

# Detecting special nuclear material with active interrogation methods

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IAEA Third Technical Meeting on Radiation Detection Instrument for Nuclear Security

Vienna, 17.08.2023

# Outline

1. Detecting special nuclear material
2. Active interrogation
3. Preliminary results
4. Conclusion

This work is sponsored by the German federal office for radiation protection under grant agreement 3620R01613



# Detecting Special Nuclear Material

- Special Nuclear Material (SNM) (highly enriched) uranium (HEU) (weapon grade) plutonium
- SNM out of regulatory control
  - Smuggling
  - Blackmailing
  - Use in an
    - unconventional explosives (aka. radiological dispersal devices)
    - Improvised nuclear weapons

"Nuclear and radioactive material will always attract malevolent interest from terrorists and other criminals. We can never relax our guard. Even countries with little or no nuclear or other radioactive material on their territory must remain vigilant."

[Statement Direktor General R. Grossi, IAEA, Vienna, February 2020](#)

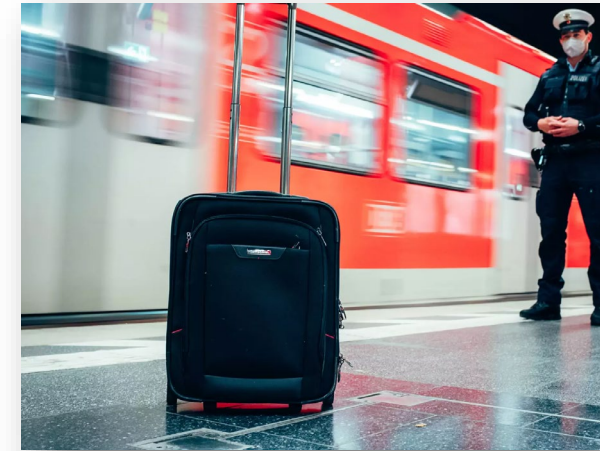
- Capability for SNM detection is necessary for threat mitigation



# Detecting Special Nuclear Material (SNM)

## Our focus on Response to Nuclear Security Events

- Scenarios
  - Intelligence indicate illegal activities involving radioactive or nuclear material
  - unknown suspicious object found
- RDD or IND?
  - In-situ measurement
  - Non-destructible
  - Restricted time for measurement
- All equipment must be man-portable



<https://www.s-bahn-muenchen-magazin.de/herrenloses-gepackstueck>

### Questions:

- Is SNM present?
- What mass?
- Oxide or metal?
- Is shielding or moderator present?
- Any indication of high explosive?

# Detecting Special Nuclear Material (SNM)

## Passive detection

### Plutonium

- 769 keV gammas from Pu-239
  - Plus several low energy lines
- Always Pu-240 intermixture
  - Large number of spontaneous fission neutrons
  - WGPu emits less
- Shielding needs large amount of material

### Uranium

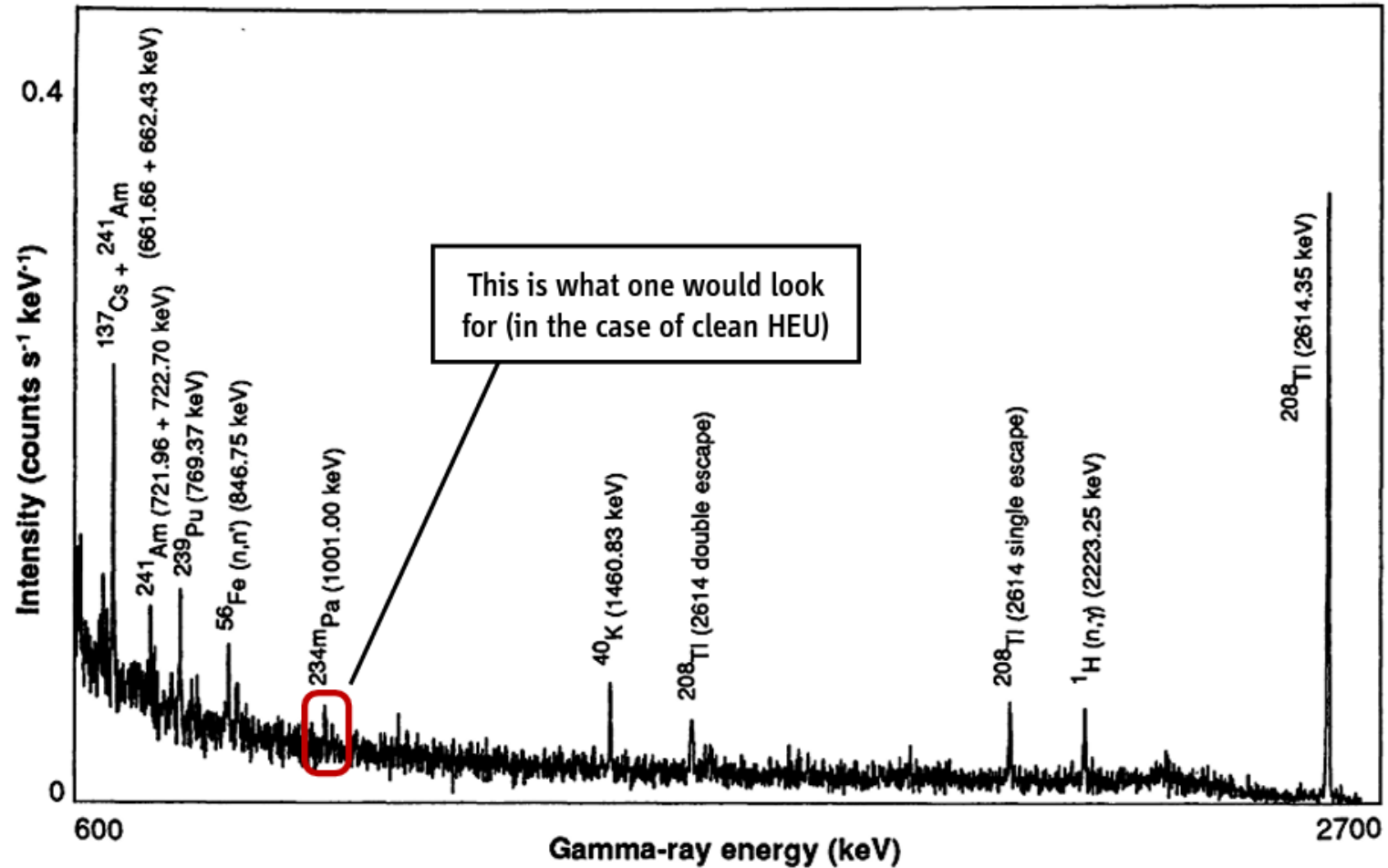
- 1001 keV Gamma line
  - From Po-214m daughter of U-238

