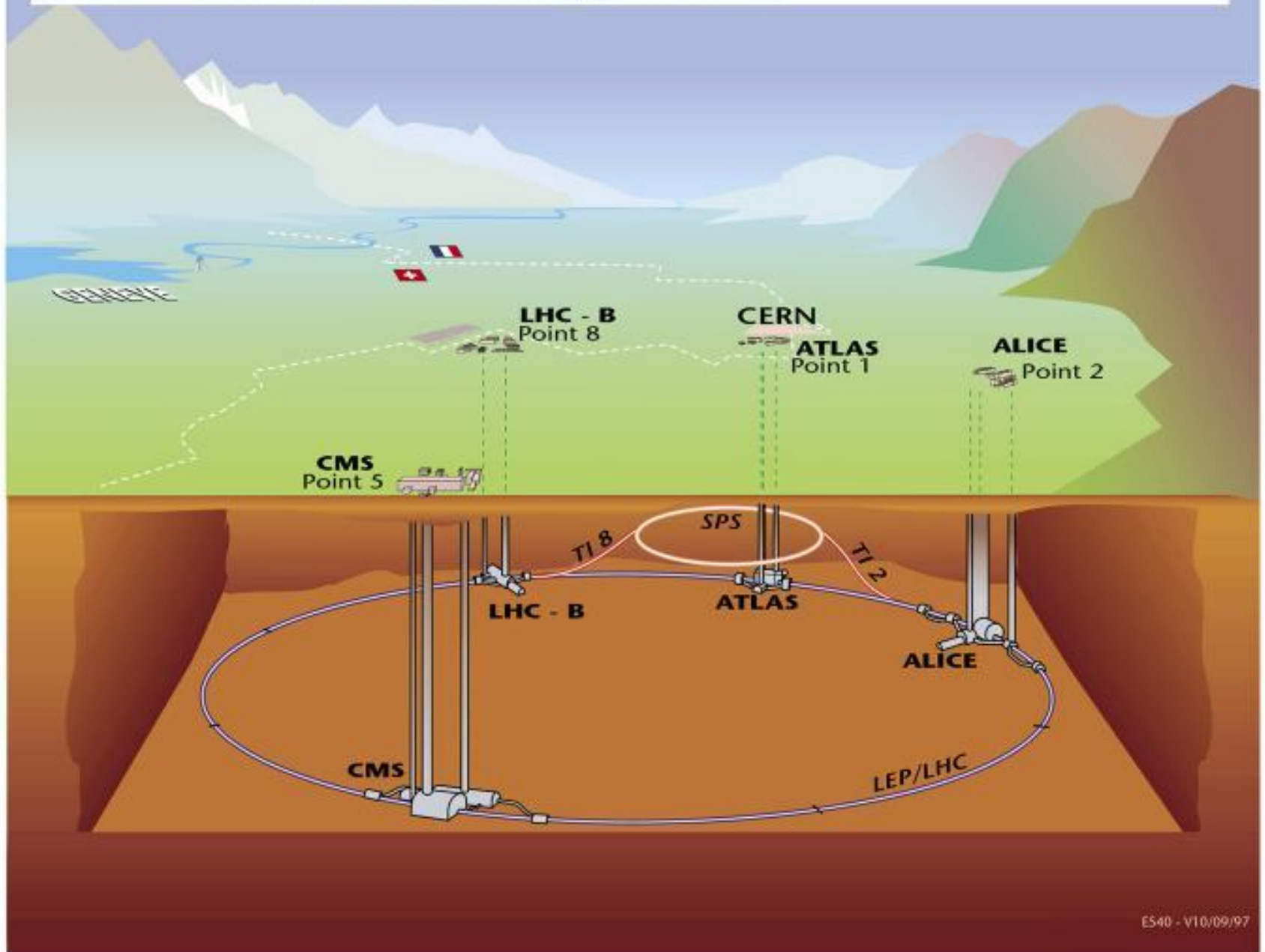
- AD Antiproton Decelerator
- PS Proton Synchrotron
- SPS Super Proton Synchrotron

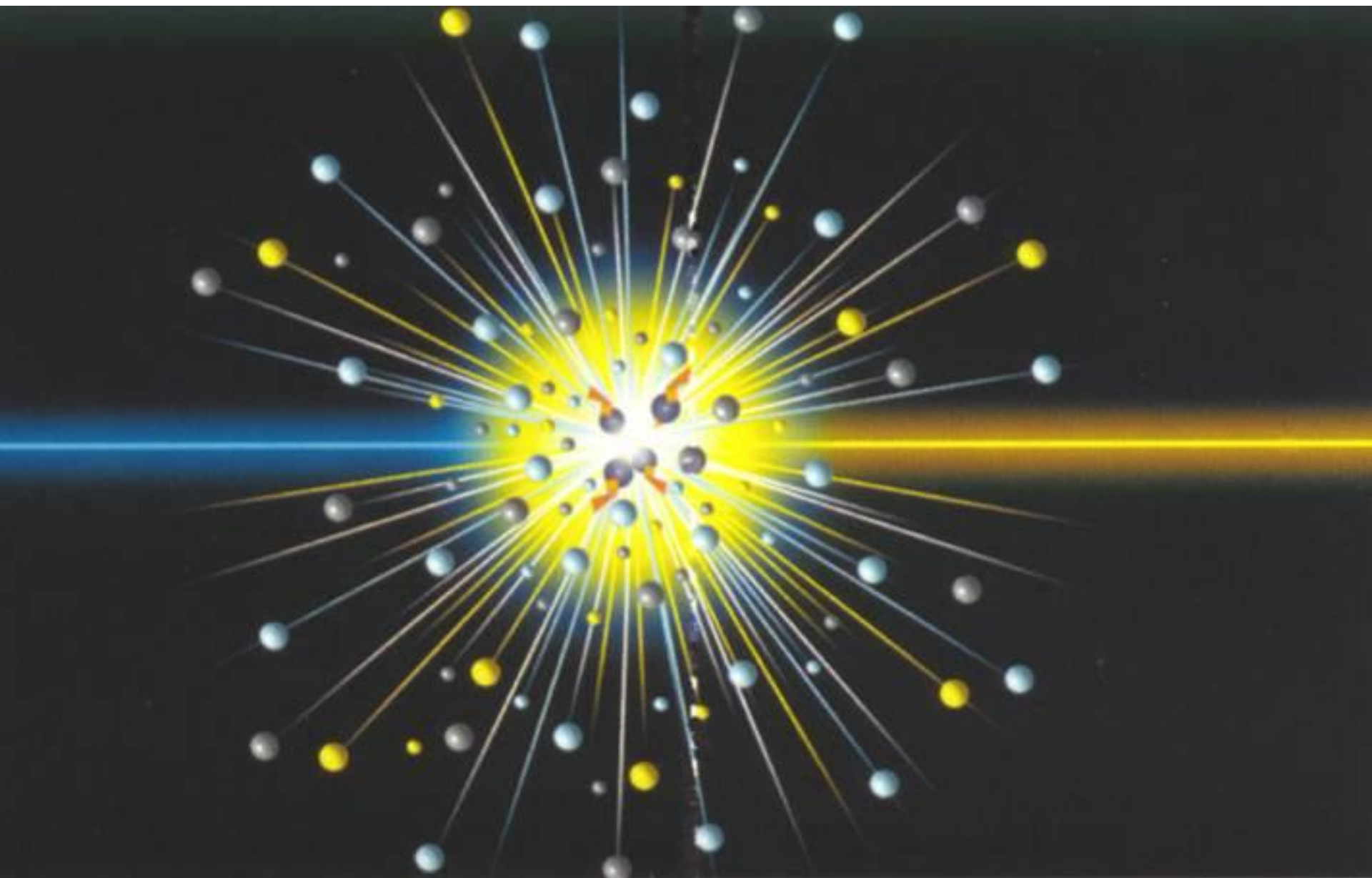
- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS Cern Neutrinos Gran Sasso

