

Expanding TMTpro reagents to 32-plex for high-throughput quantitative proteomics on Orbitrap platforms

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Abstract

Thermo Scientific™ TMTpro reagents enable researchers to simultaneously identify and quantify proteins and peptides from many samples in a single LC-MS/MS experiment. Current TMTpro isobaric mass tags incorporate ¹³C & ¹⁵N stable isotopes to allow quantitative analysis of up to 18 samples in parallel by high-resolution MS/MS analysis. To further increase multiplexing capability, we developed an additional isobaric set of 17 isotopologues that incorporate a single ²H isotope on the reporter group to yield distinct reporter ion masses that differ from the existing set by 3 mDa. In combination with the traditional reagent set, the deuterated reagents enable multiplexed quantitative analysis of up to 35 samples on Thermo Scientific™ Orbitrap platforms. Here, we characterize the novel TMTpro variants and assess their performance for 32-plex quantification.

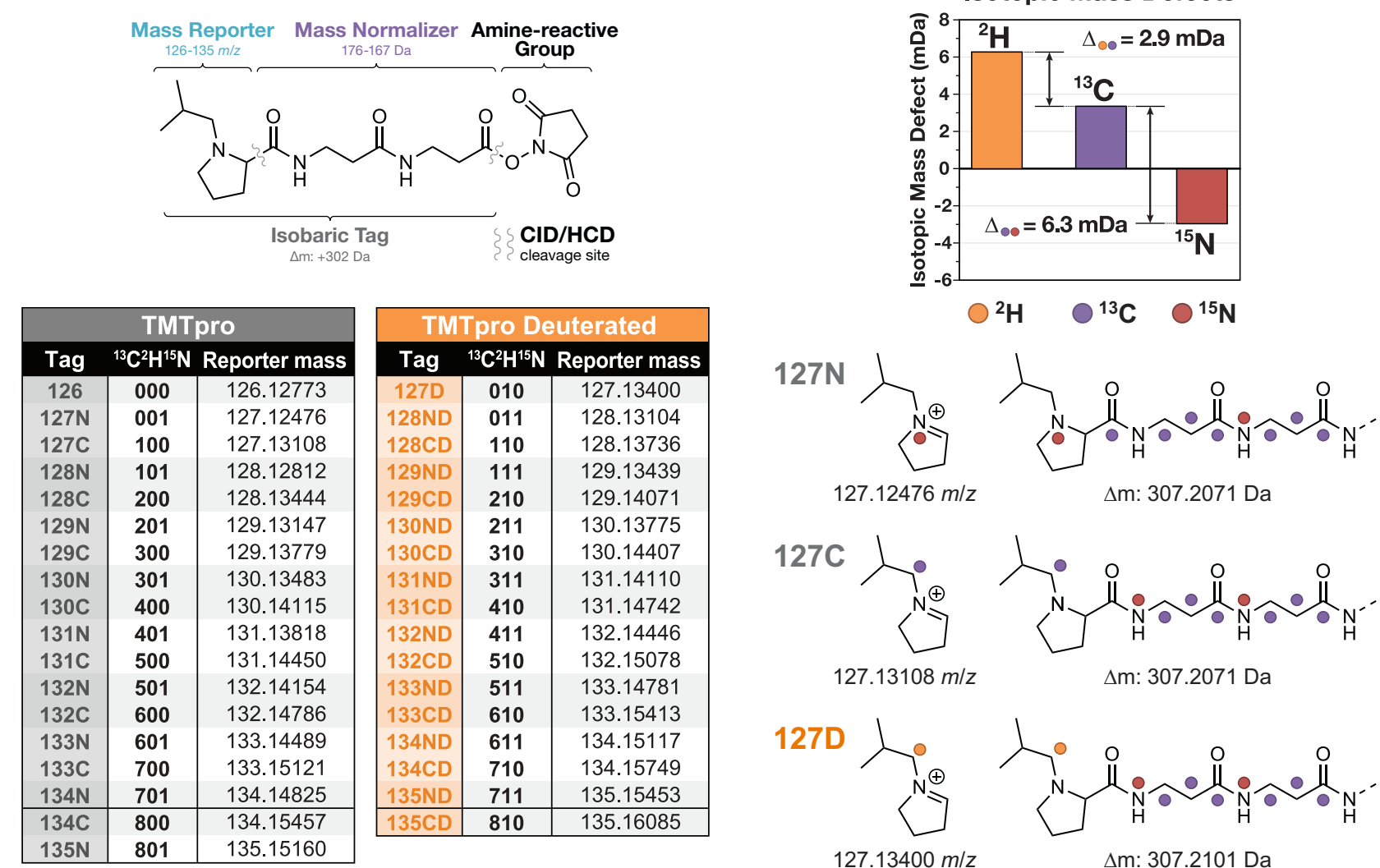
Introduction

Thermo Scientific™ TMTpro reagents are isobaric tandem mass tags that permit multiplexed relative quantification of samples by LC-MS/MS analysis. The reagent structure features a reporter group and a mass normalizer group, across which heavy stable isotopes are incorporated, and an amine-reactive group (Figure 1) for derivatization of peptide N-termini and lysine side chains. All reagents in the multiplex set are structurally identical and have the same nominal mass, but each incorporates nine ¹³C & ¹⁵N heavy stable isotopes in a unique configuration between the reporter and mass normalizer. Samples are differentially labeled with each reagent in the multiplex set, the labeled samples are combined, and the pooled sample is subjected to LC-MS/MS analysis on an Orbitrap MS platform using high-resolution acquisition. Differentially labeled peptides incur the same mass shift, and single precursors are measured in MS spectra. Peptides across all samples are thus co-analyzed upon MS/MS acquisition, and fragmentation generates unique reporter ions in the low mass region of MS/MS spectra with intensities that reflect the relative protein abundance in each sample.