**Shielding of HEU is relative easy**

- U-235: 15 n/s

# Gamma Spectrum of an actual nuclear weapon

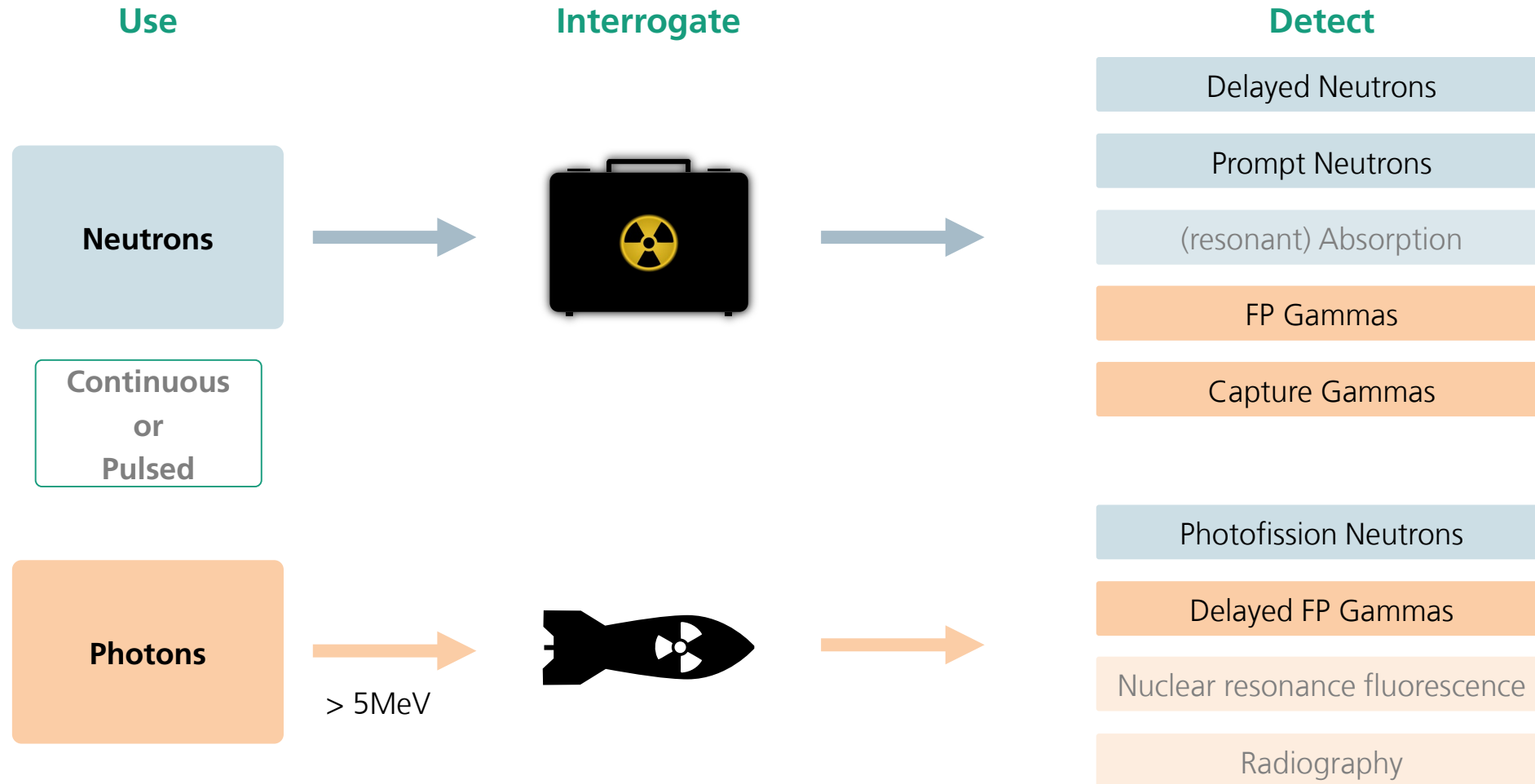
1989 "Black Sea Experiment" - Soviet SLCM in launch tube (Slawa / Moskwa)



S. Fetter, T. B. Cochran, L. Grodzins, H. L. Lynch, and M. S. Zucker, "Measurements of Gamma Rays from a Soviet Cruise Missile," Science, 248, 18 May 1990, pp. 828-834

# If passive detection (of HEU) does not work, what else?

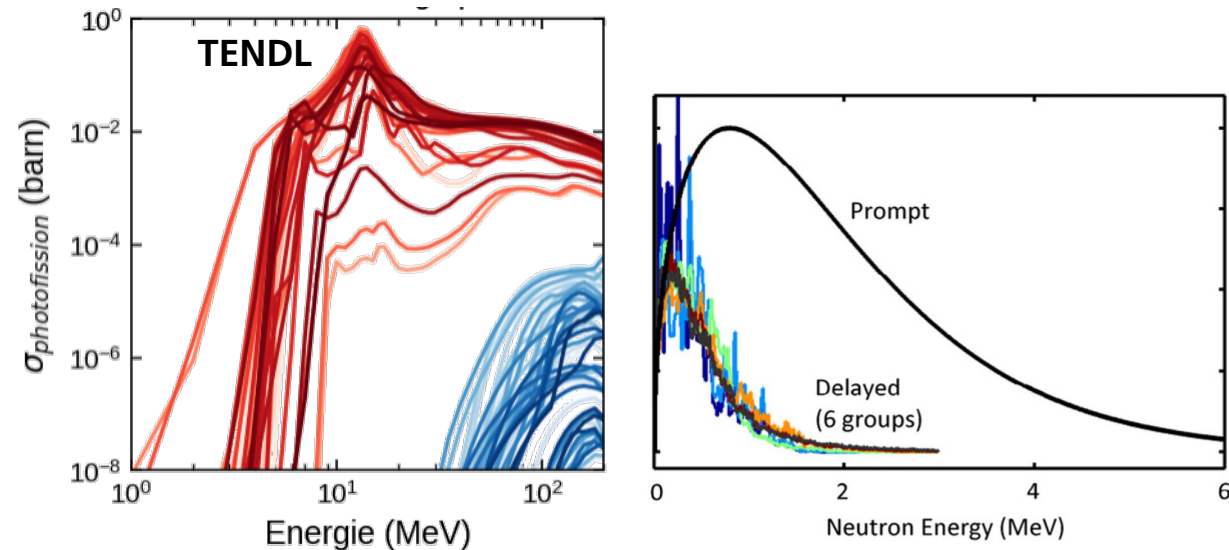
## Active Interrogation



# Signatures from active interrogation

## Fission

- Clearly the major signature
- Photofission needs  $E_{ph} \sim 3-5$  MeV
- Yields  $\bar{\nu} = 2.5-3$  Neutrons, 6-7 Photons
  - 1% delayed neutrons (0.1 – 60 s)
  - Photons from fission products (various  $T_{1/2}$ )

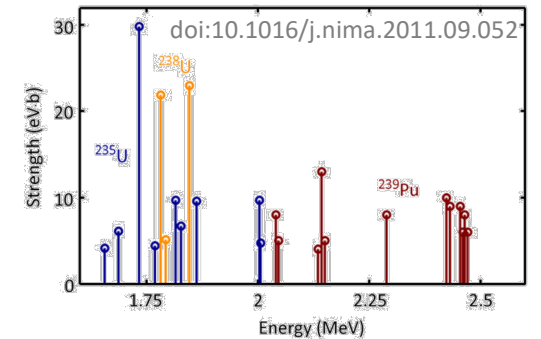


## Various nuclear Reactions

- $(n, \gamma)$ ,  $(n, n')$ ,  $(n, p)$ ,  $(n, d)$ ,  $(n, t)$ ,  $(n, \alpha)$ , ....
  - Normally leaves an excited nucleus  $\rightarrow$  Characteristic gamma line
- $(n, \gamma)$  / PGNAA commonly employed, can identify many isotopes

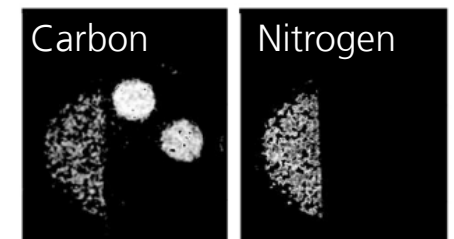
## Nuclear resonance fluorescence

- resonant  $\gamma$  absorption / reemission
- Line width of meV
- Bremsstrahlung source is good
- Complex detection



## Neutron absorption spectroscopy

- Radiography with isotopic contrast
  - Neutron absorption in resonances
  - TOF energy discrimination
- Needs very short pulsed neutron source



doi:10.1088/1748-0221/4/05/P05016

# Active interrogation sources

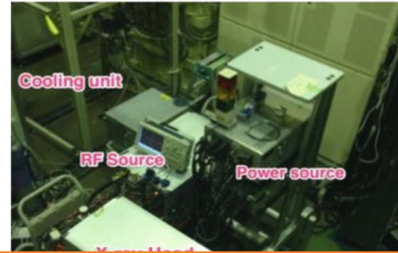
## Photons

### Cargo inspection



<https://www.linevsystems.com/>

### Japan – R&D



Specification	
RF frequency	9.3 GHz
Beam focusing	RF focusing
X-ray Intensity	2 Gy/min at 1 m
RF source	9.3 GHz Magnetron 1.3MW, Pulse width 4µs Repetition rate 200 pps
Electron gun	Voltage 35kV Pulse Peak Current 300 mA
	200 kg (with Pd shielding)
	100 kg
	120 kg
	100 kg

**No photon system suitable for Nuclear Security Event Responders**

**Not commercially available**

### Medic

<1600 kg



<https://www.oem-products.siemens-healthineers.com/linear-accelerator>

### US Army



<https://www.cma.army.mil/high-energy-xray-generator/>

# Active interrogation sources

## Neutrons

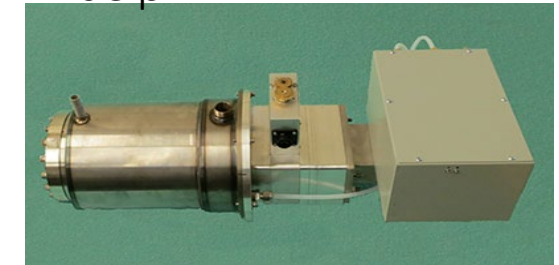
- Isotope sources (Am/Be,  $^{252}\text{Cf}$ )
- **Neutron generator**
  - Compact accelerator
  - fusion reaction
    - Deuterium-Deuterium: 2,5 MeV
    - Deuterium-Tritium: 14,1 MeV
  - Sealed designs available
  - Several vendors
  - Source strength:  $10^8 - 10^{10}$  n/s (DT)
  - Continuous or pulsed emission
  - No emission in off state
  - (relative) reliable technology

## Selection of different neutron generators

Starfire nGen 300



Adelphi DT 110



VNIIA ING-31



Thermo miniGen



Sodern Genie 16

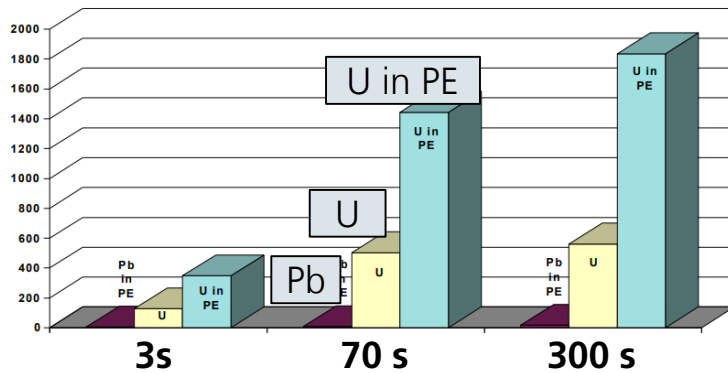


# Envisioned measurements

Subject to detailed numerical modeling

- neutron generator source
- Precondition: use existing neutron and gamma detectors
  - High efficiency mobile  $^3\text{He}$  multiplicity counter
  - High efficiency HPGe

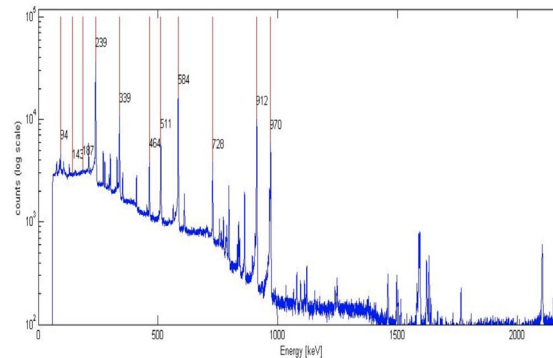
## Delayed neutrons



Rosenstock et.al. IAEA symposium Oct.1997

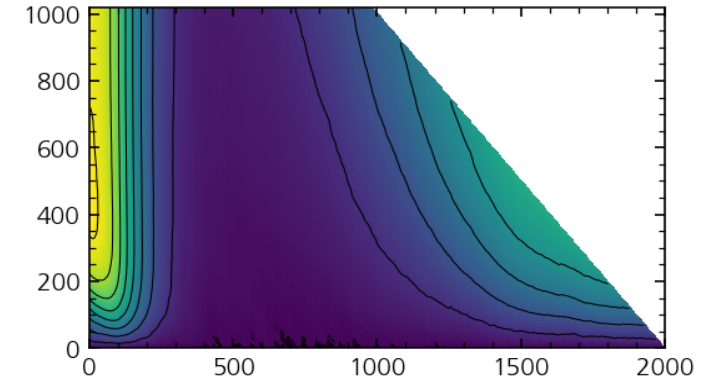
- Especially useful to detect HEU
- Very easy to implement

## Gamma spectrum



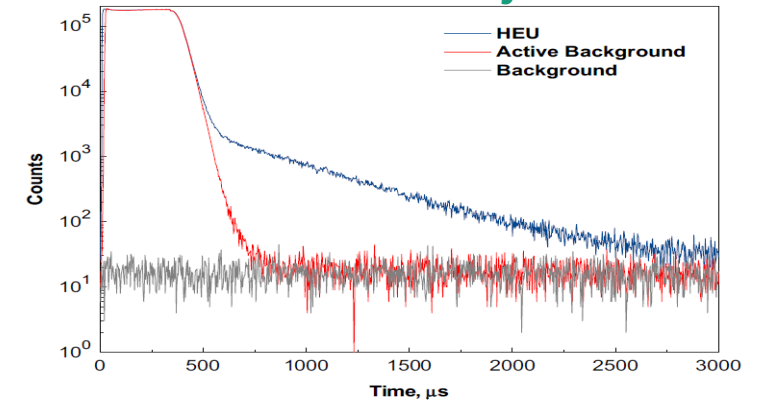
- Use  $(n,\gamma)$  to identify several isotops
- Measure fission product delayed gamma
- Easy to implement
- HPGe susceptible to neutron damage

## Feynman Variance



- Detect correlations (fission neutrons)
- Data interpretation challenging

## Differential-die-away



DOI:10.1109/TNS.2009.2014760

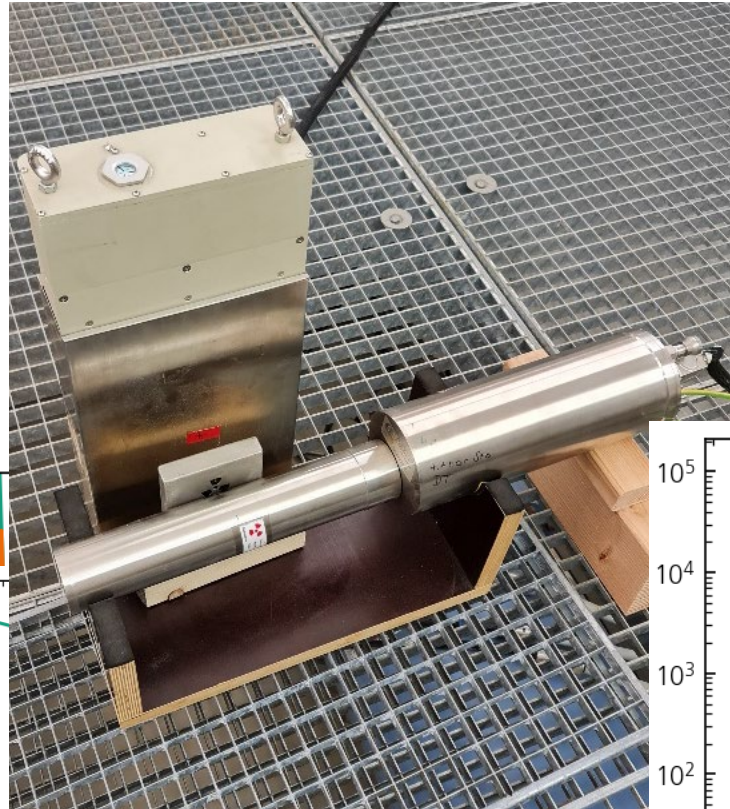
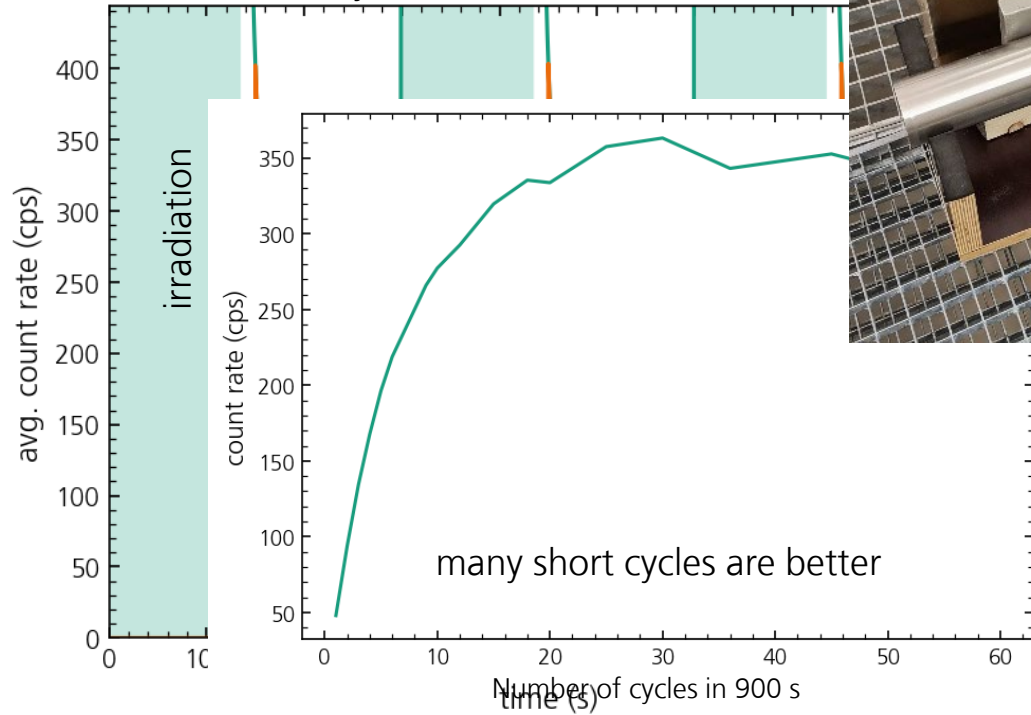
- Detect prompt fission neutrons from HEU
- Pulsed neutron emission
- Data interpretation challenging

# Preliminary results

## Delayed neutrons

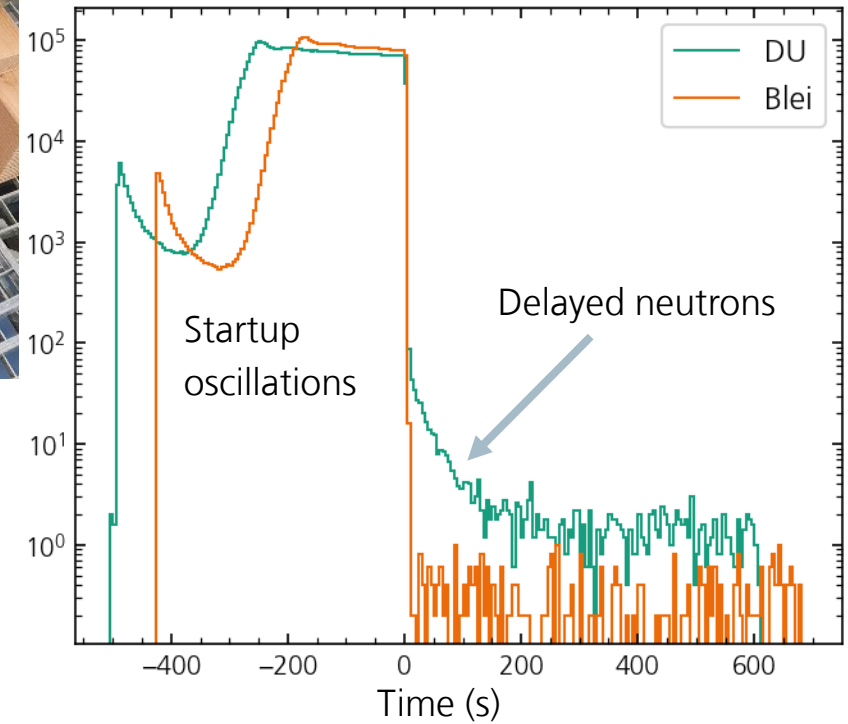
### MCNP Simulation

- Signal / noise optimization
- Determination of minimum detectable mass
- different test objects



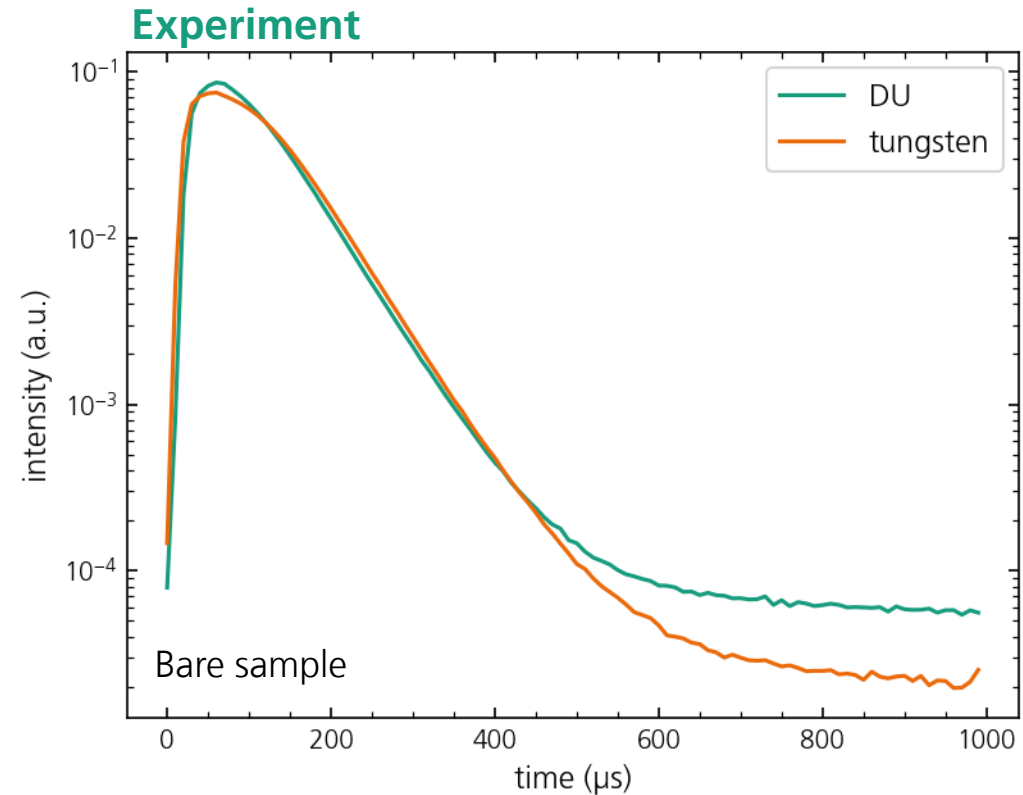
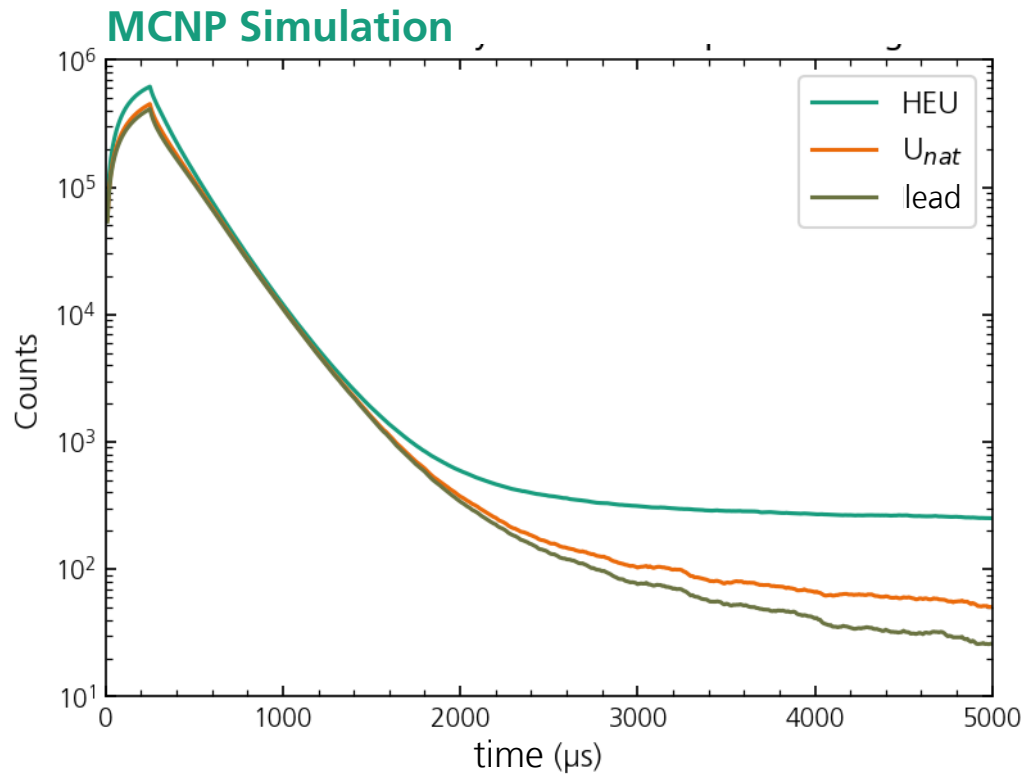
### Initial experiments

- Fraunhofer INT generator
- measured depleted uranium vs. lead



# Preliminary results

## Differential-die-away

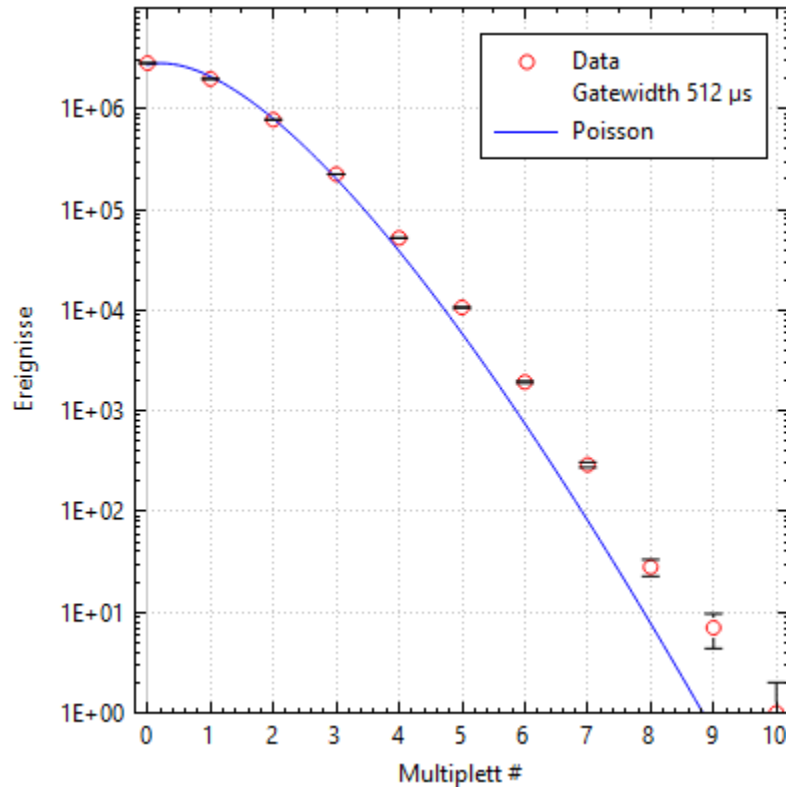


- Difference exists
- Determination of background difficult
- More modeling and experimental effort is needed

# Preliminary results

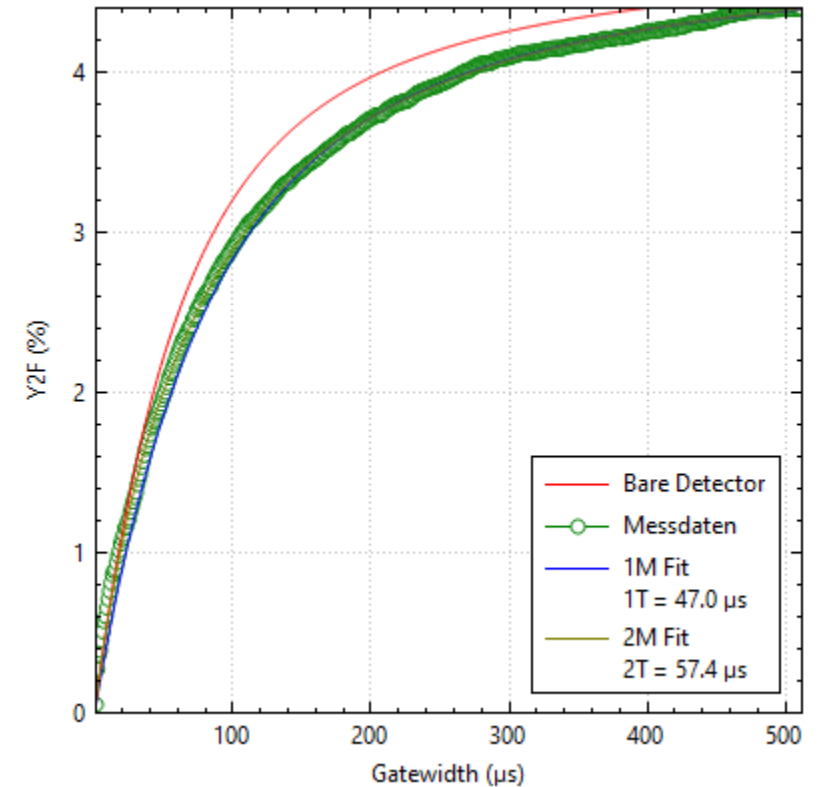
## Feynman variance

### What is the Feynman Variance?



$$Y_{2F} = \frac{M_2}{M_1} - \frac{1}{2} \frac{M_1}{M_0}$$

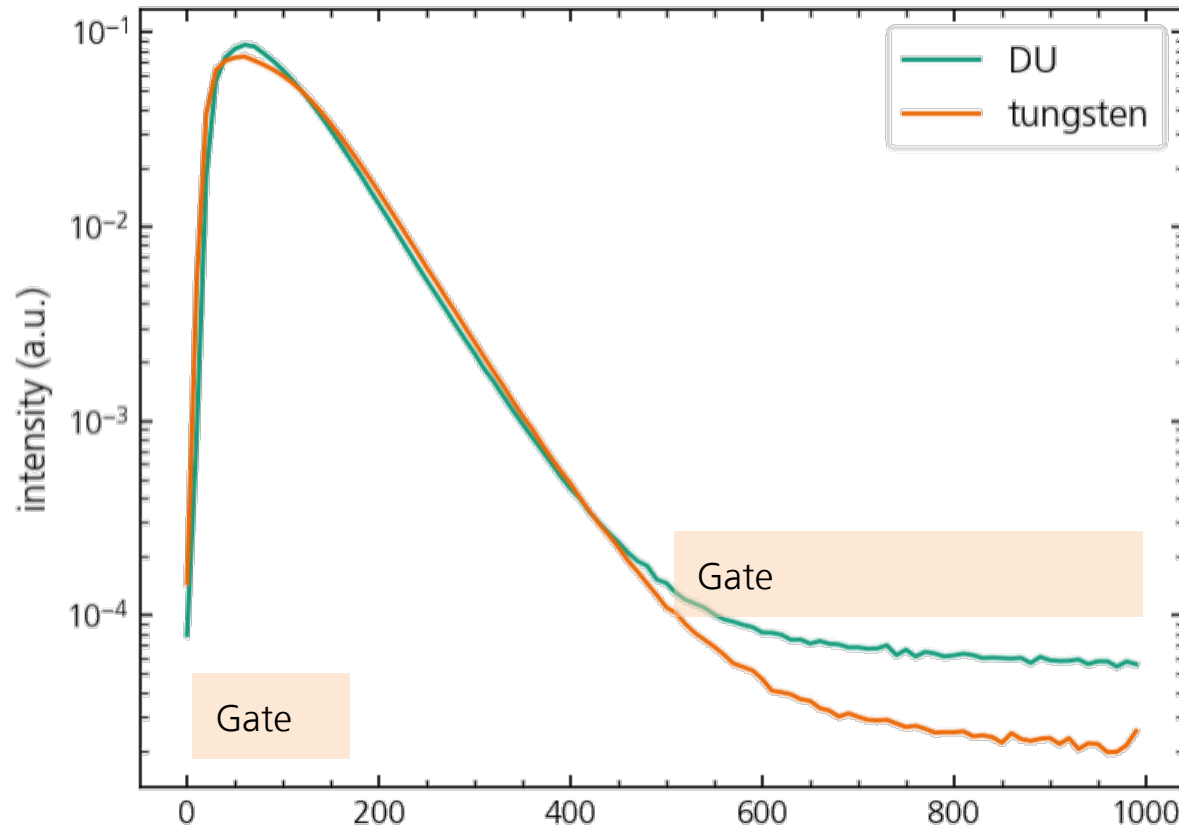
- Measure of deviation from Poisson statistic
- Captures correlation in detected events, specially fission neutrons
- Susceptible to dead-time, double pulsing, count rate variations, etc.



# Preliminary results

## Feynman variance

### Feynman Variance with pulsed interrogation

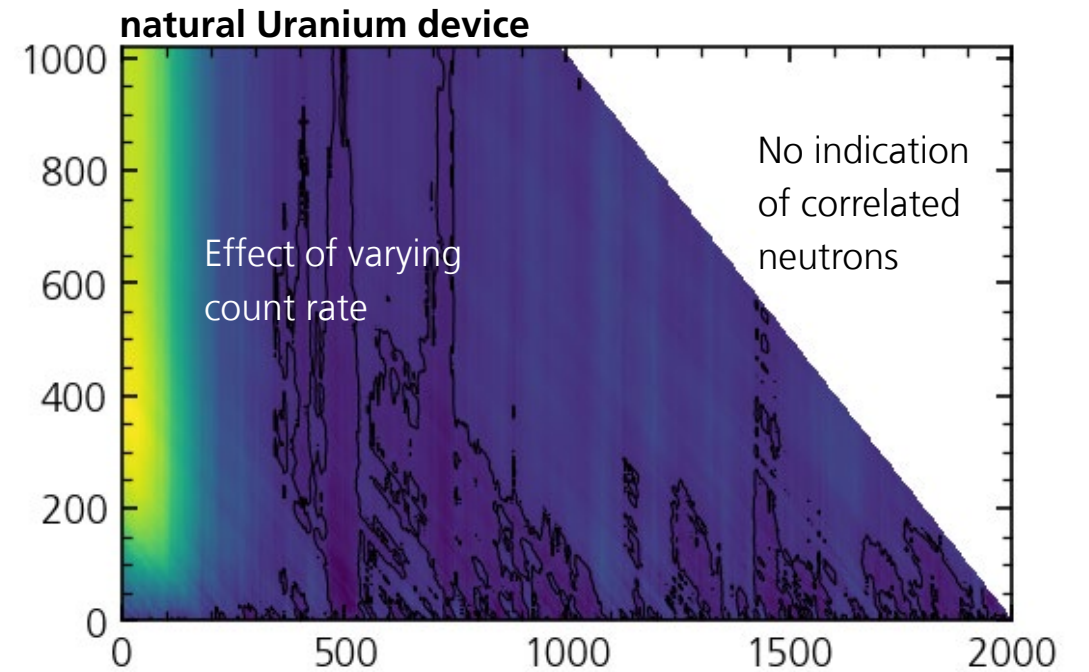
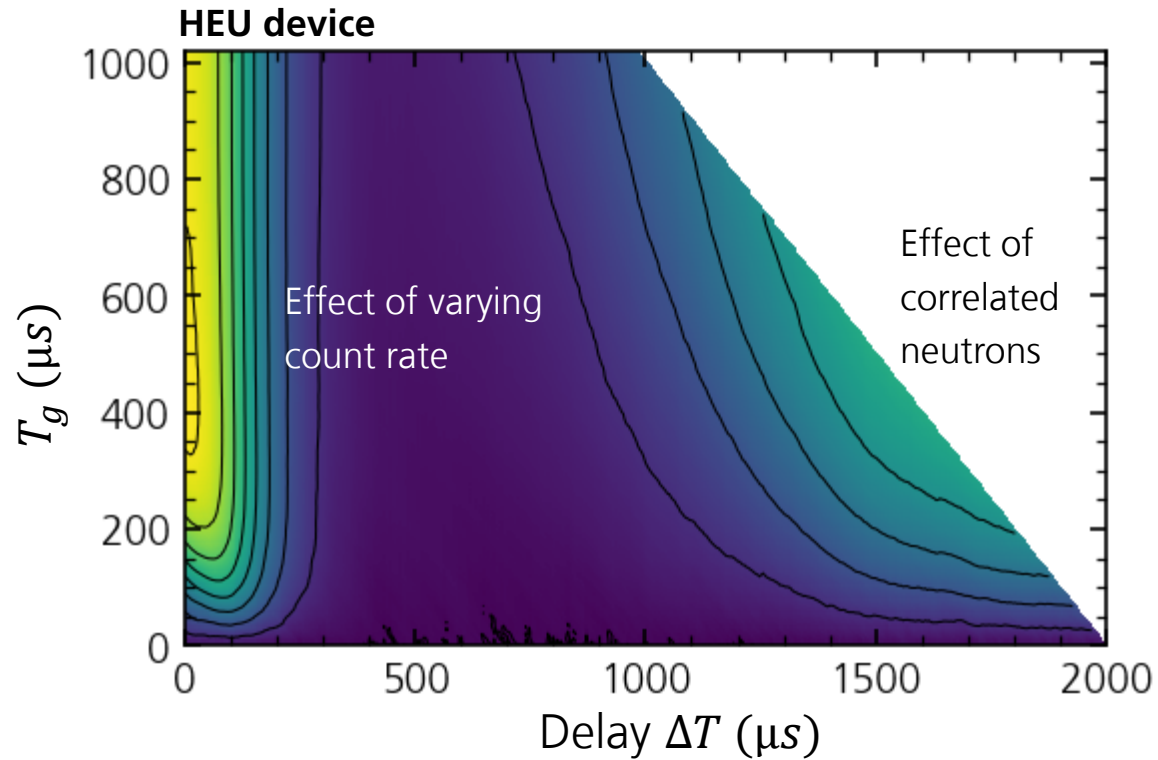


- Starting of gate relative to trigger signal of neutron generator
- Feynman Variance is 2D function of Gate Length  $T_g$  and time relative to trigger signal  $\Delta T$
- Gate has to fit within pulse

# Preliminary results

Feynman variance

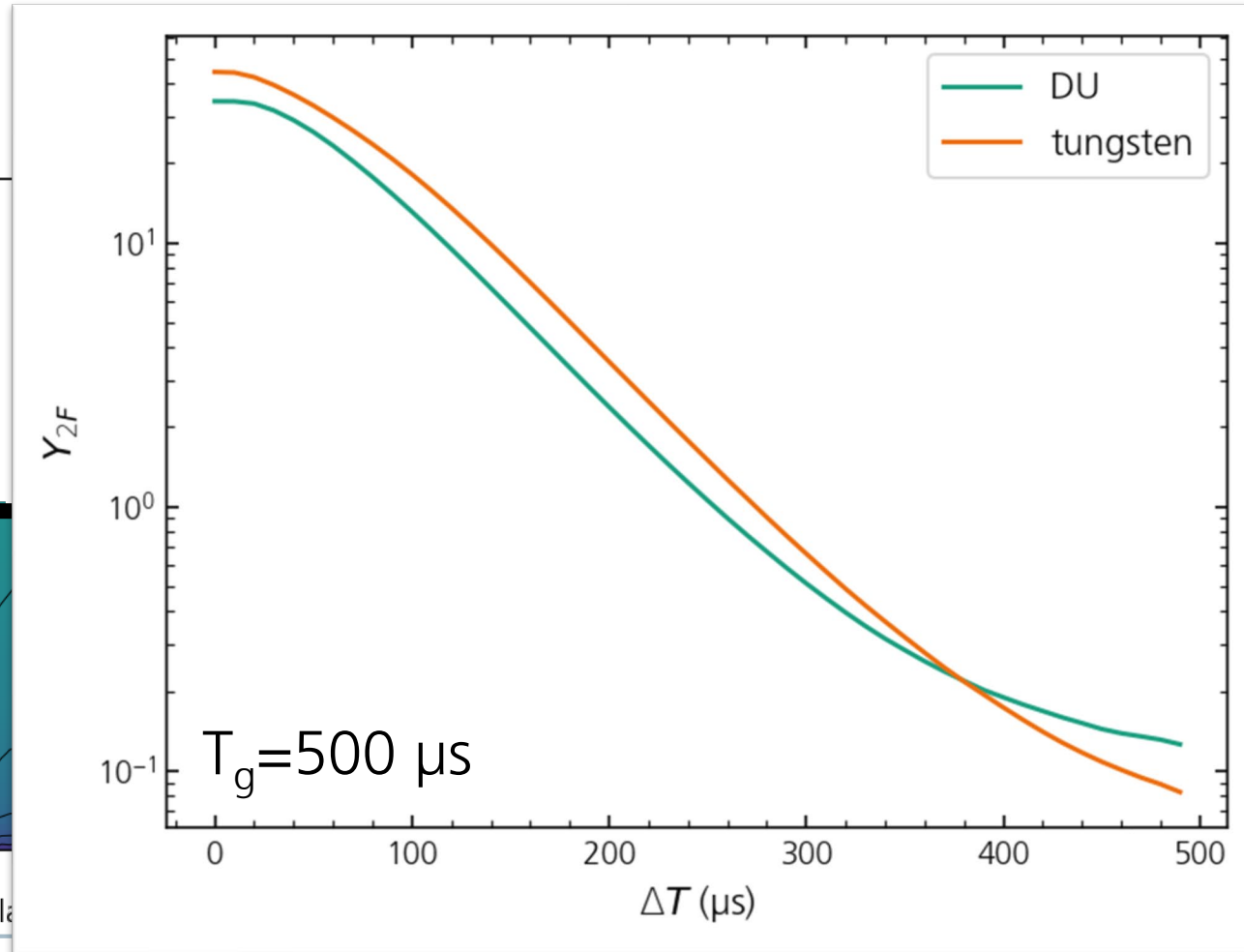
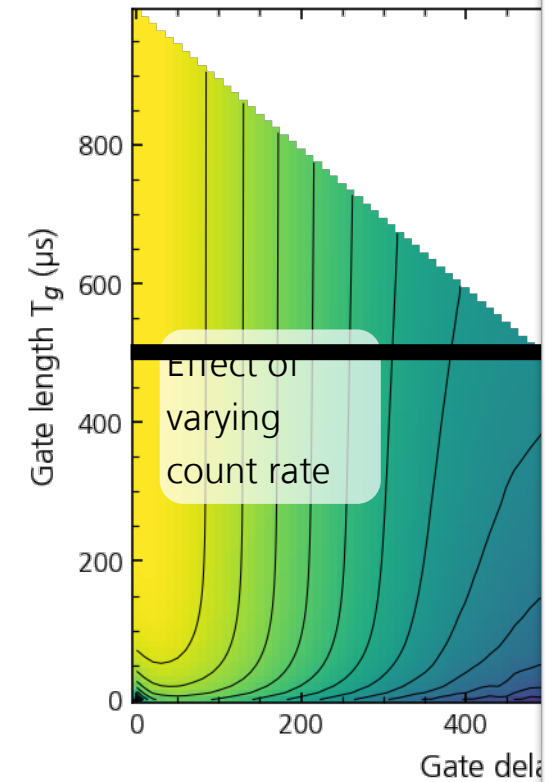
## Simulation results



# Very preliminary results

Feynman variance

## Experimental results



- Neutron generator show some fluctuations
- DU drops little bit slower than tungsten
- More tests needed with new generator.
  - longer pulse time

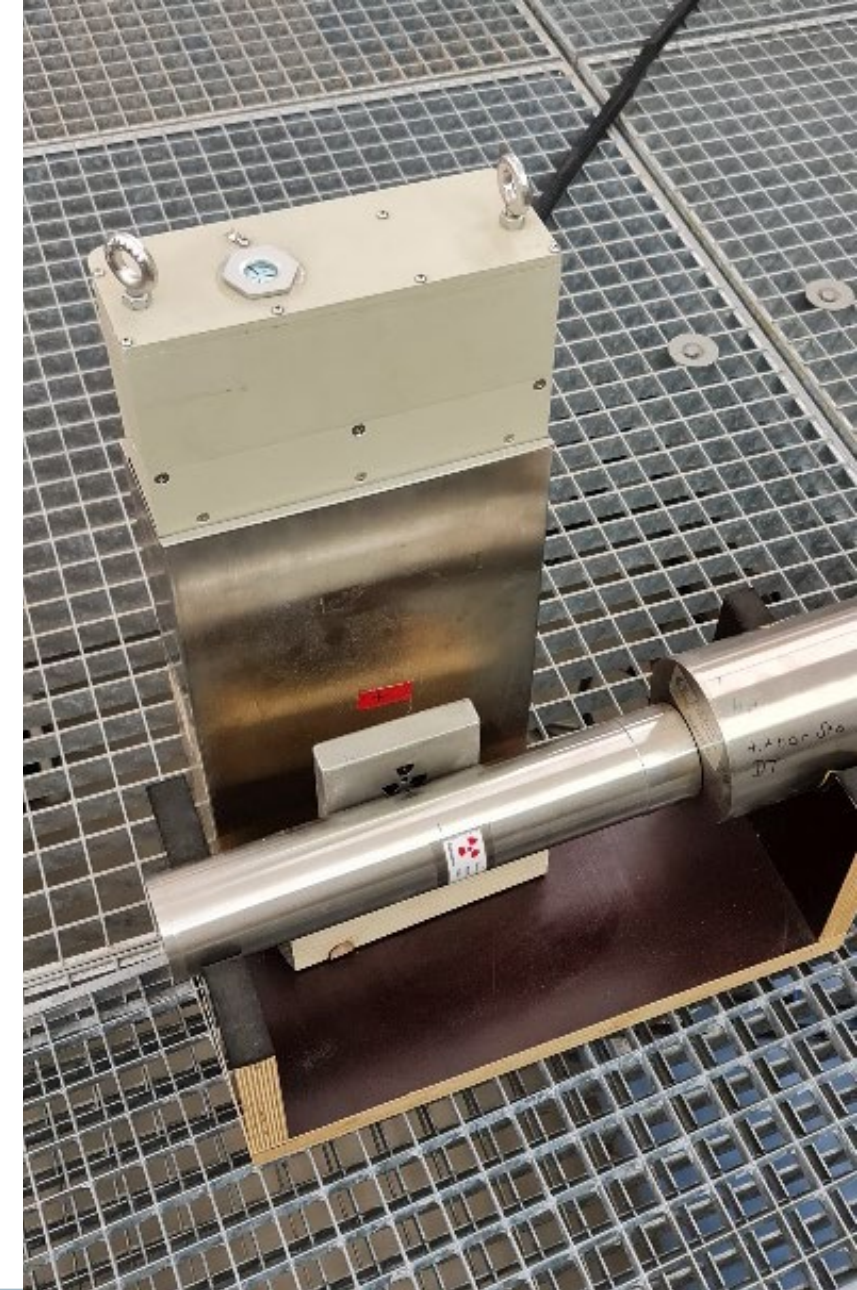
# Next steps

- More tests with the new generator
- Perform gamma measurements
  - Simulations are challenging
    - Coupling of neutron and photon transport
    - Data for e.g.  $(n,\gamma)$  for SNM could be improved
- Perform measurements with actual SNM



# Conclusions

- Passive detection of SNM is in many cases possible
- It is challenging in the case of (shielded) HEU
- Active interrogation
  - provides further measurement opportunities
  - is more involved
  - has the chance for increased detection of SNM
  - might provide additional information



## Contact

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[olaf.schumann@int.fraunhofer.de](mailto:olaf.schumann@int.fraunhofer.de)



# Thank you for your attention

# Mini style guide

## Text formats

### Edit master text format

Second level

#### Third level

- