

Anmerkungen zur Theorie

Dieter Zeppenfeld
KET Treffen, Bad Honnef, 19.11.2016

KIT Center Elementary Particle and Astroparticle Physics - KCETA



Teilchentheorie: Standorte in Deutschland



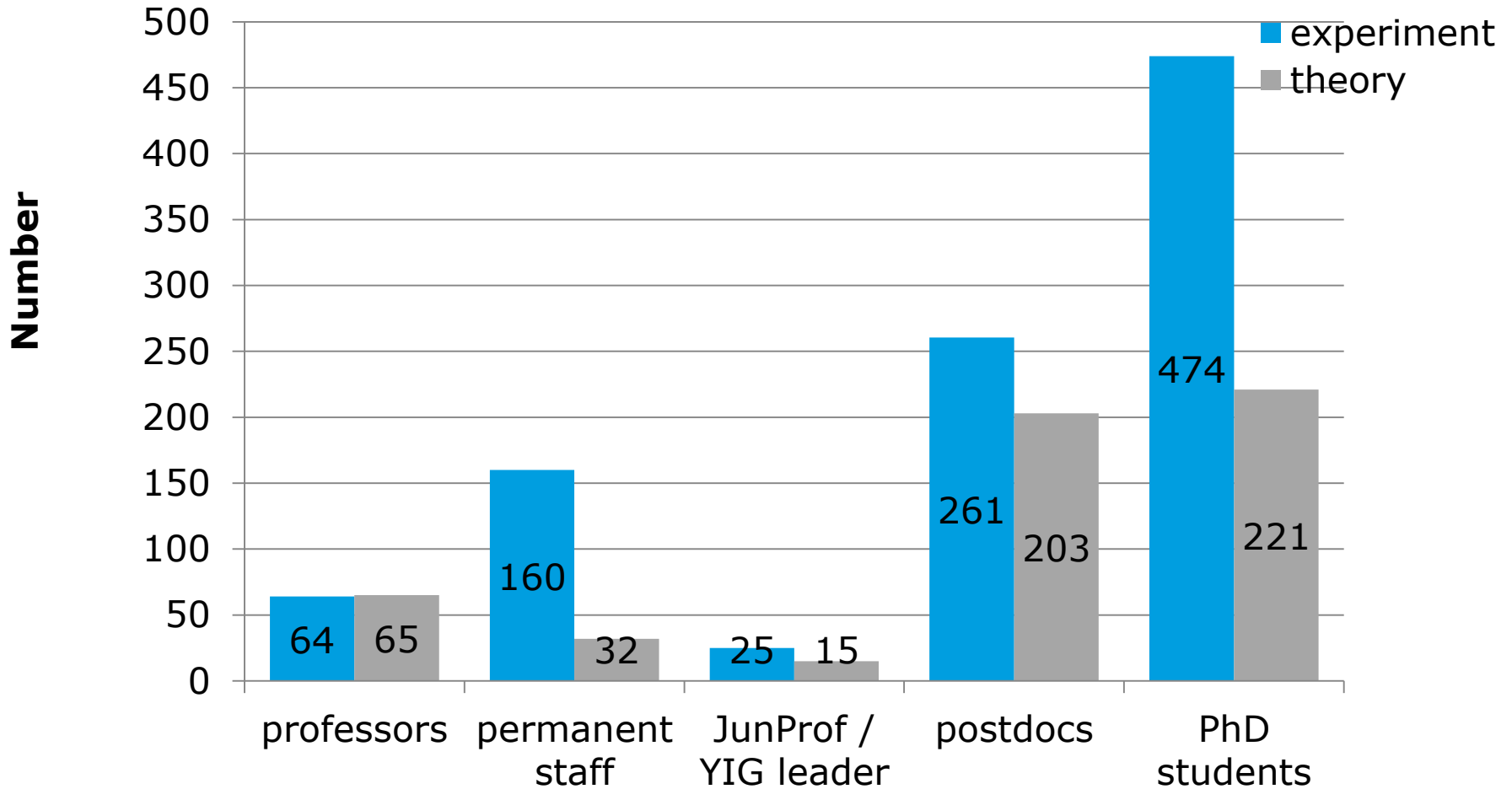
Total numbers of theorists in Germany (according to 2013 KET poll)

- Professors and senior staff: **65**
- Permanent (senior) scientists: **32**
- Junior-Professors and YIG-Leaders: **15**
- Postdocs and other fixed term positions: **203 FTE's**
- PhD Students: **221**