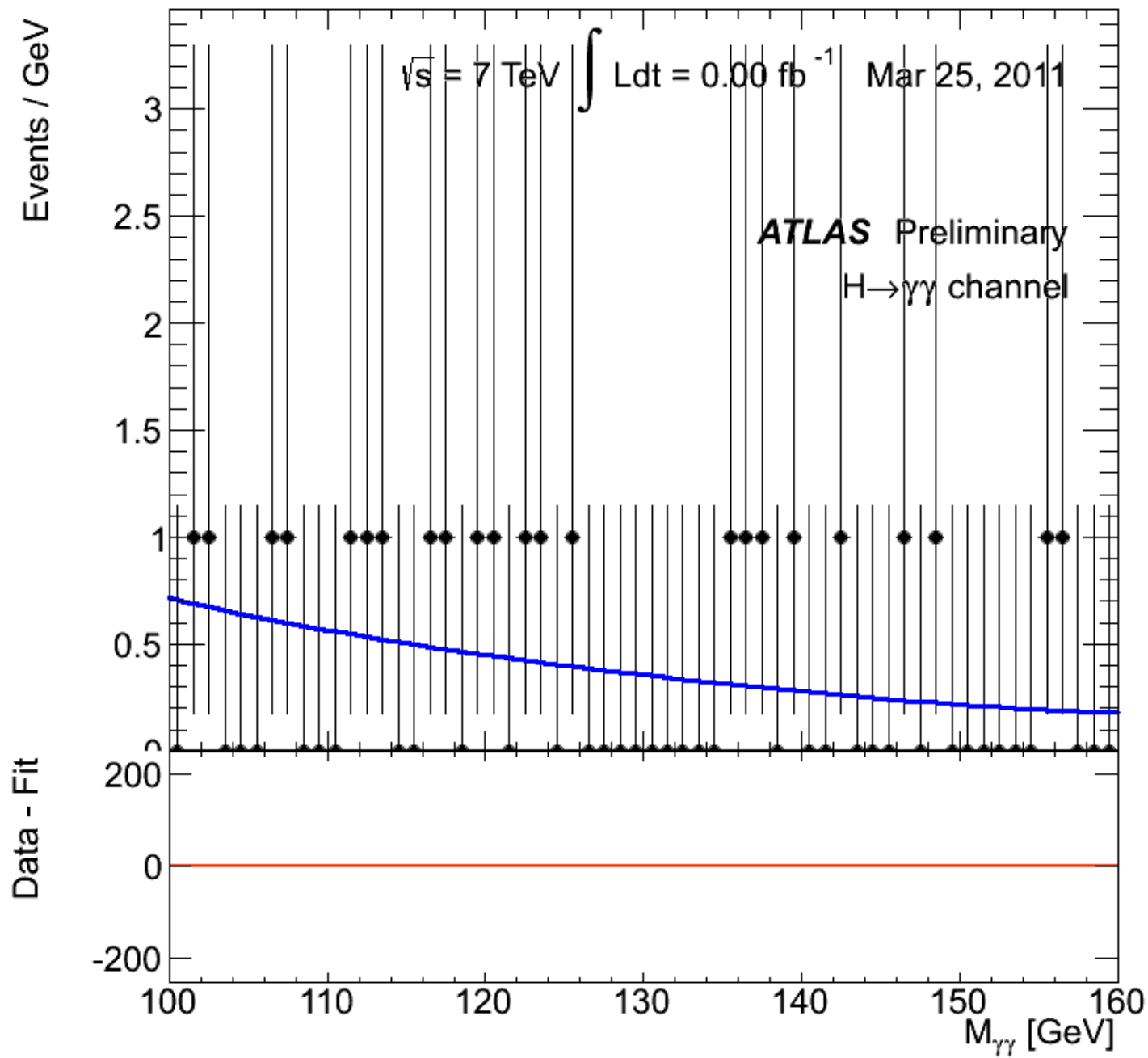
# LHC Experiments



# Overall view of the LHC experiments.











Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT  
Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC,  
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Naples, New Mexico, New York, Nijmegen BINP Novosibirsk, Ohio SU, Okayama, Oklahoma,  
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SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook,  
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Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia,  
UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin,  
Wuppertal, Würzburg, Yale, Yerevan

The project comprises ~4000 people in the collaboration  
+ thousand of industrial relations



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Netherlands	180
Norway	70
Poland	356
Portugal	121
Romania	137
Serbia	55
Slovakia	137
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**2726**

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USA	1211

## ASSOCIATE MEMBERS

India	387	<b>778</b>
Lithuania	39	
Pakistan	71	
Turkey	165	
Ukraine	116	

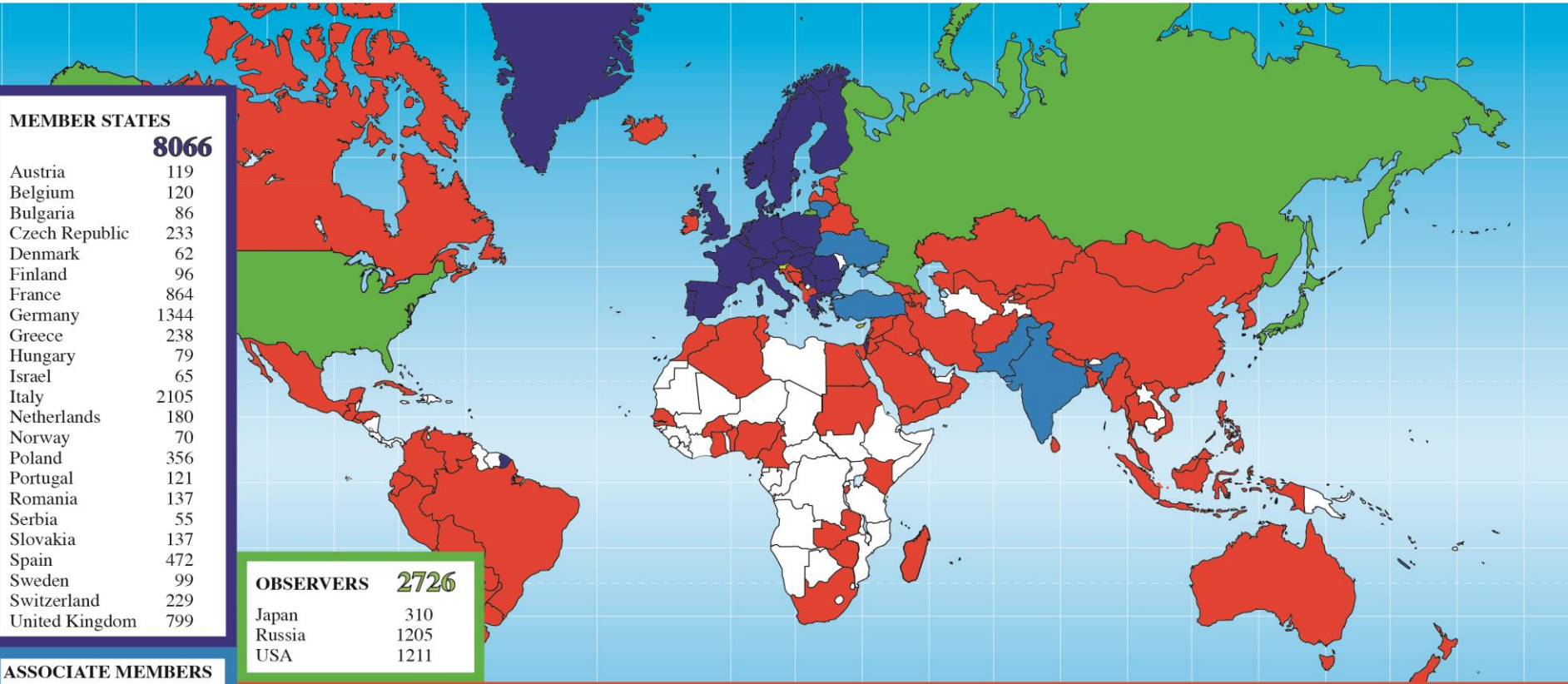
## ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

**59**

Cyprus	26
Slovenia	33

## OTHERS 1999

Albania	4	Bolivia	3	Ecuador	10	Iraq	1	Malta	9	Palestine	7	Sudan	1
Algeria	14	Bosnia & Herzegovina	3	Egypt	27	Ireland	13	Mexico	85	Paraguay	1	Syria	1
Argentina	26	Brazil	127	El Salvador	1	Jordan	2	Mongolia	2	Peru	6	Taiwan	56
Armenia	22	Burkina Faso	1	Estonia	15	Kazakhstan	10	Montenegro	11	Philippines	3	Thailand	26
Australia	36	Burundi	1	Georgia	51	Kenya	1	Morocco	24	Saint Kitts and Nevis	1	Tunisia	4
Azerbaijan	10	Cameroon	1	Ghana	1	Korea	183	Myanmar	2	San Marino	1	Uruguay	1
Bahrain	1	Canada	170	Guatemala	1	Kyrgyzstan	1	Nepal	7	Saudi Arabia	4	Uzbekistan	3
Bangladesh	8	Chile	21	Hong Kong	1	Latvia	4	New Zealand	5	Senegal	1	Venezuela	9
Belarus	45	China	576	Honduras	1	Lebanon	27	Nigeria	4	Singapore	5	Viet Nam	11
Benin	1	Colombia	44	Iceland	4	Luxembourg	4	North Korea	4	South Africa	56	Zambia	1
		Croatia	50	Indonesia	11	Madagascar	1	North Macedonia	3	Sri Lanka	10	Zimbabwe	2
		Cuba	16	Iran	58	Malaysia	22	Oman	3				