The TMTpro reagent structure supports a maximum of nine ¹³C/¹⁵N isotopes on the isobutylproline reporter group, permitting a total of ten nominal mass reporters between 126–135 Da. By exchanging a ¹³C for a ¹⁵N isotope on the reporter group, up to 18 unique reporters with Δm : 6 mDa are possible which can be distinguished in Orbitrap MS/MS spectra acquired at resolving power (RP) $\geq 50K$ (at 200 *m/z*).

To increase multiplexing further without changing the tag structure, we incorporated a single ²H isotope onto the reporter group to impart a 3 mDa mass difference and permit an additional 17 unique reporter ion masses to be created. To do this without requiring expensive custom starting reagents, adding synthetic steps, or reducing synthetic yield, we opted to incorporate the ²H isotope into the isobutyl group via a deuterated reducing agent during synthesis. The Δm : 3 mDa reporters can be distinguished in MS/MS spectra acquired in the Orbitrap mass analyzer at RP $\geq 75K$ or TurboTMT 45K. Combining the deuterated tags with the existing tags permits multiplexed quantitative analysis of up to 35 samples.

Figure 1. TMTpro 35-plex isotopic configurations



Materials and methods

Sample Preparation

HeLa S3 cells were grown in sMEM supplemented with 10% FBS, 1x Glutamax and 1% Pen/Strep. HeLa digest samples were prepared using the Thermo Scientific EasyPep™ MS sample prep kit protocol. Peptides were reconstituted in 100 mM TEAB pH 8.5, labeled for 1 hr with TMTpro reagents, and cleaned up using the EasyPep SPE protocol.

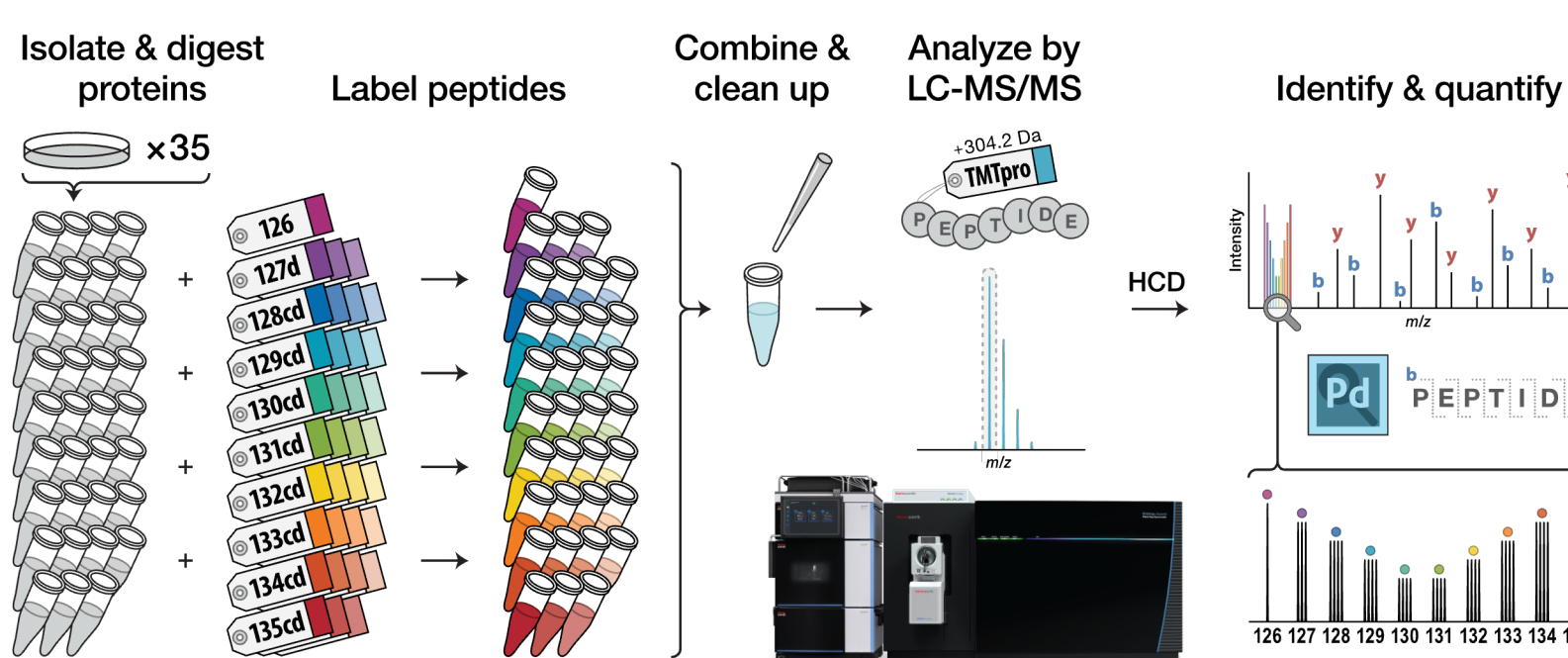
LC-MS/MS analysis

Samples were analyzed by nanoflow LC-MS/MS using a Thermo Scientific™ Orbitrap Eclipse™ Tribrid™ mass spectrometer interfaced with a Thermo Scientific™ Vanquish™ Neo UHPLC system using a 50cm C18 Thermo Scientific™ EASY-Spray™ column with a gradient elution of 2–32% ACN with 0.1% formic acid over 120 min at a flow rate of 300 nL/min. FT-MS scans (RP: 120K at 200 *m/z*) and HCD FT-MS² scans (RP: $\geq 75K$ or TurboTMT 50K) were acquired using a 3 sec DDA scan cycle with 60 sec dynamic exclusion. RTS SPS-MS³ acquisition was also performed.

Data Analysis

Raw data was processed by Thermo Scientific™ Proteome Discoverer™ 3.0 using the SEQUEST® HT search algorithm with a UniProt human protein database. Peptide modifications consisted of static carbamidomethylation (C), dynamic oxidation (M), and either static or dynamic TMTpro tags (N-terminus, K; Δm : 304.2071 Da). Protein and peptide identifications were filtered to a 1% FDR threshold using Percolator. Reporter ions were integrated within an 11 ppm window.