Einige Standorte mit mehreren Gruppen

Employees in particle physics in Germany

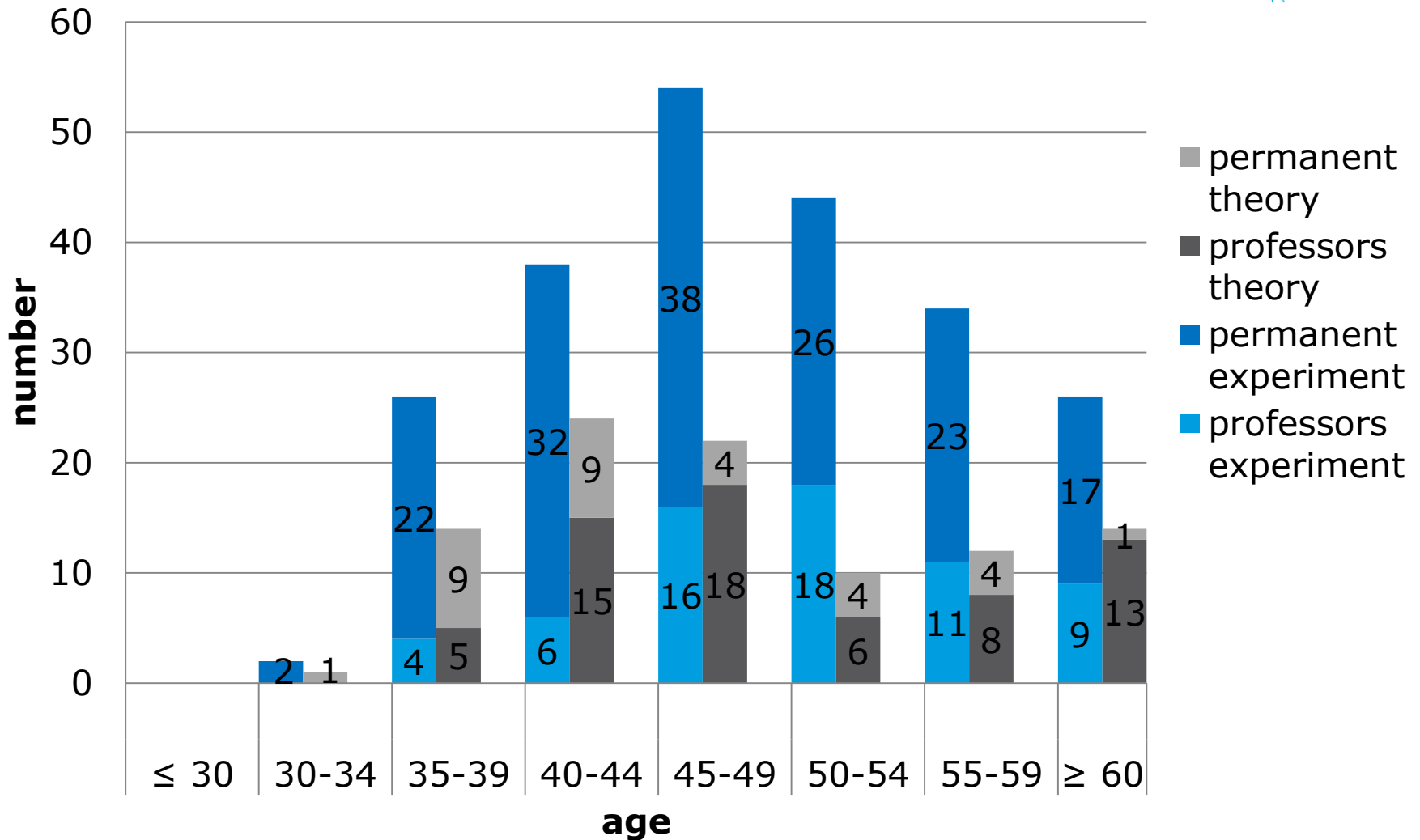
total: 1475; total experiment: 939; total theory: 536



Permanent employees including professors by age



total professors theory 65; total professors experiment: 64
 total permanent staff theory: 32; total permanent staff experiment: 160;

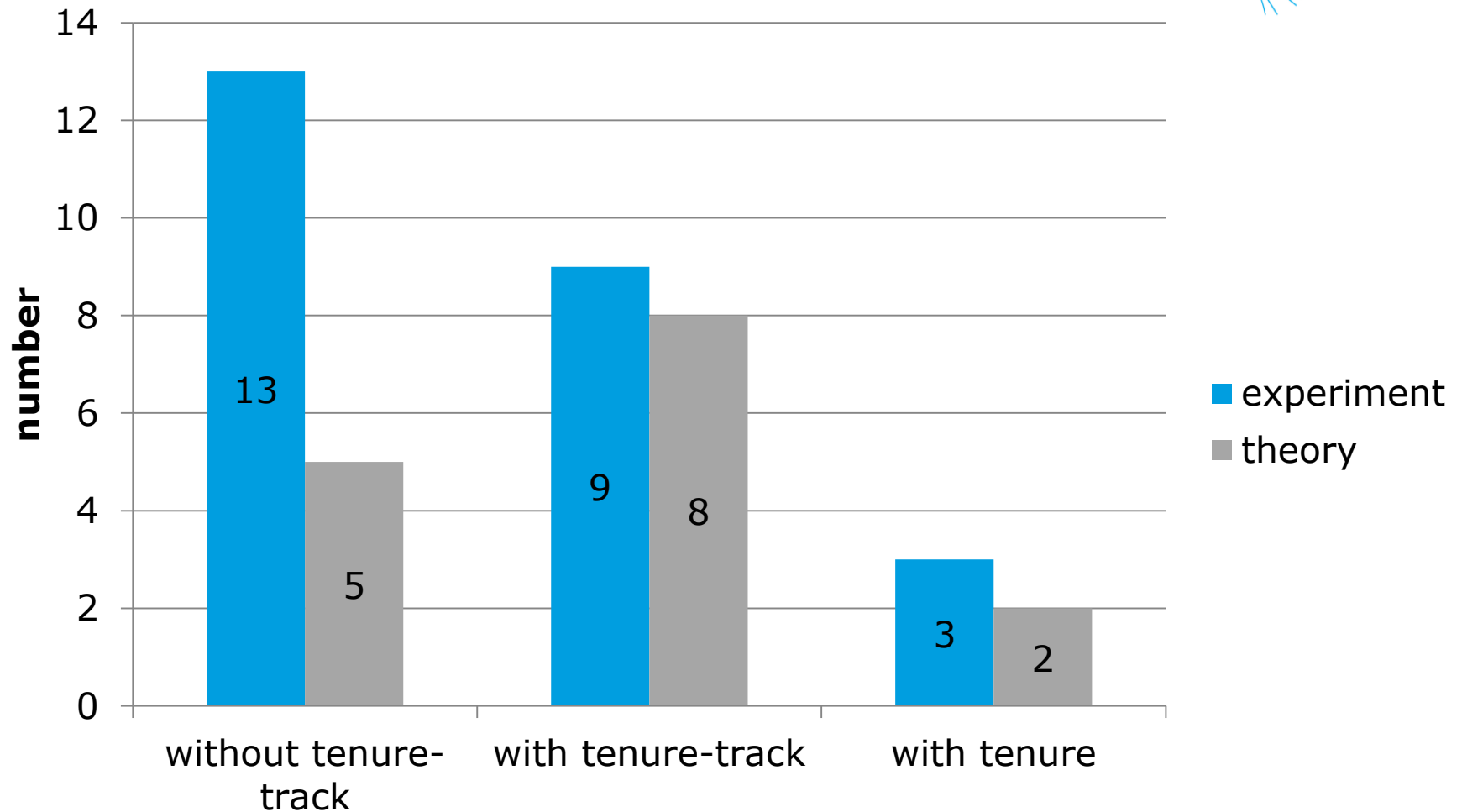


Altersstruktur in der Theorie

- Relativ niedrige Zahl an Pensionierungen in den nächsten 10-15 Jahren: **ca. 2 pro Jahr**
- Danach 4-5 freie permanente Theoriestellen pro Jahr zu erwarten
- Das Juniorprofessurenprogramm kann sich in der Teilchentheorie als besonders hilfreich erweisen und sollte nach Möglichkeiten ausgenutzt werden!

JunProfs & young investigator group leaders

total experiment 25; total theory 15

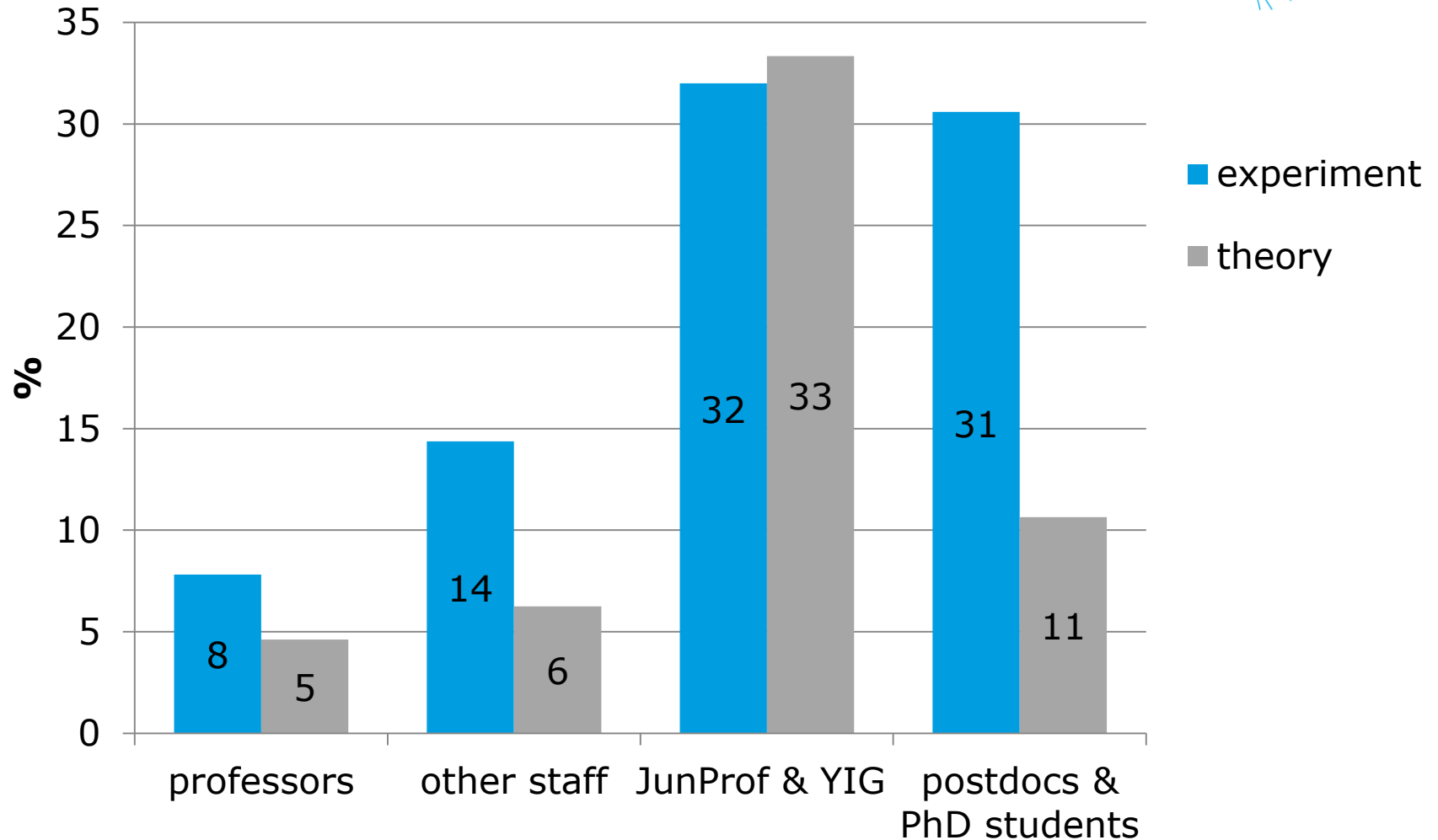


Tenure-Track ist in Teilchentheorie präferiertes Modell:



Percentage of women

total 15%; total experiment: 18%; total theory 11%



Starke Anstrengung zur Rekrutierung von Doktorandinnen weiterhin notwendig

Sonderforschungsbereiche:

- SFB/TR33 **The Dark Universe**
Heidelberg; Bonn; München 2006
- SFB/TR55 **Hadron Physics from Lattice QCD**
Regensburg; Wuppertal 2008
- SFB/TR110 **Symmetries and the Emergence of Structure in QCD**
Bonn; Beijing; Bochum; München 2012
- SFB647 **Space - Time - Matter: Analytic and Geometric Structures**
Berlin 2005
- SFB 676 **Particles, Strings, and the Early Universe**
Hamburg 2006

- Beobachtung: keine SFB's in wichtigen Kernbereichen des KET
- Problem 1: verbesserte Zusammenarbeit Theorie/Exp. in SFB durch Doppelförderungsproblematik behindert
- Problem 2: Sichtbarkeit an den Unis (SFB verleiht Prestige)

One theory highlight of 2015/16

Advances achieved by NNLO QCD corrections (and higher) are leading to a paradigm shift: precision comparison of experiment and theory at hadron colliders at the few percent level → improved sensitivity to BSM

Examples

- N3LO corrections to Higgs production

Anastasiou, Duhr, Dulat, Herzog, Mistlberger: arXiv:1503.06056

- NNLO corrections to top pair production

Czakon, Heymes, Mitov: arXiv:1511.00549

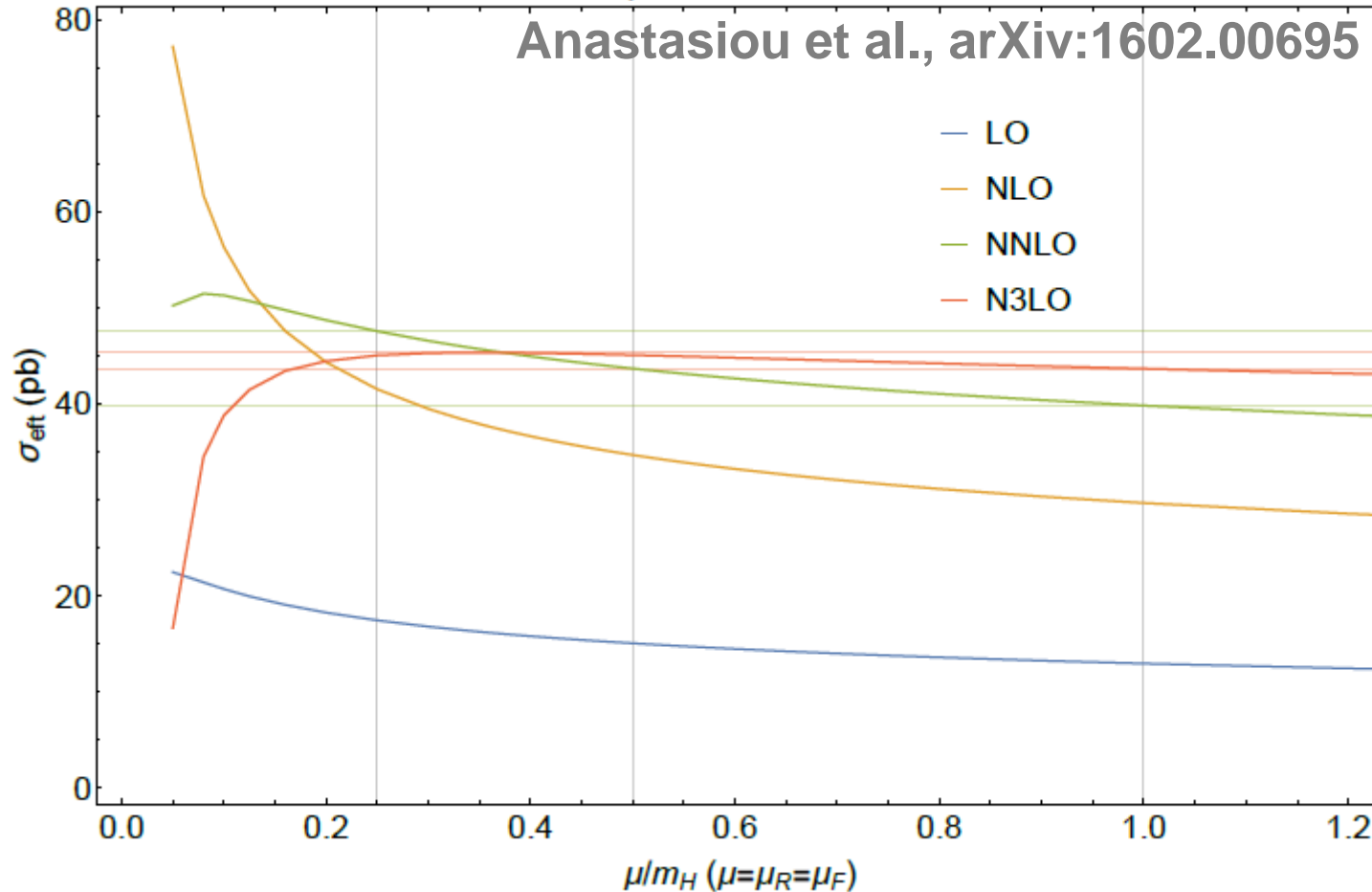
- NNLO corrections to $p_T(Z)$ and to Z+jet production

Gehrmann-De Ridder, Gehrmann, Glover, Huss, Morgan; arXiv:1507.02850 arXiv:1605.04295

$\sigma(gg \rightarrow h)$ now known up to N3LO:

setup 1, EFT, 13 TeV

Anastasiou et al., arXiv:1602.00695

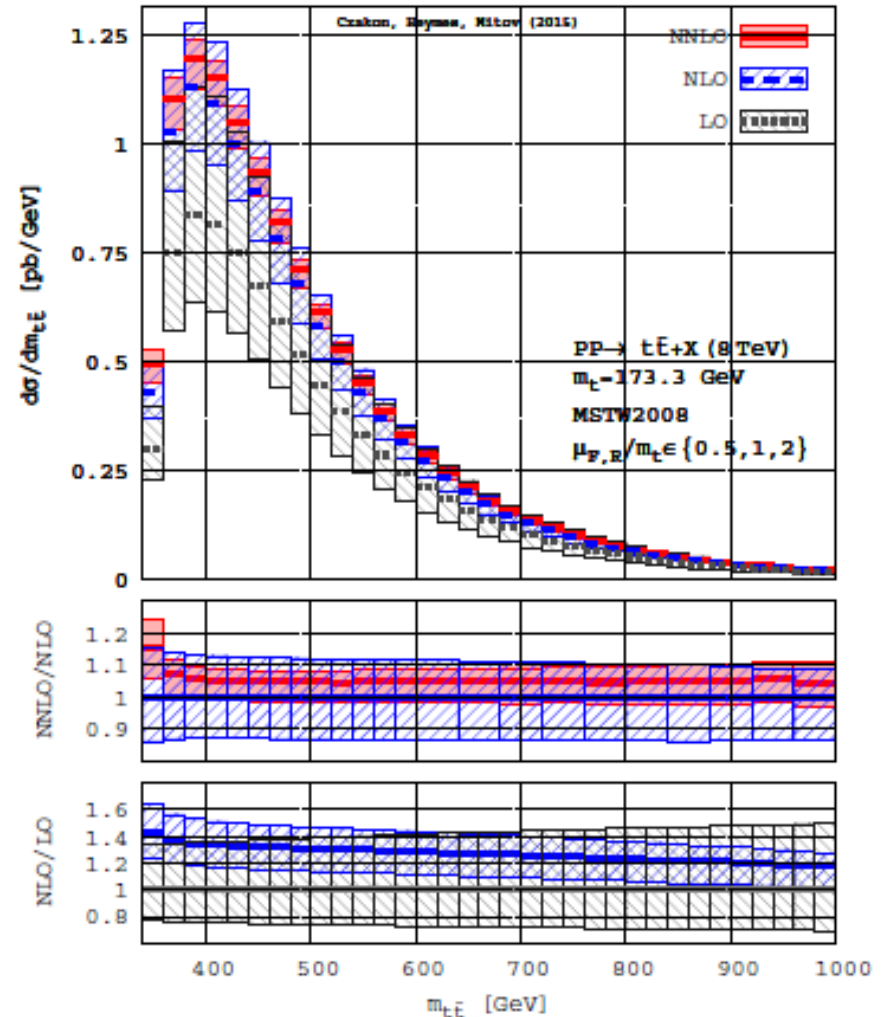


$$\sigma = 48.58 \text{ pb}^{+2.22 \text{ pb} (+4.56\%)}_{-3.27 \text{ pb} (-6.72\%)} \text{ (theory)} \pm 1.56 \text{ pb} (3.20\%) \text{ (PDF} + \alpha_s)$$

Top-pair cross section at NNLO

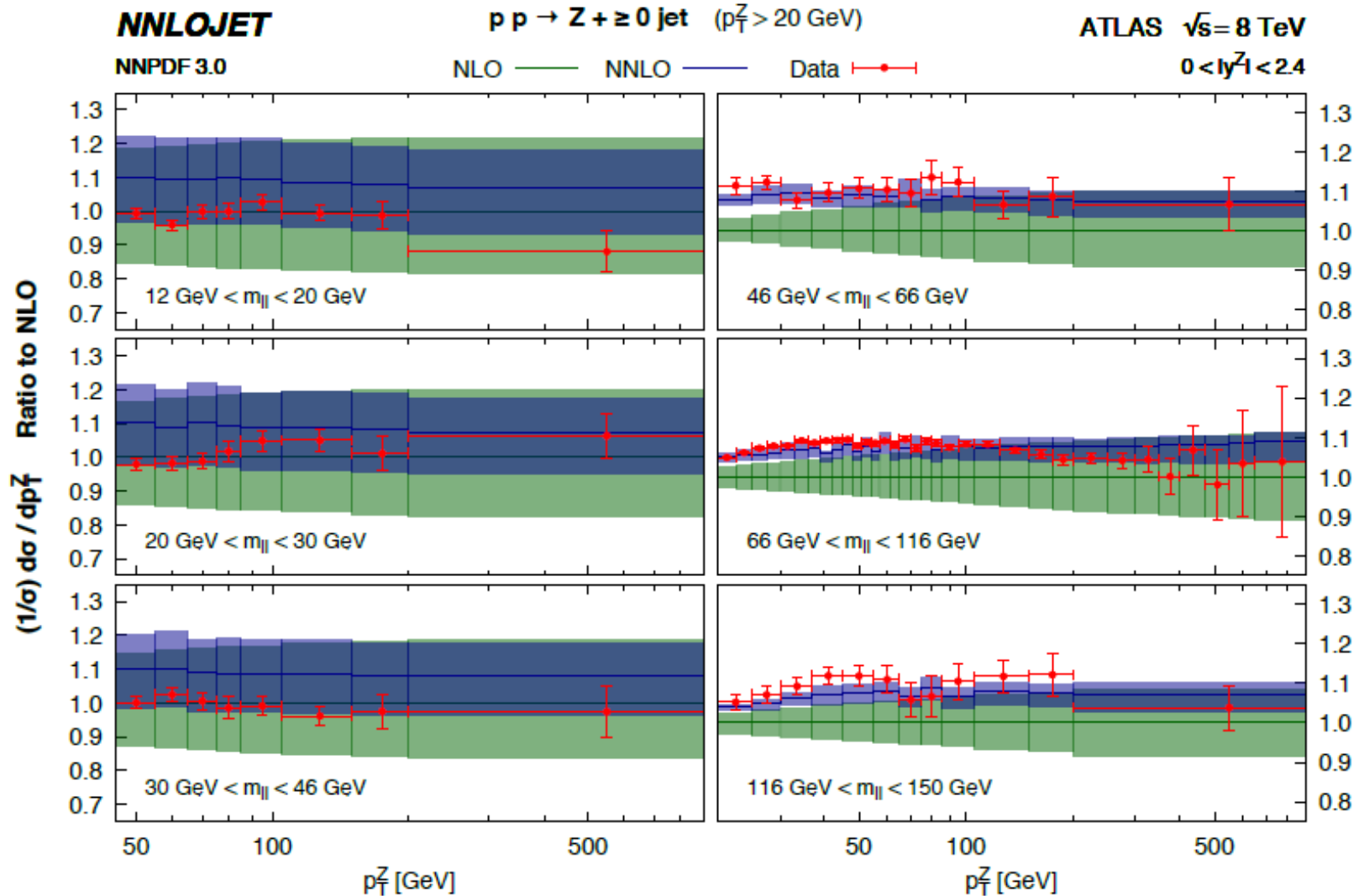
Czakon, Heymes, Mitov: arXiv:1511.00549

- Full Monte Carlo for stable top quarks
- Builds on earlier total cross section calculation
- Strongly reduced scale dependence
- Improves agreement with top transverse momentum measurement
- Small change in top-pair invariant mass distributions at NNLO
→ stable prediction for BSM search
- Benefits from improved gluon pdf determination, just like Higgs cross section

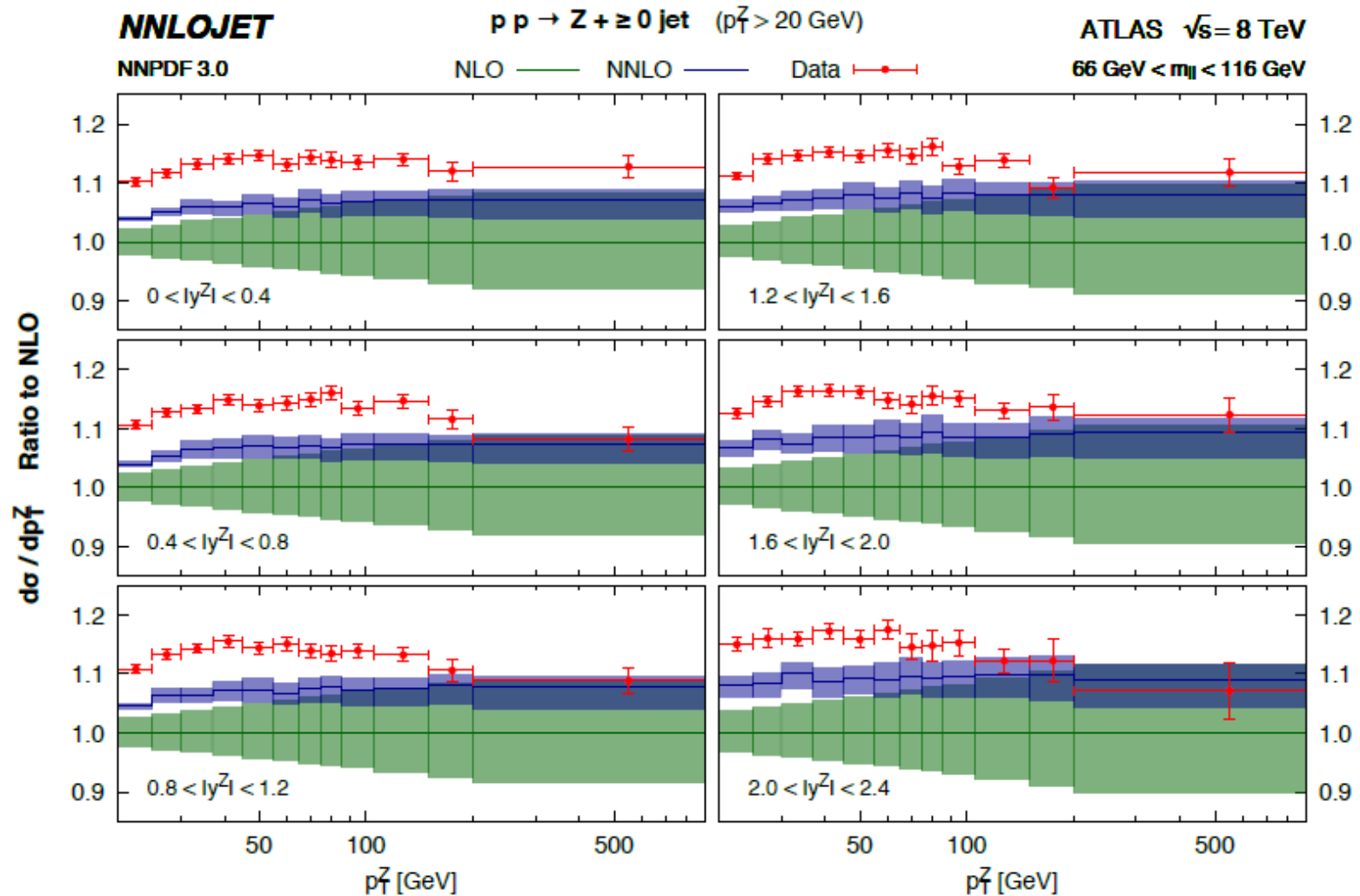


Z+jet and Z pT-distribution at NNLO

Gehrmann-De Ridder et al., arXiv:1605.04295

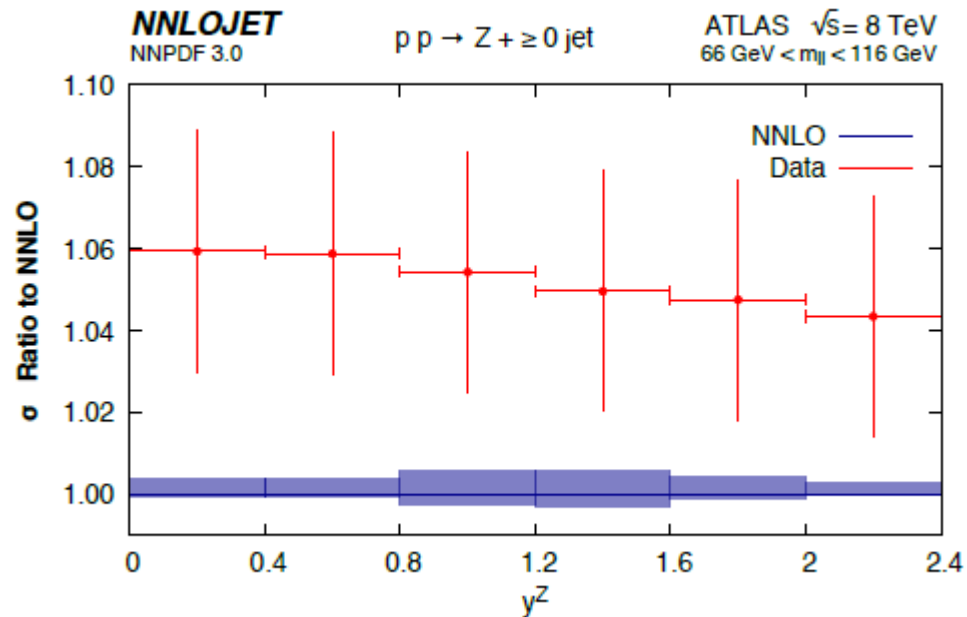


pT(Z) in rapidity bins: absolute comparison



Gehrmann-De Ridder et al., arXiv:1605.04295

Normalization to fiducial Z cross sections

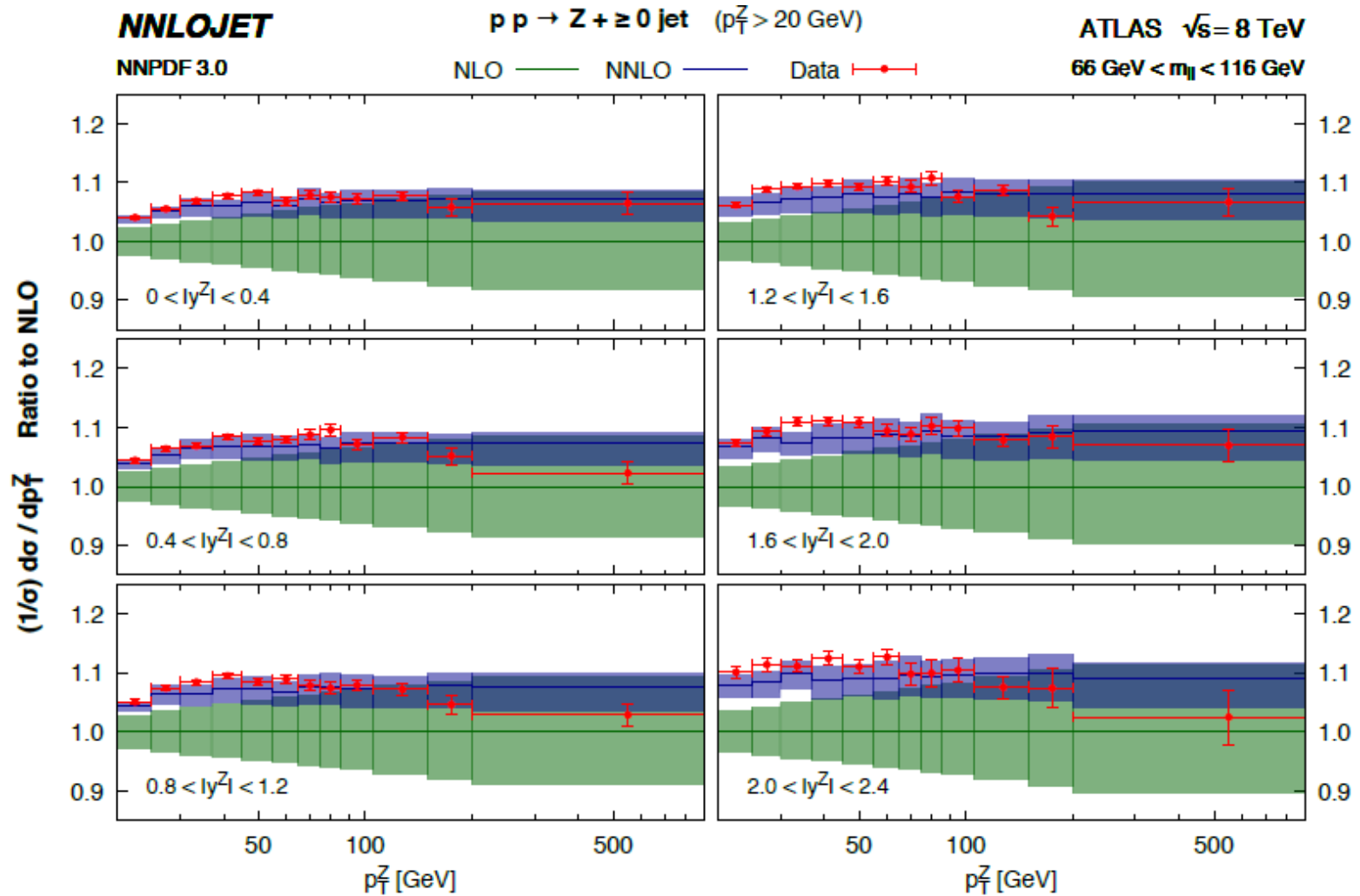


Measured total Z rate
(in rapidity bins) is
also high

Cancel common luminosity
error and partially cancel
pdf uncertainty by taking ratios

Gehrmann-De Ridder et al., arXiv:1605.04295

pT(Z) in rapidity bins: normalized to fiducial cross section



Gehrmann-De Ridder et al., arXiv:1605.04295

Benefits of precision Z+jets comparison

- Z+jets is dominated by quark-gluon scattering at LO
 - extract gluon distribution with NNLO precision
 - improved predictions for $gg \rightarrow H$ and top production
- Use $Z \rightarrow \ell\ell$ data and NNLO predictions to extrapolate to very high p_T Z+jet events with Z decay to neutrinos
 - excellent normalization of one of the main backgrounds to monojet searches for dark matter

Zusammenfassung

- Deutschland ist bei Präzisionsrechnungen sehr stark und in die internationalen Aktivitäten eingebunden: neben NNLO (und höher) auch NLO QCD und elektroschwache Korrekturen, Monte Carlo Entwicklung etc.
- NXLO Entwicklungen sind nur kleiner Teil exzellenter Theorie in Deutschland, Europa und weltweit
- Erfolgreiche Zusammenarbeit von Theorie und Experiment in vielen Bereichen
- Zahl der neu zu besetzenden Stellen in der Theorie in den nächsten Jahren relativ niedrig, aber kann stark vom Juniorprofessurenprogramm profitieren