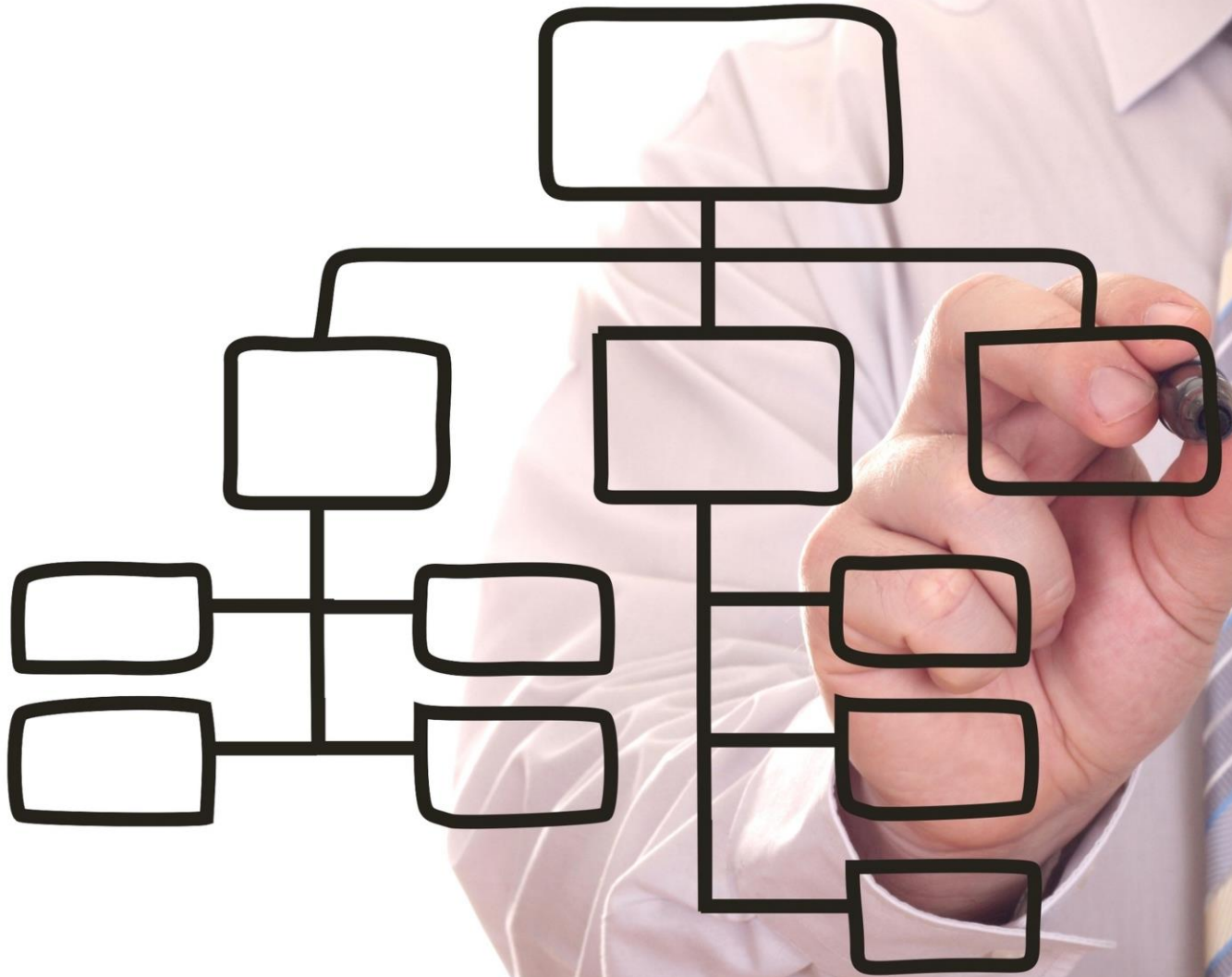










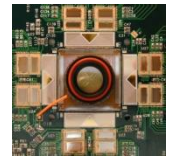








# Evolution of Experiments



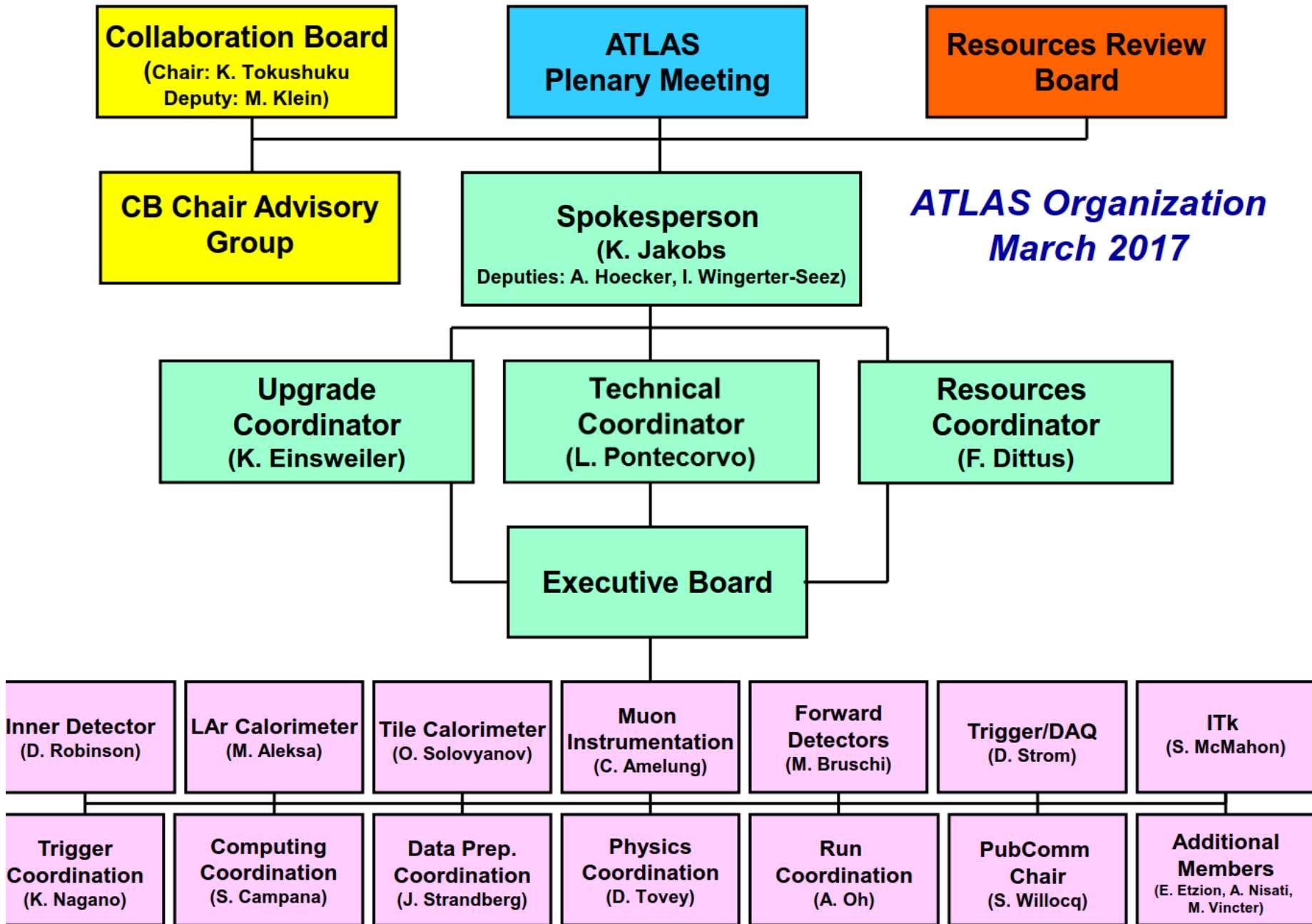
- Initial (conceptual) project planning started by informal, ad-hoc group(s) of interested scientists in mid 1980's
- Timeline
  - Late 1980's: Further R&D was needed to prove feasibility of proposed technical concepts. CERN initiated formal, generic detector R&D projects
  - Early 1990's: Bottom-up detector proposals; merging into Letters of Intent (LoI, 1992)
  - Mid 1990's: Technical Proposals (TP, 1995); sub-detector prototyping; sub-system Technical Design Reviews (TDRs)
  - Late 1990/Early 2000's: Approval of Cost Book; signing of MoU; start of detector modules manufacturing (always following a Production Readiness Review PRR and respective TDRs); start of installation at CERN (cavern handed over in 2003)
  - Mid 2000's: Installation, commissioning of Detectors in the cavern; completed in 2008 for initial runs
- Initial project coordination was implicit and handled by the contact persons for the early proposals. After LoI in 1992, the project coordination was carried out by elected mgmt teams
  - Later on, reporting interactions got defined and set up in the MoU (signed in 1998)



# Memorandum of Understanding (MoU)

- The Project Charter is the Memorandum of Understanding (MoU)
- Legally non-binding agreement based on best effort
- Drafted between **CERN** (Host Lab) and **Funding Agencies**, the MoU describes the sharing of detector hardware construction responsibilities and costs
- Relationship between the Host Lab and ATLAS broadly defined
- Fundamental principle of *deliverables* (in-kind contributions)
  - Potluck party
  - Deliverables grouped around **sub-projects**
  - Items not pledged for are pooled centrally, funds collected as “tax”
- The construction cost envelope in 1995 Swiss Francs was 475 MCHF
  - Direct costs, excluding manpower, R&D, institute infrastructure, prototyping, VAT
  - Major exchange rates fixed (e.g.  $\$/CHF=1.1$ ;  $GBP/CHF =1.8$ )
  - No centralized budget contingency
  - CERN provides technical infrastructure support, but is also a participating scientific institute
- Project personnel (management, project leaders, coordinators) are elected by the **community**
- Participating institutes have equal voting rights





# Charged-particle multiplicities in $pp$ interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC $\star\star$

ATLAS Collaboration

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## ABSTRACT

The first measurements from proton–proton collisions recorded with the ATLAS detector at the LHC are presented. Data were collected in December 2009 using a minimum-bias trigger during collisions at a centre-of-mass energy of 900 GeV. The charged-particle multiplicity, its dependence on transverse momentum and pseudorapidity, and the relationship between mean transverse momentum and charged-particle multiplicity are measured for events with at least one charged particle in the kinematic region  $|\eta| < 2.5$  and  $p_T > 500$  MeV. The measurements are compared to Monte Carlo models of proton–proton collisions and to results from other experiments at the same centre-of-mass energy. The charged-particle multiplicity per event and unit of pseudorapidity at  $\eta = 0$  is measured to be  $1.333 \pm 0.003$  (stat.)  $\pm 0.040$  (sys.), which is 5–15% higher than the Monte Carlo models predict.

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## 1. Introduction

Inclusive charged-particle distributions have been measured in  $pp$  and  $p\bar{p}$  collisions at a range of different centre-of-mass energy [1]. Many of these measurements have been used to constrain phenomenological models of soft-hadronic interactions and to properties at higher centre-of-mass energies. Most of the previous charged-particle multiplicity measurements were obtained by selection data with a double-arm coincidence trigger, thus removing large fractions of diffractive events. The data were then further corrected to remove the remaining single-diffractive component. This selection is referred to as non-single-diffractive (NSD). In some cases, despite being inelastic non-diffractive, the residual double-diffractive component was also subtracted. The selection of NSD or inelastic non-diffractive charged-particle spectra involves model-dependent corrections for the diffractive components and for effects of the trigger selection with no charged particles within the acceptance of the detector. The measurement presented in this Letter implements a diffractive strategy, which uses a single-arm trigger overlapping with the acceptance of the tracking volume. Results are presented as inelastic distributions, with minimal model-dependence, by requiring one charged particle within the acceptance of the measurement. This Letter reports on a measurement of primary charged particles with a momentum component transverse to the beam direction.

## ATLAS Collaboration

G. Aad<sup>48</sup>, E. Abat<sup>18a,\*</sup>, B. Abbott<sup>110</sup>, J. Abdallah<sup>11</sup>, A.A. Abdelalim<sup>49</sup>, A. Abdesselam<sup>117</sup>, O. Abdinov<sup>11</sup>, M. Abolins<sup>88</sup>, H. Abramowicz<sup>151</sup>, H. Abreu<sup>114</sup>, E. Acerbi<sup>89a,89b</sup>, B.S. Acharya<sup>162a,162b</sup>, M. Ackers<sup>20</sup>, D.L. Adams<sup>24</sup>, T.N. Ady<sup>56</sup>, J. Adelman<sup>173</sup>, M. Aderholz<sup>99</sup>, C. Adorisio<sup>36a,36b</sup>, P. Adrago<sup>128</sup>, S. Aefsky<sup>22</sup>, J.A. Aguilar-Saavedra<sup>123b</sup>, M. Aharrouche<sup>81</sup>, S.P. Ahlen<sup>21</sup>, F. Ahles<sup>48</sup>, A. Ahmad<sup>146</sup>, H. Ahmed<sup>2</sup>, M. Ahsan<sup>40</sup>, G. Aielli<sup>132a,132b</sup>, T. Akdogan<sup>18a</sup>, P.F. Akesson<sup>29</sup>, T.P.A. Akesson<sup>153</sup>, A.V. Akimov<sup>94</sup>, A. Aktas<sup>48</sup>, M.S. Alam<sup>1</sup>, M.A. Alam<sup>76</sup>, J. Albert<sup>167</sup>, G. Alexander<sup>55</sup>, M. Aleksa<sup>29</sup>, I.N. Aleksandrov<sup>65</sup>, M. Aleppo<sup>89a,89b</sup>, F. Alessandria<sup>89a</sup>, C. Alexa<sup>25a</sup>, G. Alibrandi<sup>151</sup>, G. Alexandre<sup>49</sup>, T. Alexopoulos<sup>9</sup>, M. Alroob<sup>20</sup>, M. Aliev<sup>15</sup>, G. Alimonti<sup>89a</sup>, J. Alison<sup>119</sup>, M. Aliyev<sup>1</sup>, P.P. Allport<sup>73</sup>, S.E. Allwood-Spiers<sup>53</sup>, J. Almond<sup>82</sup>, A. Aloisio<sup>102a,102b</sup>, R. Alon<sup>169</sup>, A. Alonso<sup>79</sup>, J. Alonso<sup>14</sup>, M.G. Alviggi<sup>102a,102b</sup>, K. Amako<sup>6</sup>, P. Amaral<sup>29</sup>, G. Ambrosini<sup>16</sup>, G. Ambrosio<sup>89a</sup>, C. Amelung<sup>22</sup>, V.V. Ammosov<sup>127,\*</sup>, A. Amorim<sup>123a</sup>, G. Amorós<sup>165</sup>, N. Amran<sup>151</sup>, C. Anastopoulos<sup>13</sup>, T. Andeen<sup>29</sup>, C.F. Anders<sup>48</sup>, K.J. Anderson<sup>30</sup>, A. Andreazza<sup>89a,89b</sup>, V. Andrei<sup>58a</sup>, M.L. Andrieux<sup>55</sup>, X.S. Anduaga<sup>70</sup>, A. Angerami<sup>34</sup>, F. Anghinolfi<sup>29</sup>, N. Anjos<sup>123a</sup>, A. Annovi<sup>47</sup>, A. Antonaki<sup>8</sup>, M. Anton S. Antonelli<sup>19a,19b</sup>, J. Antos<sup>143b</sup>, B. Antunovic<sup>41</sup>, F. Anulli<sup>131a</sup>, S. Aoun<sup>83</sup>, G. Arabidze<sup>8</sup>, I. Aracena<sup>14</sup>, Y. Arai<sup>96</sup>, A.T.H. Arce<sup>14</sup>, J.P. Archambault<sup>28</sup>, S. Arfaoui<sup>29</sup>, B. J.-F. Argüin<sup>14</sup>, T. Argyropoulos<sup>93</sup>, E. Arik<sup>1</sup>, M. Arik<sup>18a</sup>, A.J. Armbruster<sup>87</sup>, K.E. Arms<sup>108</sup>, S.R. Armstrong<sup>24</sup>, O. Arnaeaf<sup>4</sup>, C. Arnault<sup>114</sup>, A. Artamonov<sup>95</sup>, D. Arutinov<sup>20</sup>, M. Asai<sup>142</sup>, S. Asai<sup>153</sup>, R. Asfandiyarov<sup>170</sup>, S. Ask<sup>82</sup>, B. Åsman<sup>144a</sup>, D. Asner<sup>28</sup>, L. Asquith<sup>77</sup>, K. Assamagan<sup>24</sup>, A. Astbury<sup>167</sup>, A. Astvatsatourov<sup>52</sup>, B. Athar<sup>1</sup>, G. Atoian<sup>1</sup>, B. Aubert<sup>4</sup>, B. Auerbach<sup>173</sup>, E. Auge<sup>114</sup>, K. Augusten<sup>126</sup>, M. Aurousseau<sup>10</sup>, N. Austin<sup>73</sup>, G. Avolio<sup>161</sup>, R. Avramidou<sup>9</sup>, D. Axen<sup>166</sup>, C. Ay<sup>54</sup>, G. Azules<sup>93c</sup>, Y. Azuma<sup>153</sup>, M.A. Baak<sup>29</sup>, G. Baccagliioni<sup>89a</sup>, C. Bacci<sup>133a,133b</sup>, A.M. Bach<sup>14</sup>, H. Bachacou<sup>135</sup>, K. Bachas<sup>29</sup>, G. Bachy<sup>29</sup>, M. Backes<sup>49</sup>, E. Badescu<sup>25</sup>, P. Bagnaia<sup>131a,131b</sup>, Y. Bai<sup>32a</sup>, D.C. Bailey<sup>156</sup>, T. Bain<sup>155</sup>, J.T. Baines<sup>128</sup>, O.K. Baker<sup>173</sup>, M.D. Baker<sup>24</sup>, S. Baker<sup>77</sup>, F. Baltasar Dos Santos Pedrosa<sup>29</sup>, E. Banas<sup>38</sup>, P. Banerjee<sup>93</sup>, S. Banerjee<sup>167</sup>, D. Banfi<sup>89a</sup>, A. Bangeri<sup>136</sup>, V. Bansal<sup>167</sup>, S.P. Baranov<sup>94</sup>, S. Baranov<sup>65</sup>, A. Barashkou<sup>65</sup>, T. Barber<sup>27</sup>, E.L. Barberi<sup>30a,50b</sup>, M. Barbero<sup>20</sup>, D.Y. Bardin<sup>65</sup>, T. Barillari<sup>99</sup>, M. Barisonzi<sup>172</sup>, T. Barklow<sup>142</sup>, N. Barlow<sup>27</sup>, B.M. Barnett<sup>128</sup>, R.M. Barnett<sup>14</sup>, A. Baronecchi<sup>133a</sup>, M. Barone<sup>47</sup>, A.J. Barr<sup>117</sup>, F. Barreil<sup>1</sup>, J. Barreiro Guimarães da Costa<sup>37</sup>, P. Barrillon<sup>114</sup>, V. Barthelend<sup>99</sup>, H. Bartko<sup>99</sup>, R. Bartoldus<sup>142</sup>, D. Bartsch<sup>20</sup>, R.L. Bates<sup>53</sup>, S. Bathé<sup>24</sup>, L. Batkova<sup>143a</sup>, J.R. Batley<sup>27</sup>, A. Battaglia<sup>16</sup>, M. Battistin<sup>29</sup>,

ATLAS Collaboration / Physics

G. Battistoni<sup>89a</sup>, F. Bauer<sup>135</sup>, H.S. Bawa<sup>142</sup>, M. Bazal<sup>1</sup>, R. Beccherle<sup>50a</sup>, N. Beckeri<sup>18a</sup>, P. Bechtel<sup>41</sup>, G.A. Be<sup>1</sup>, A.J. Beddall<sup>18c</sup>, A. Beddall<sup>18c</sup>, V.A. Bednyakov<sup>65</sup>, C. Be<sup>1</sup>, M. Belfiore<sup>99</sup>, G.A.N. Belanger<sup>28</sup>, C. Belanger-Cha<sup>1</sup>, G. Bella<sup>151</sup>, L. Bellagamba<sup>18a</sup>, F. Bellina<sup>10</sup>, G. Bellon<sup>1</sup>, O. Beltramoello<sup>29</sup>, A. Belyanin<sup>75</sup>, S. Ben Ami<sup>150</sup>, O. M. Benedi<sup>81</sup>, B.H. Bencisek<sup>161</sup>, N. Benekos<sup>163</sup>, Y. Be<sup>1</sup>, M. Benoit<sup>114</sup>, J.R. Bensinger<sup>22</sup>, K. Benslama<sup>129</sup>, S. B. E. Bergeas Kuitmann<sup>144a,144b</sup>, N. Berger<sup>4</sup>, F. Bergh<sup>1</sup>, P. Bernat<sup>114</sup>, R. Bernhard<sup>48</sup>, C. Bernius<sup>77</sup>, T. Berry<sup>76</sup>, M.I. Besana<sup>89a,89b</sup>, N. Besson<sup>135</sup>, S. Bethke<sup>99</sup>, R.M. F. J. Biesiadzka<sup>14</sup>, M. Biglietti<sup>131a,131b</sup>, H. Bilokon<sup>47</sup>, M. C. Bini<sup>131a,131b</sup>, C. Biscarat<sup>178</sup>, R. Bischof<sup>62</sup>, U. Biten<sup>73</sup>,

32

ATLAS Collaboration / Physics

I.A. Christidi<sup>77</sup>, A. Christov<sup>48</sup>, D. Chromek-Burchart<sup>29</sup>, E. Cicalini<sup>121a,121b</sup>, A.K. Ciftci<sup>34</sup>, R. Ciftci<sup>34</sup>, D. Cincin<sup>34</sup>, A. Ciocio<sup>14</sup>, M. Cirilli<sup>87</sup>, M. Citterio<sup>89a</sup>, A. Clark<sup>49</sup>, R.W. B. Clement<sup>55</sup>, C. Clement<sup>144a,144b</sup>, D. Clements<sup>53</sup>, R.J. A. Cocco<sup>30a,50b</sup>, J. Cochran<sup>64</sup>, R. Coco<sup>92</sup>, P. Coe<sup>117</sup>, S. C. C. Cojocar<sup>28</sup>, J. Colas<sup>4</sup>, B. Cole<sup>34</sup>, A.P. Colijn<sup>105</sup>, C. J. Collot<sup>55</sup>, G. Colon<sup>84</sup>, R. Coluccia<sup>72a,72b</sup>, G. Comune<sup>8</sup>, M. Consonni<sup>104</sup>, S. Costantinescu<sup>25a</sup>, C. Conta<sup>118a,118b</sup>, B.D. Cooper<sup>75</sup>, A.M. Cooper-Sarkar<sup>117</sup>, N.J. Cooper-Smi<sup>117</sup>, M. Corradi<sup>19a</sup>, S. Correard<sup>53</sup>, F. Corvieux<sup>95d</sup>, A. Corso<sup>117</sup>,

32

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D. Fassoulis<sup>8</sup>, B. Fathollahzadeh<sup>156</sup>, L. Fayard<sup>114</sup>, F. O.L. Fedin<sup>120</sup>, I. Fedorov<sup>29</sup>, V. Fedorov<sup>29</sup>, L. Feligioni<sup>1</sup>, A.B. Fenyuk<sup>127</sup>, J. Ference<sup>143b</sup>, J. Ferland<sup>82</sup>, B. Ferna<sup>1</sup>, J. Ferrando<sup>117</sup>, V. Ferrara<sup>41</sup>, A. Ferrari<sup>154</sup>, P. Ferrari<sup>1</sup>, D. Ferrere<sup>49</sup>, C. Ferretti<sup>87</sup>, F. Ferro<sup>30a,50b</sup>, M. Flisar<sup>1</sup>, A. Filippos<sup>9</sup>, F. Filthaut<sup>104</sup>, M. Fincke-Keeler<sup>167</sup>, M.C. Fischer<sup>20</sup>, M.J. Fisher<sup>108</sup>, S.M. Fisher<sup>128</sup>, H.F. Flach<sup>1</sup>, P. Fleischmann<sup>171</sup>, S. Fleischmann<sup>20</sup>, E. Fleuret<sup>78</sup>, T. F. Föhlich<sup>58a</sup>, M. Fokitis<sup>9</sup>, T. Fonseca Martin<sup>76</sup>, J. Fo<sup>1</sup>, D. Fortin<sup>157a</sup>, J.M. Foster<sup>82</sup>, D. Fournier<sup>14</sup>, A. Fousse<sup>1</sup>, P. Francavilla<sup>121a,121b</sup>, S. Franchino<sup>118a,118b</sup>, D. Franco<sup>1</sup>, M. Fraternali<sup>118a,118b</sup>, S. Fratina<sup>119</sup>, J. Freestone<sup>82</sup>, S. A. B. Frey<sup>27</sup>, G. Frey<sup>154</sup>, F. Frey<sup>154</sup>, S. Frey<sup>154</sup>,

36

ATLAS Collabora

N. Massol<sup>4</sup>, A. Mastroberardino<sup>36a,36b</sup>, T. Mas<sup>1</sup>, H. Matsunaga<sup>153</sup>, T. Matsushita<sup>67</sup>, C. Mattareo<sup>1</sup>, J.K. Mayer<sup>156</sup>, A. Mayne<sup>138</sup>, R. Mazini<sup>149</sup>, M. F. Mazzucchi<sup>49</sup>, J. Mc Donald<sup>85</sup>, S.P. Mc Keer<sup>87</sup>, K.W. McFarlane<sup>56</sup>, S. McGarvie<sup>76</sup>, H. McGlone<sup>1</sup>, T.R. McElvan<sup>76</sup>, T.J. McMahon<sup>117</sup>, R.A. McPhene<sup>1</sup>, M. Medinnis<sup>41</sup>, R. Meera-Lebbai<sup>110</sup>, T.M. Meg<sup>1</sup>, K. Meier<sup>58a</sup>, J. Meinhardt<sup>48</sup>, B. Meirose<sup>48</sup>, C. I. P. Mendez<sup>98</sup>, L. Mendoza Navas<sup>160</sup>, Z. Meng<sup>1</sup>, P. Mermod<sup>117</sup>, L. Merola<sup>102a,102b</sup>, C. Meroni<sup>85</sup>, J. Metcalfe<sup>103</sup>, A.S. Mete<sup>64</sup>, S. Meuser<sup>20</sup>, J.-P. W.T. Meyer<sup>64</sup>, J. Miao<sup>32d</sup>, S. Michal<sup>29</sup>, L. Micu<sup>1</sup>, A. Migliaccio<sup>102a,102b</sup>, L. Mijovic<sup>74</sup>, G. Mikenb<sup>1</sup>, D.W. Miller<sup>142</sup>, R.J. Miller<sup>88</sup>, W.J. Mills<sup>165</sup>, C.M. D. Milstein<sup>169</sup>, S. Mima<sup>109</sup>, A.A. Minaenko<sup>127</sup>, B. Mindur<sup>37</sup>, M. Mineev<sup>65</sup>, Y. Ming<sup>129</sup>, L.M. S. Miscetti<sup>47</sup>, A. Misiejuk<sup>76</sup>, A. Mitra<sup>117</sup>, J. Mi<sup>1</sup>, P.S. Miyagawa<sup>82</sup>, Y. Miyazaki<sup>139</sup>, J.-Y. Mjörnmark<sup>1</sup>, P. Mockett<sup>137</sup>, S. Moed<sup>57</sup>, V. Moeller<sup>27</sup>, K. Mō<sup>1</sup>, S. Mohrhardt-Mock<sup>99</sup>, A.M. Moiseev<sup>127,\*</sup>, R. M. J. Monk<sup>77</sup>, E. Monnier<sup>83</sup>, G. Montarou<sup>33</sup>, S. M. T.B. Moore<sup>84</sup>, G.F. Moorhead<sup>86</sup>, C. Mora Herre<sup>1</sup>, G. Morello<sup>36a,36b</sup>, D. Moreno<sup>160</sup>, M. Moreno I. J. Morin<sup>75</sup>, Y. Morita<sup>66</sup>, A.K. Morley<sup>86</sup>, G. Mor<sup>1</sup>,

A. Tonazzo<sup>133a,133b</sup>, G. Tong<sup>32a</sup>, A. Tonoyan<sup>13</sup>, C. Topfel<sup>16</sup>, N.D. Topilin<sup>65</sup>, E. Torrence<sup>113</sup>, E. Torró Pastor<sup>165</sup>, J. Toth<sup>83,u</sup>, F. Touchard<sup>83</sup>, D.R. Tovey<sup>138</sup>, T. Trefzger<sup>171</sup>, I. Treis<sup>20</sup>, L. Tremblet<sup>29</sup>, A. Tricoli<sup>29</sup>, I.M. Trigger<sup>157a</sup>, G. Trilling<sup>14</sup>, S. Trincza-Duvoid<sup>78</sup>, T.N. Trinh<sup>78</sup>, M.F. Tripanza<sup>70</sup>, N. Triplett<sup>64</sup>, W. Trischnik<sup>156</sup>, A. Trivedi<sup>241</sup>, Z. Trka<sup>125</sup>, B. Trocmé<sup>55</sup>, C. Troncon<sup>89a</sup>, A. Trzupek<sup>38</sup>, C. Tsarouchas<sup>9</sup>, J.C.-L. Tseng<sup>117</sup>, M. Tsiakiris<sup>105</sup>, P.V. Tsiaresika<sup>80</sup>, D. Tsoniou<sup>148</sup>, G. Tsipolitis<sup>9</sup>, V. Tsiskaridze<sup>51</sup>, E.G. Tskhadadze<sup>51</sup>, I.I. Tsukerman<sup>95</sup>, V. Tsulaia<sup>122</sup>, J.-W. Tsung<sup>20</sup>, S. Tsumo<sup>86</sup>, D. Tsybychev<sup>146</sup>, J.M. Tuggle<sup>30</sup>, M. Turala<sup>38</sup>, D. Turecek<sup>126</sup>, I. Turk Cakir<sup>36</sup>, E. Turlay<sup>105</sup>, P.M. Puts<sup>34</sup>, M.S. Twomey<sup>137</sup>, M. Tyldal<sup>144a,144b</sup>, M. Tyndel<sup>128</sup>, D. Tzpadalos<sup>17</sup>, H. Tyrvainen<sup>29</sup>, E. Tzamaridoukaki<sup>9</sup>, G. Tzanouk<sup>8</sup>, K. Uchida<sup>115</sup>, I. Ueda<sup>153</sup>, M. Uglind<sup>13</sup>, M. Uhlenbrock<sup>20</sup>, M. Uhrmacher<sup>54</sup>, F. Ukegawa<sup>158</sup>, G. Unal<sup>29</sup>, D.G. Underwood<sup>5</sup>, A. Undrus<sup>4</sup>, G. Unei<sup>161</sup>, Y. Unno<sup>66</sup>, D. Urbanec<sup>34</sup>, E. Urkovsky<sup>151</sup>, P. Urquijo<sup>49b</sup>, P. Urrejoa<sup>31a</sup>, G. Usai<sup>7</sup>, M. Uslenghi<sup>118a,118b</sup>, L. Vacavani<sup>89</sup>, V. Vacek<sup>126</sup>, B. Vachon<sup>85</sup>, S. Vahsen<sup>14</sup>, C. Valderanis<sup>99</sup>, J. Valenta<sup>124</sup>, P. Valente<sup>131a</sup>, S. Valentini<sup>19a,19b</sup>, S. Valkar<sup>125</sup>, E. Valladolid Gallego<sup>165</sup>, S. Vallecorsa<sup>150</sup>, J.A. Vallés Ferrer<sup>165</sup>, R. Van Berg<sup>119</sup>, H. van der Graaf<sup>105</sup>, E. van der Kraaij<sup>105</sup>, E. van der Poel<sup>105</sup>, D. Van Der Ster<sup>29</sup>, B. Van Ejik<sup>105</sup>, N. van Eldik<sup>84</sup>, P. van Gemmeren<sup>5</sup>, Z. van Kesteren<sup>105</sup>, I. van Vulpen<sup>105</sup>, W. Vandelli<sup>29</sup>, G. Vandoni<sup>29</sup>, A. Vaniachine<sup>5</sup>, P. Vankov<sup>73</sup>, F. Vannuzzi<sup>78</sup>, F. Varela Rodriguez<sup>29</sup>, R. Vari<sup>131a</sup>, F.W. Varnes<sup>6</sup>, D. Varouchas<sup>14</sup>,

40

ATLAS Collaboration / Physics Letters B 688 (2010) 21–42

Z. Zhao<sup>32b</sup>, A. Zhemchugov<sup>65</sup>, S. Zheng<sup>32a</sup>, J. Zhong<sup>149,2</sup>, B. Zhou<sup>87</sup>, N. Zhou<sup>34</sup>, Y. Zhou<sup>149</sup>, C.G. Zhu<sup>32d</sup>, H. Zhu<sup>41</sup>, Y. Zhu<sup>170</sup>, X. Zhuang<sup>98</sup>, V. Zhuravlov<sup>99</sup>, B. Zikic<sup>143a</sup>, R. Zimmermann<sup>20</sup>, S. Zimmermann<sup>48</sup>, S. Zimmermann<sup>48</sup>, M. Ziolkowski<sup>140</sup>, R. Zitoun<sup>4</sup>, V. Zivković<sup>34</sup>, V.V. Zmouchok<sup>127,\*</sup>, G. Zobernig<sup>170</sup>, A. Zoccoli<sup>19a,19b</sup>, Y. Zolnierowski<sup>4</sup>, A. Zsenei<sup>29</sup>, M. zur Nedden<sup>15</sup>, V. Zutshi<sup>5</sup>

<sup>1</sup> University at Albany, 1400 Washington Ave, Albany, NY 12222, United States  
<sup>2</sup> University of Alberta, Department of Physics, Edmonton, AB T6G 2G7, Canada  
<sup>3</sup> Ankara University<sup>30</sup>, Faculty of Sciences, Department of Physics, TR 06100 Tandoğan, Ankara; Dumlupınar University<sup>30</sup>, Faculty of Arts and Sciences, Department of Physics, Kutayya; Gazi University<sup>30</sup>, Faculty of Arts and Sciences, Department of Physics, 06500 Teşekküllük, Ankara; TOBB University of Economics and Technology<sup>30</sup>, Faculty of Arts and Sciences, Division of Physics, 06560 Söğütözü, Ankara; Turkish Atomic Energy Authority<sup>30</sup>, 06330 Ludümlü, Ankara, Turkey  
<sup>4</sup> LAPD, Université de Savoie, CNRS/IN2P3, Annecy-le-Vieux, France  
<sup>5</sup> Aachen National Laboratory, Aachen University, Germany, 52074 S. C. G. Aachen, Germany  
<sup>6</sup> INFN, Sezione di Padova, Italy, 35100 Padova, Italy

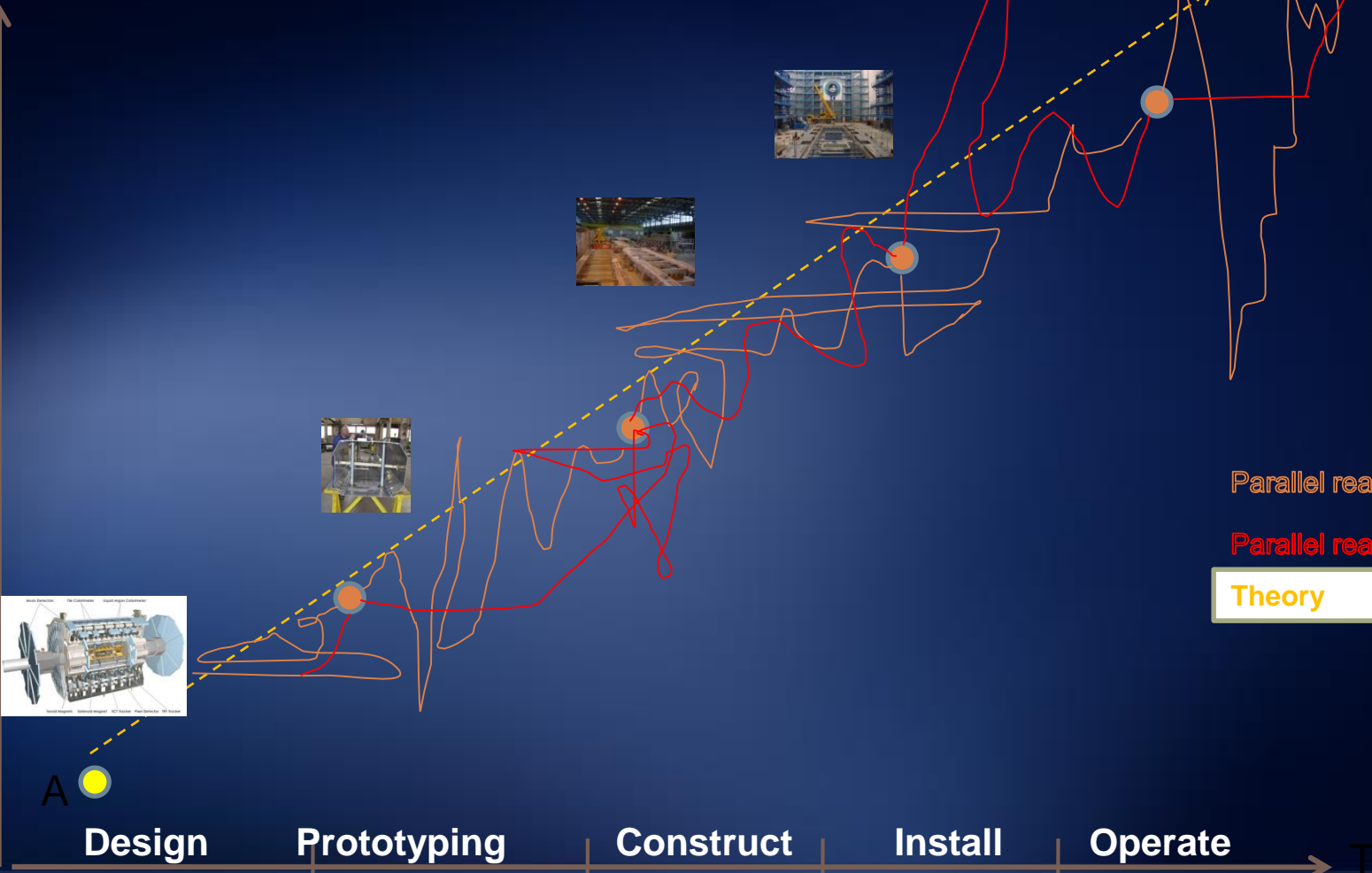
<sup>7</sup> University of Alberta, 1400 Washington Ave, Albany, NY 12222, United States  
<sup>8</sup> Iowa State University, Department of Physics and Astronomy, Ames High Energy Physics Group, Ames, IA 50011-3160, United States  
<sup>9</sup> Joint Institute for Nuclear Research, JINR Dubna, RU-141 989 Moscow Region, Russia  
<sup>10</sup> KEK, High Energy Accelerator Research Organization, 1-1 Ohno, Tsukuba-shi, Ibaraki-ken 305-0801, Japan  
<sup>11</sup> Kobe University, Graduate School of Science, 1-1 Rokkodai-cho, Nada-ku, JP - Kobe 657-8501, Japan  
<sup>12</sup> Kyoto University, Faculty of Science, Okawa-cho, Kitashiro-ku, Kyoto-shi, JP - Kyoto 606-8502, Japan  
<sup>13</sup> Simon Fraser University, Department of Physics, 8888 University Drive, CA - Burnaby, BC V5A 1S6, Canada  
<sup>14</sup> SLAC National Accelerator Laboratory, Stanford, CA 94309, United States  
<sup>15</sup> Comenius University, Faculty of Mathematics, Physics & Informatics<sup>30</sup>, Mlynska dolina F2, SK-84248 Bratislava; Institute of Experimental Physics of the Slovak Academy of Sciences, Dept. of Subnuclear Physics<sup>30</sup>, Watsonova 47, SK-04353 Kosice, Slovak Republic  
<sup>16</sup> Stockholm University, Department of Physics<sup>30</sup>, The Oskar Klein Centre<sup>30</sup>, Alnåvna, SE-106 91 Stockholm, Sweden  
<sup>17</sup> Royal Institute of Technology (KTH), Physics Department, SE-106 91 Stockholm, Sweden  
<sup>18</sup> Stony Brook University, Department of Physics and Astronomy, Nicolls Road, Stony Brook, NY 11794-3800, United States  
<sup>19</sup> University of Sussex, Department of Physics and Astronomy, Pevensey 2 Building, Falmer, Brighton BN1 9QJ, United Kingdom  
<sup>20</sup> University of Sydney, School of Physics, AU - Sydney NSW 2006, Australia  
<sup>21</sup> Institute of Physics, Academia Sinica, TW - Taipei 11529, Taiwan  
<sup>22</sup> Technion, Israel Inst. of Technology, Department of Physics, Technion City, IL - Haifa 32000, Israel  
<sup>23</sup> Tel Aviv University, Raymond and Beverly Sackler School of Physics and Astronomy, Ramat Aviv, IL - Tel Aviv 69978, Israel  
<sup>24</sup> University of Victoria, Department of Physics and Astronomy, Victoria, BC V8W 2Y2, Canada  
<sup>25</sup> The University of Tokyo, International Center for Elementary Particle Physics and Department of Physics, 7-3-1 Hongo, Bunkyo-ku, JP - Tokyo 113-0033, Japan  
<sup>26</sup> Tokyo Metropolitan University, Graduate School of Science and Technology, 1-1 Minami-Osawa, Hachioji, Tokyo 192-0397, Japan  
<sup>27</sup> Institute of Technology, 2-12-1 Hi-34 O-okayama, Meguro, Tokyo 152-8551, Japan  
<sup>28</sup> University of Toronto, Department of Physics, 60 Saint George Street, Toronto M5S 1A5, Ontario, Canada  
<sup>29</sup> TRIUMF<sup>30</sup>, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, York University<sup>30</sup>, Department of Physics, 4700 Keele St., Toronto, Ontario, M3J 1P3, Canada  
<sup>30</sup> University of Toronto, Institute of Pure and Applied Sciences, 1-1 Terasaki, UTM, Ibaraki 305-8571, Japan  
<sup>31</sup> Tufts University, School of Technology Center, 4 Colby Street, Medford, MA 02155, United States  
<sup>32</sup> Universidad Antonio Narino, Centro de Investigaciones, Cra 3 Eje No.47A-15, Bogotá, Colombia  
<sup>33</sup> University of California, Irvine, Department of Physics & Astronomy, CA 92697-4575, United States  
<sup>34</sup> INFN Gruppo Collegato di Udine<sup>30</sup>; ICTP<sup>30</sup>; Strada Costiera 1, IT-34014 Trieste, University of Udine, Dipartimento di Fisica<sup>30</sup>, via delle Scienze 208, IT-33100 Udine, Italy  
<sup>35</sup> University of Illinois, Department of Physics, 1110 Green Street, Urbana, IL 61801, United States  
<sup>36</sup> University of Uppsala, Department of Physics and Astronomy, P.O. Box 516, SE-751 20 Uppsala, Sweden  
<sup>37</sup> Instituto de Física Corpuscular (IFC), Centro Mixto UVN-CSIC, Apdo. 22085 ES-46107 Valencia, Spain  
<sup>38</sup> Instituto de Microelectrónica de Barcelona (IMB-CNM-CSIC), 08193 Bellaterra Barcelona, Spain  
<sup>39</sup> University of British Columbia, Department of Physics, 6224 Agricultural Road, CA - Vancouver, BC V6T 1Z1, Canada  
<sup>40</sup> University of Victoria, Department of Physics and Astronomy, P.O. Box 3055, Victoria, BC V8W 3P8, Canada  
<sup>41</sup> Waseda University, WIDE, 3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan  
<sup>42</sup> The Weizmann Institute of Science, Department of Particle Physics, P.O. Box 26, IL-76100, Rehovot, Israel  
<sup>43</sup> University of Wisconsin, Department of Physics, 1150 University Avenue, Madison, WI 53706, United States  
<sup>44</sup> Julius-Maximilians-Universität Würzburg, Physikalisches Institut, Am Hubland, 97074 Würzburg, Germany  
<sup>45</sup> Bergische Universität, Fachbereich C, Physics, Postfach 102710, Gauss-Strasse 20, D-42099 Wuppertal, Germany  
<sup>46</sup> University of Illinois, Department of Physics, 1110 Green Street, Urbana, IL 61801, United States  
<sup>47</sup> Yerevan Physics Institute, Alkhanian Brothers Street, 2, AM-375036 Yerevan, Armenia  
<sup>48</sup> ATLAS-Canada Tier-1 Data Centre-4004 Wesbrook Mall, Vancouver, BC, V6T 2A3, Canada  
<sup>49</sup> GRIDKA Tier-1 FZK, Forschungszentrum Karlsruhe GmbH, Stuebenstr. Center for Computing (SCC), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldsdorf, Germany  
<sup>50</sup> Port of Antwerp International (PIA), Department of Physics and Astronomy (UAB), Edifici D, E-08193 Bellaterra, Spain  
<sup>51</sup> Centre de Calcul CNRS/IN2P3, Domaine universitaire de la Doua, 27 bd du 11 Novembre 1918, 69622 Villurbanne Cedex, France  
<sup>52</sup> INFN-CNAF, Viale Beltrandi 62, 40127 Bologna, Italy  
<sup>53</sup> Nordic Data Grid Facility, NORDNET A/S, Kaptrupsgade 22, DK-2770 Skovstrup, Denmark  
<sup>54</sup> SARA Reken- en Netwerkdiensten, Science Park 121, 1098 XG Amsterdam, Netherlands  
<sup>55</sup> ATLAS-Canada Tier-1 Computing, Institute of Physics, Academia Sinica, No.128, Sec. 2, Academia Rd., Nankang, Taipei, Taiwan 11529, Taiwan  
<sup>56</sup> UK-T1-RAL Tier-1, Rutherford Appleton Laboratory, Science and Technology Facilities Council, Harwell Science and Innovation Campus, Didcot OX11 0QX, United Kingdom  
<sup>57</sup> RHIC and ATLAS Computing Facility, Physics Department, Building 510, Brookhaven National Laboratory, Upton, NY 11973, United States

\* Present address Fermilab, United States.

# Implementing Strategy is Not Linear



Progress



Parallel reality 1

Parallel reality 2

Theory

Design

Prototyping

Construct

Install

Operate

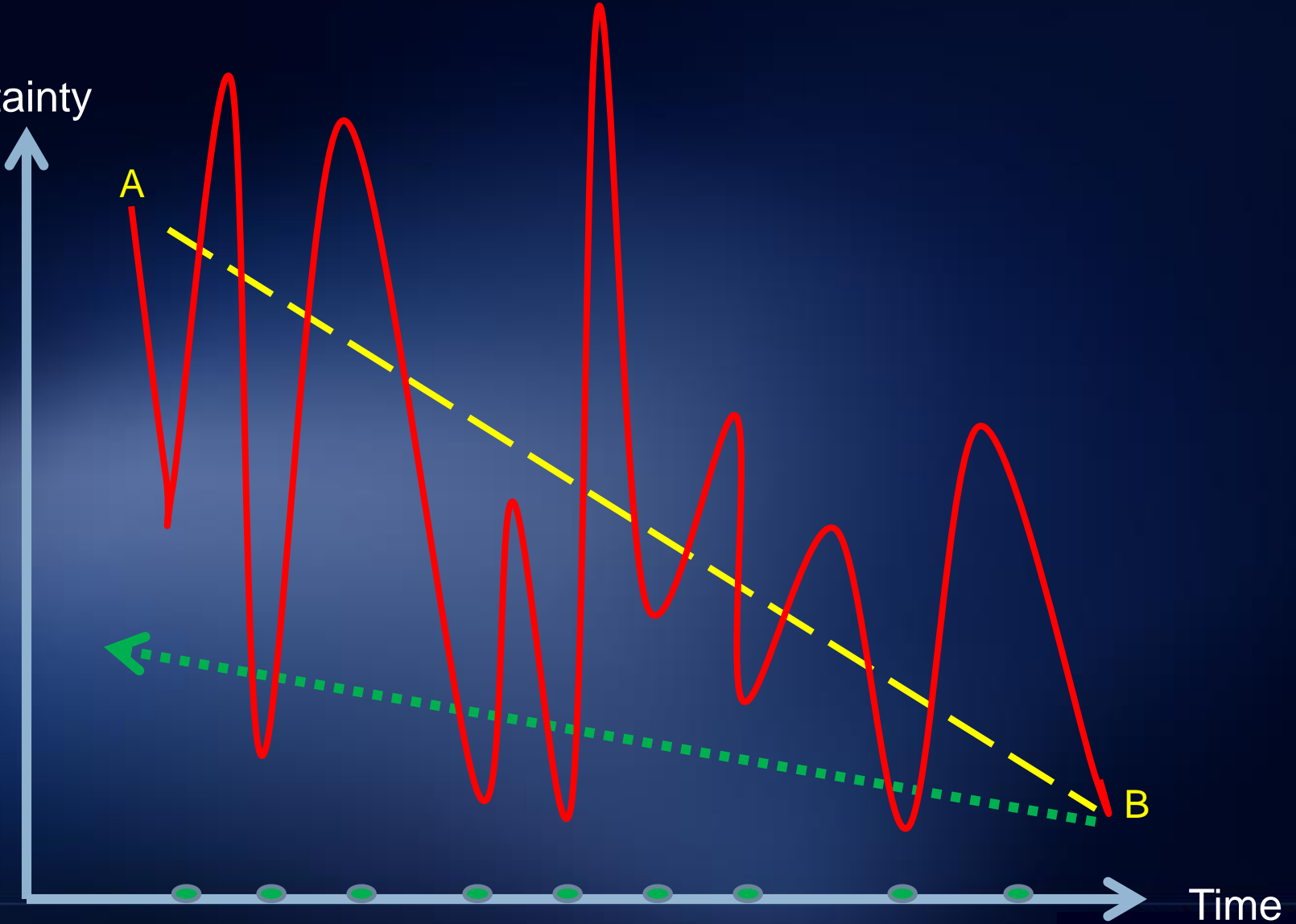
Time





# Absorbing vs. Reducing Uncertainty

Uncertainty



Time

1. Vision

2. Commitment

3. Tolerance

# Communitarian Bonds



- Shared Vision
  - One common aim of “Out of this world” discoveries; such as the Higgs
  - Better understanding of the fundamental forces and particle (Big Bang)
- Shared Commitment
  - Passion to “Can-do”
  - Members of Collaborations prepared to solve the encountered technological (and human) challenges
  - Willingness to accept also less glorious tasks for the common good
  - Some have been working for LHC Experiments since mid 1980s...
  - Trust in colleagues fulfilling their commitments (MoU)
- Shared Tolerance
  - Willingness to work together, irrespective of geographical location or language barriers
  - Willingness to share information
  - Principle of “Raw Diamond”

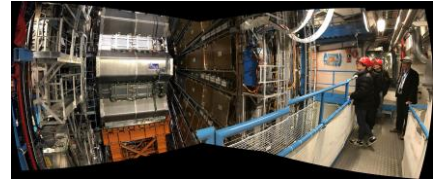


# Simple Micro Rules



- Allow people to dream (5% makes already a difference)
- Tolerate diversity
- Let the physics decide, not the hierarchy
- Collaborate and compete
- Question and justify – Respect the Dukes of Doubt rather than Kings of Truth

## Simple Macro Rules (2)



- Set up Collaboration structures that respect individual freedom and which do not impose formal authority
- Elect leaders based on technical competence, credibility and trust rather than ego and authority
- Allow ad-hoc expert teams to emerge and quickly respond to encountered scientific and technical hurdles
- Keep everyone on board, give everyone a voice
- Set up peer review processes and arbitration mechanisms

# Cultures of Experiments



- There are several underlying sub-cultures in LHC Experiments
  - Physics culture versus Engineering culture
  - Hardware oriented culture versus software/computing etc.
  - Sub-system cultures (e.g in ATLAS, "LAr culture versus Muons culture")
  - Geographical cultures ("North versus South; West versus East"; languages)
- Such cultural diversity originates itself from
  - Global nature of modern high energy physics (ca 40 countries, 70 nationalities)
  - Decentralized nature of resources, diverse funding sources
  - Different ways to account and organize resources
- Project cycles and dominating cultures
  - Sub-system/engineering culture more dominant during construction
  - Physics culture very strong during project definition (design); then resurfaces when physics analysis starts



# How are (tough) decisions made?



- Consensus-driven approach
- Bottom-up approach, in consultation with Experiment management
  - Management can't dictate, instead coordinates and steers the process
- Keep everyone on board!
- “Factorize” the encountered problems as much as possible
- Working groups come up with alternative solutions, they select and propose the most suitable one
- Leave tough decisions to the last possible moment (without compromising the schedule)
- Collaboration Board approves collaboration actions (one institute, one vote)
- Financial matters approved in the Resources Review Board
  - But I do not recall in ATLAS over 12 years no voting

# Conclusions



- LHC Experiments are large scientific projects that can be described as
  - Complex, disruptive
  - Global
  - Culturally diverse
  - Shared vision, passion, commitment and tolerance
  - Efforts made to hear the individual
- They are not managed like a corporation
- Instead,
  - Run by self-managed individuals and teams
  - Have a Spokesperson, not a CEO
  - Guided by engagement, discussions, trial & trust, and justification rather than hierarchical powers or ex-ante directives
  - A challenge for coordination ...
- So *what* is it?
  - Your comments and views would be much appreciated!