Figure 2. TMTpro 35-plex workflow



Results

Figure 3. TMTpro 35-plex reporter ions acquired at RP 90K in the Orbitrap

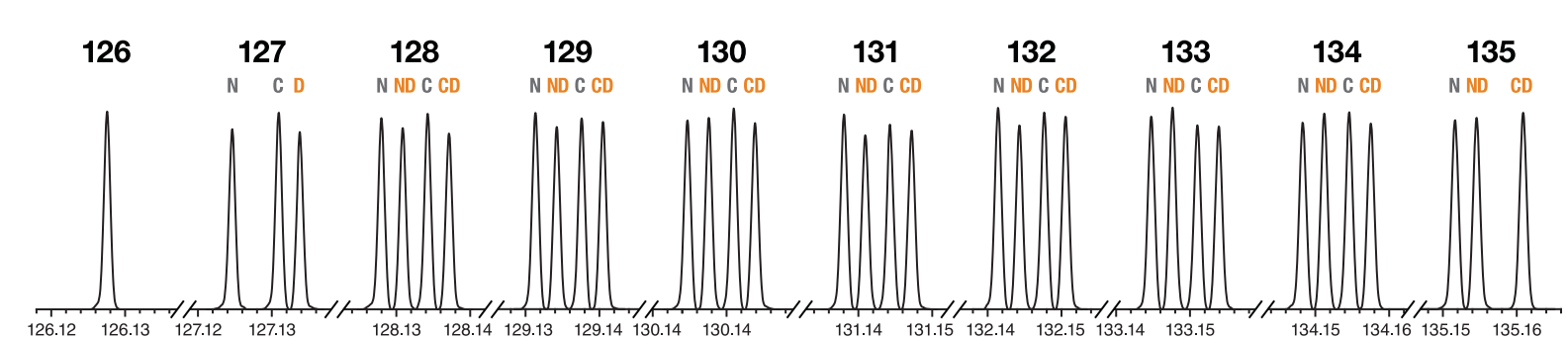


Figure 4. Reporter ion isotopic distribution for TMTpro deuterated reagent set

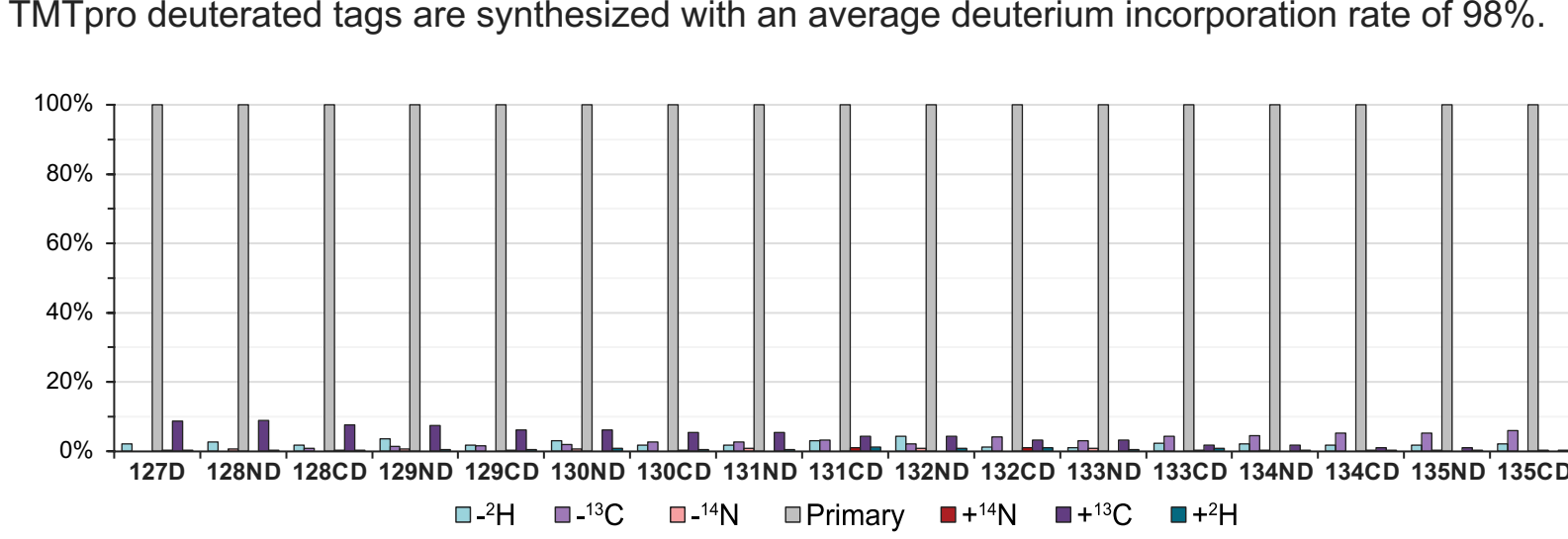


Figure 5. Resolving 3mDa TMTpro reporter ions in the Orbitrap mass analyzer. TMTpro 128N, 128ND, 128C, 128CD reagents were mixed at 1:1, 1:10, and 10:1 and analyzed by direct infusion MS to determine resolving power required to distinguish TMTpro Δm : 3 mDa reporter ions in HCD FT-MS² spectra. Reporter ion peaks are sufficiently resolved to 5% of baseline at RP 75K (at 200 *m/z*) and baseline resolved at RP $\geq 90K$.

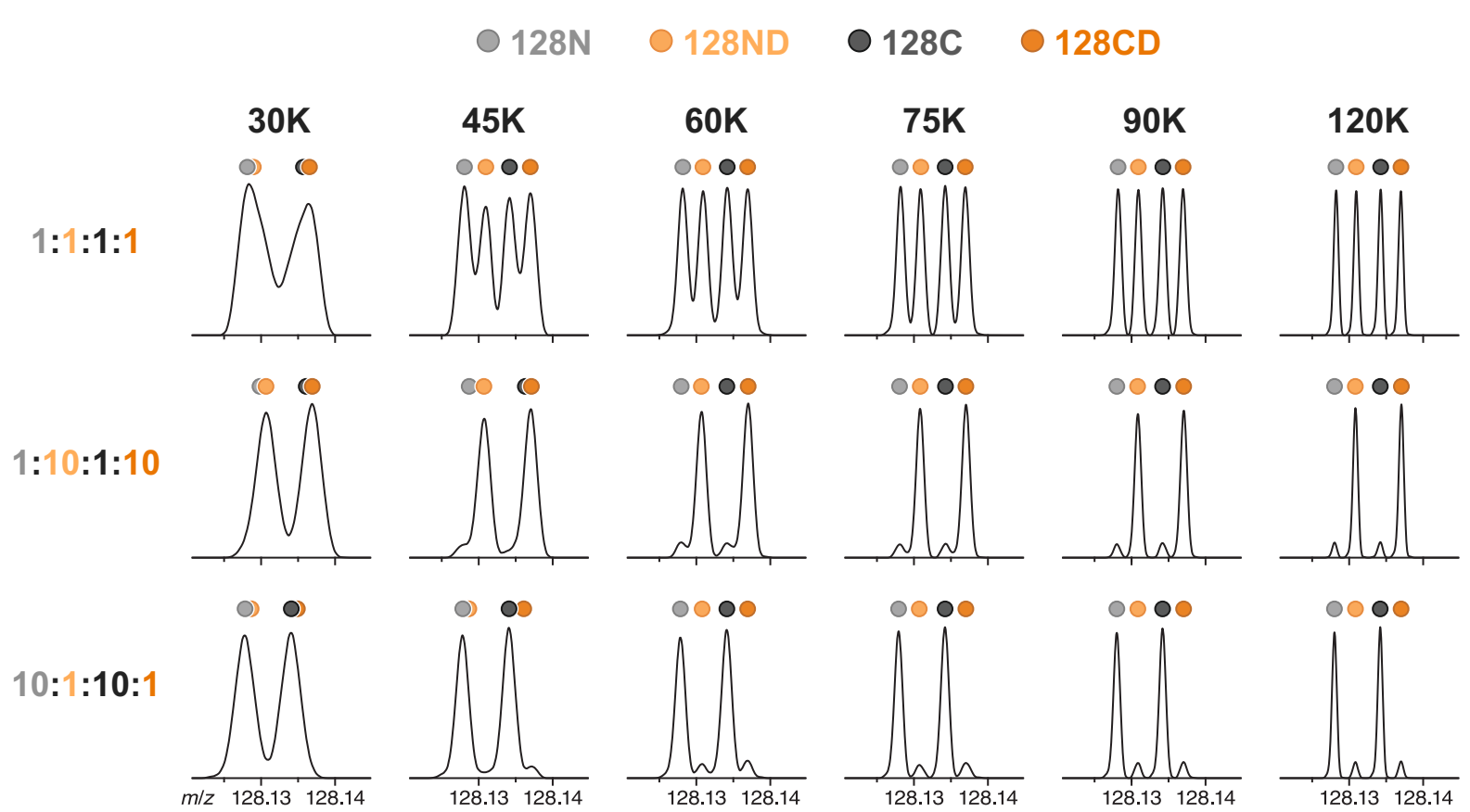


Figure 6. Characterization of RPLC retention time shift

Peptides labeled with the TMTpro deuterated reagent set are shifted ahead slightly in retention time during reversed-phase chromatography. To achieve accurate & precise quantification, reference non-deuterated channels to a non-deuterated control channel and reference deuterated channels to a deuterated control channel.

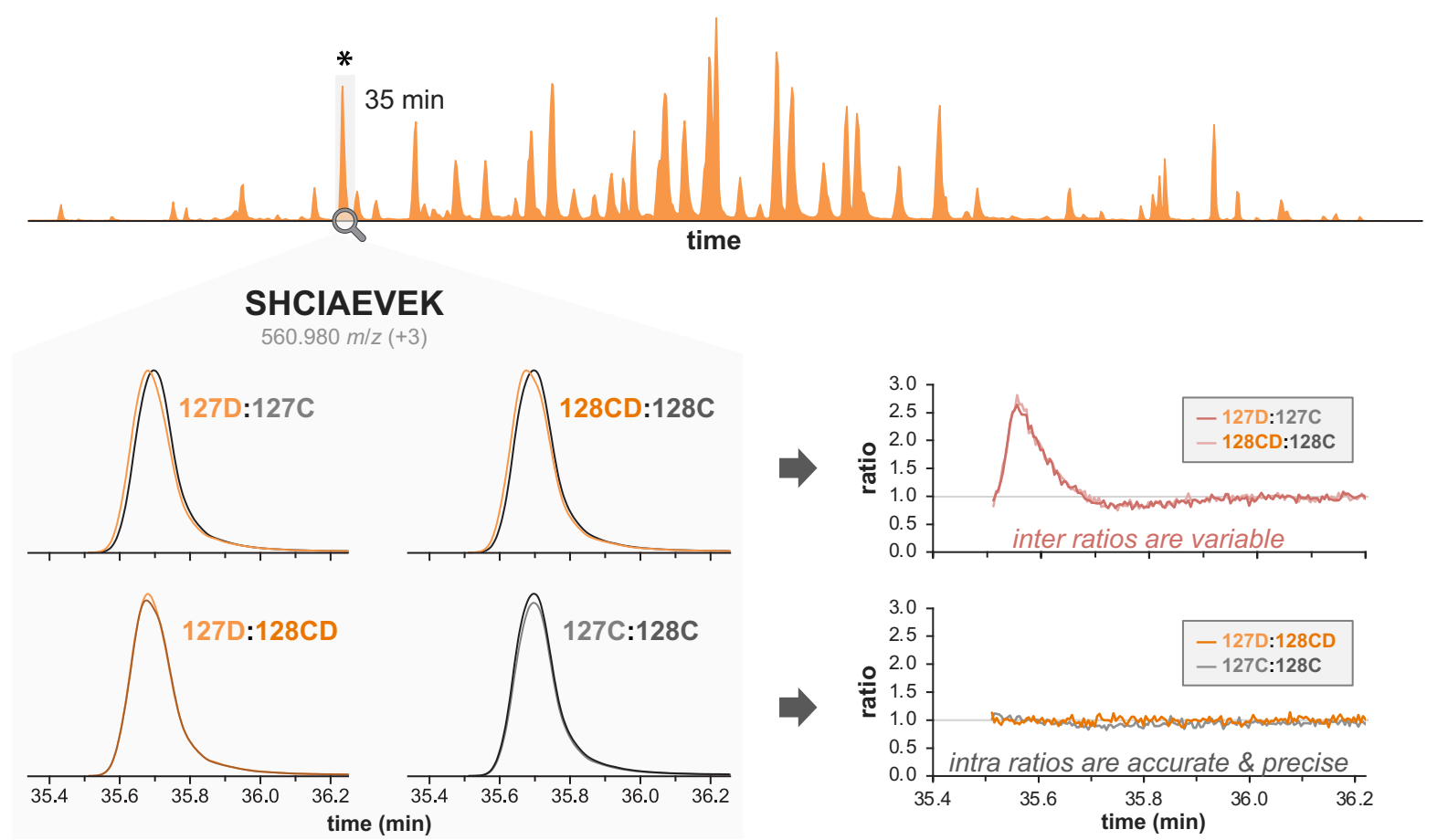


Figure 7. TMTpro deuterated reagent peptide labeling efficiency, HeLa digest. Individually TMTpro-labeled HeLa digest samples were analyzed separately by LC-MS to assess peptide labeling efficiency. TMTpro deuterated reagents label both N-termini & lysine residues with $\geq 99.5\%$ efficiency. All peptides (100%) contained at least one tag.

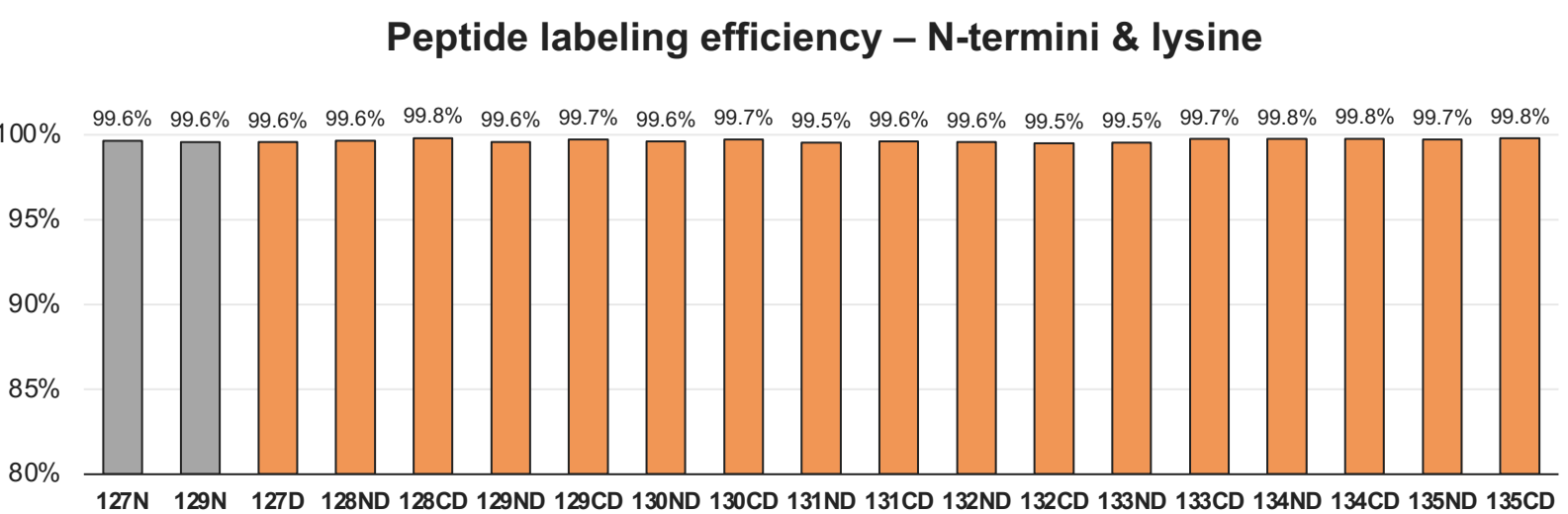


Figure 8. TMTpro 32-plex vs. 16-plex quantification – HCD FT-MS², PSMs. HeLa digest samples labeled with TMTpro 16-plex, 16-plex deuterated, and 32-plex reagents show that the three multiplex sets achieve equivalent quantitative performance for MS² acquisition at RP 50K & 75K. The % abundance was calculated separately for the deuterated and non-deuterated sets by dividing the abundance of each channel by the sum of abundances for that set. Isotopic interference correction not applied.

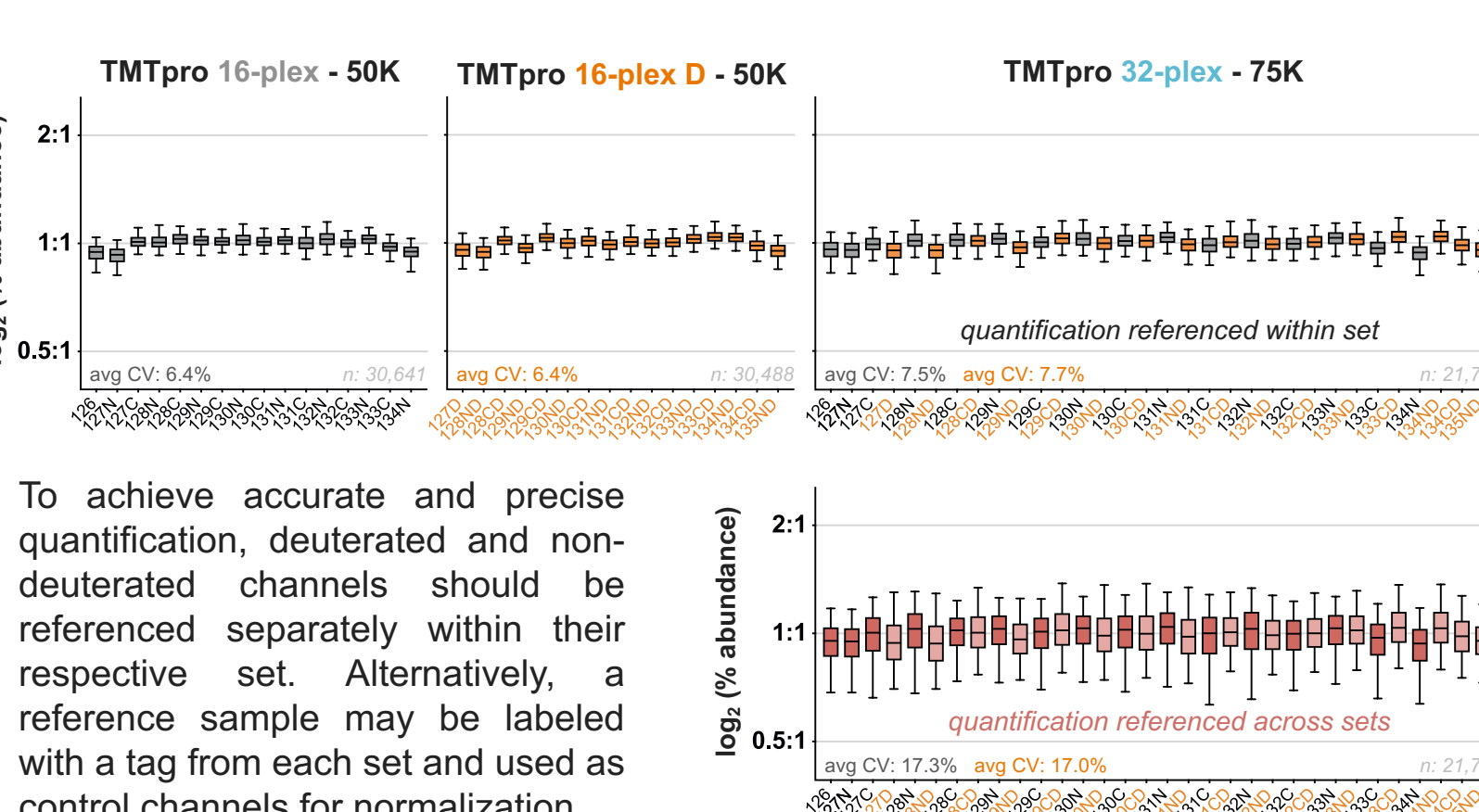


Figure 9. Quantitative performance at different MS² resolving powers – MS², PSMs

HeLa digest samples labeled with TMTpro 32-plex reagents were combined at 1:10 ratio between non-deuterated and deuterated channels to compare quantitative performance at different MS² resolving powers. TurboTMT RP 45K and eFT RP 75K provide a good balance of quantitative accuracy & precision and acquisition speed. 8 of 32 channels shown; reference channels 134N & 128ND; isotopic interference correction not applied.

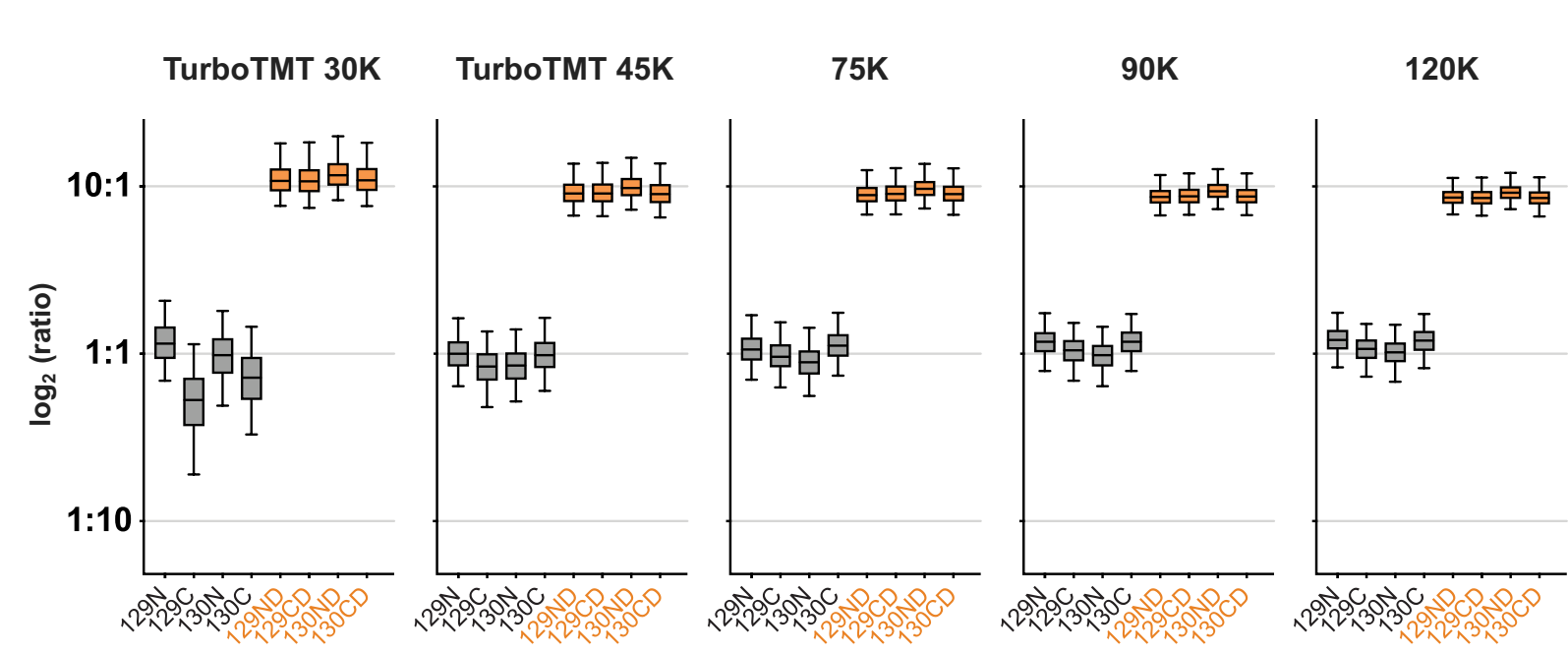


Figure 10. TMTpro 32-plex HeLa quantified proteins & peptides – HCD FT-MS²

HeLa digest samples labeled with TMTpro 32-plex reagents were analyzed using MS² acquisition methods at increasing resolving powers to assess the impact on the number of quantified proteins & peptides and % of quantified peptide spectral matches (PSMs).

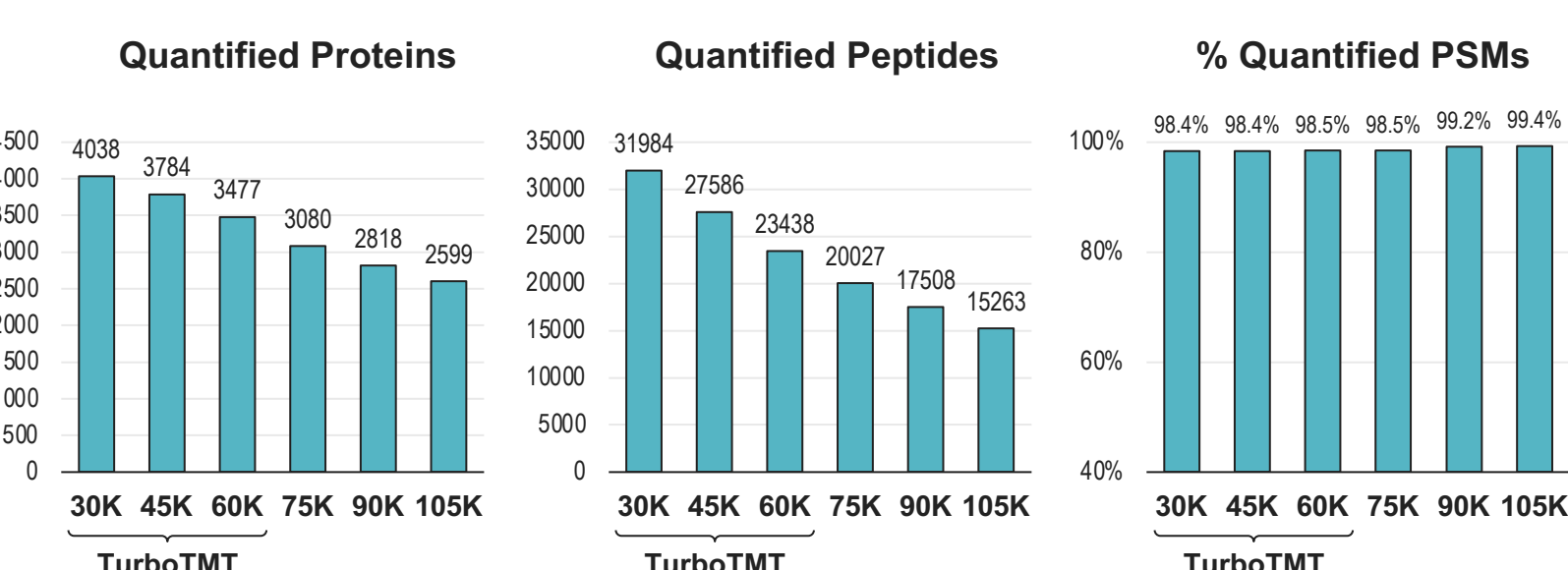


Figure 11. TMTpro 32-plex vs. 2x 18-plex bridged LC-MS experiments – RTS SPS-MS³. HeLa digest samples labeled with TMTpro 32-plex & 18-plex reagents were analyzed using RTS SPS-MS³ acquisition methods at RP 90K and TurboTMT 30K, respectively. The 32-plex experiment yields 15% more quantified proteins and 39% more quantified peptides than two 18-plex bridged experiments due to missing values between two LC-MS runs.

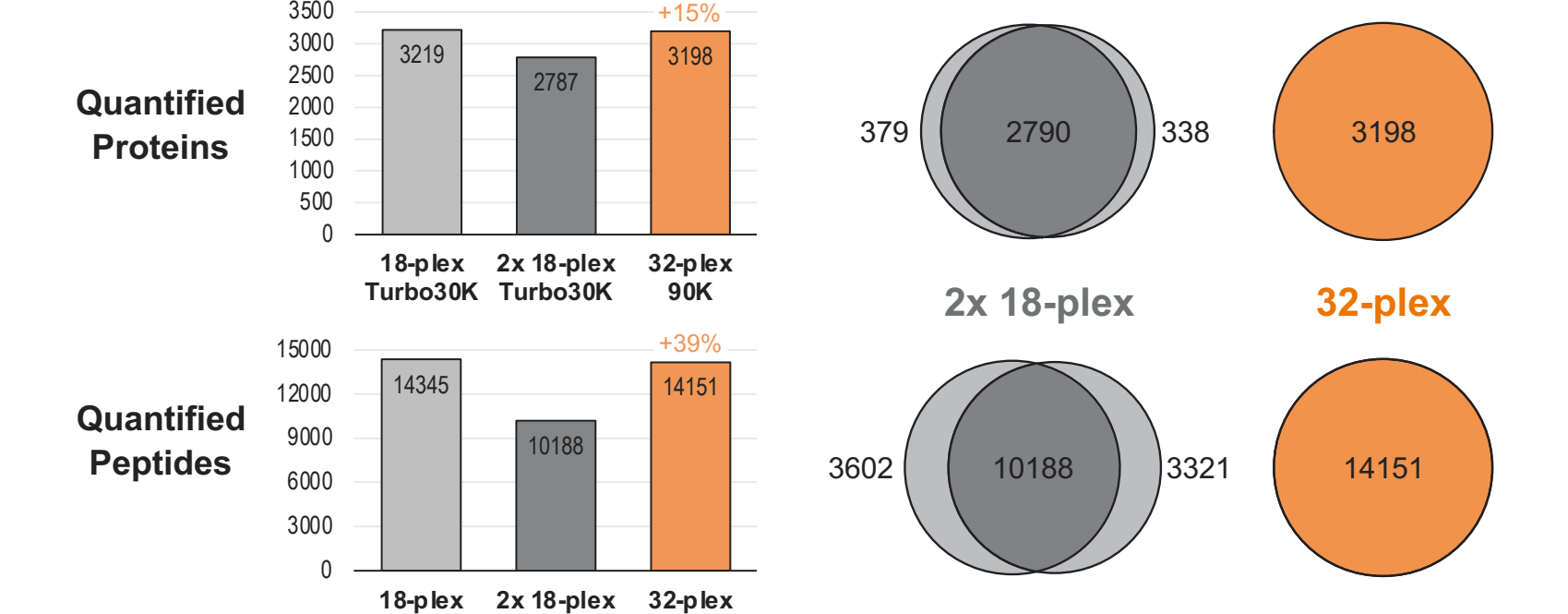
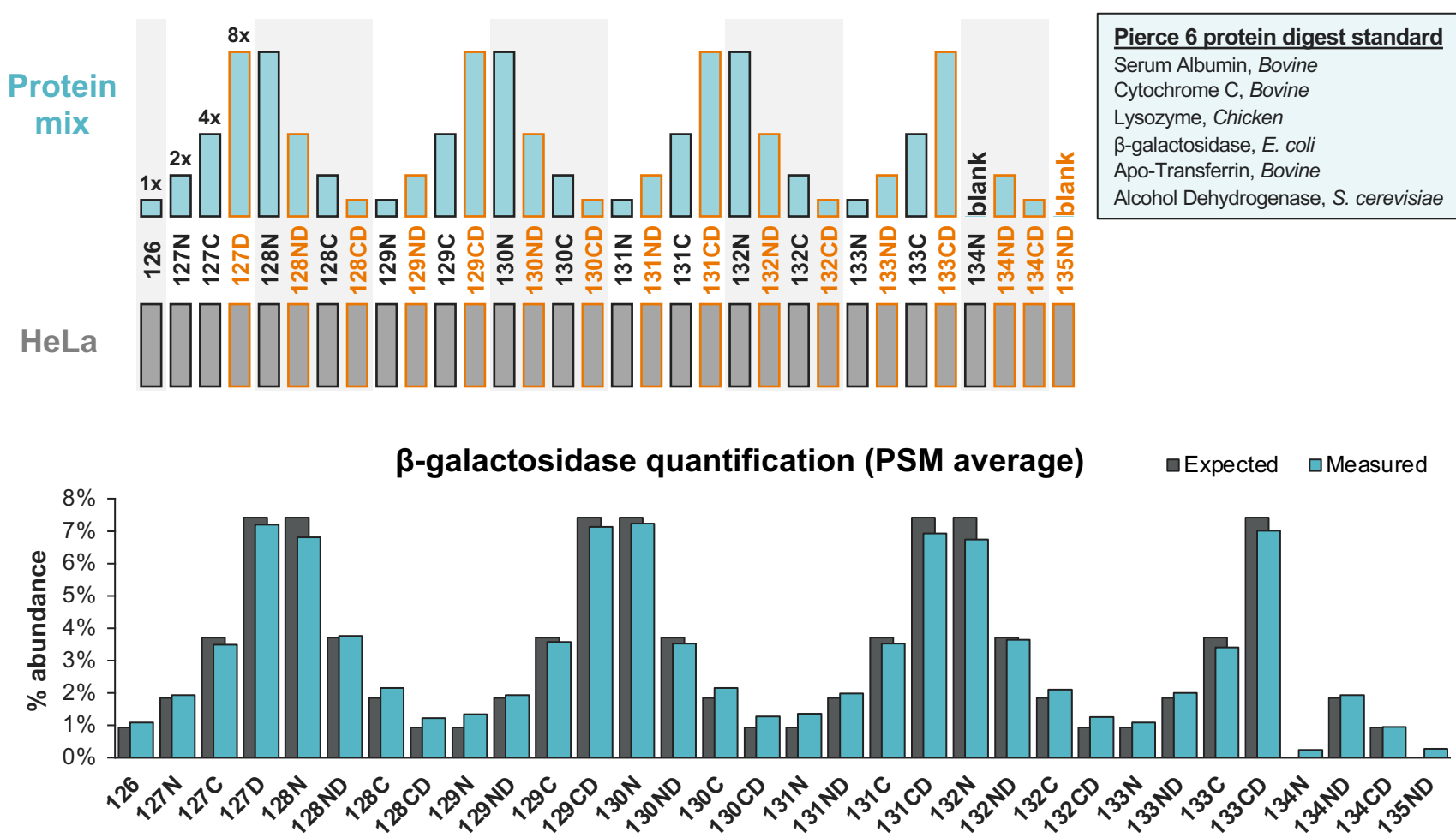


Figure 12. Quantification of protein standards in HeLa proteome background

Pierce 6 protein digest standard (equimolar) was spiked into a background of HeLa cell lysate digest at 100, 200, 400, and 800 fmol per μg of HeLa digest. Samples were labeled with TMTpro 32-plex reagents, pooled in equal amounts, cleaned by EasyPep SPE, and analyzed using an RTS SPS-MS³ acquisition method. Quantification of β -galactosidase based on 21 PSMs is shown.



Conclusions

- New isobaric TMTpro deuterated reagents enable multiplexed quantification of up to 35 samples in a single LC-MS/MS experiment on Orbitrap MS platforms
- TMTpro reporters with Δm : 3 mDa are resolved in MS/MS spectra at RP 75K & TurboTMT 45K
- TMTpro 32-plex reagents achieve equivalent quantitative performance and number of quantified proteins & peptides compared to TMTpro 18-plex reagents

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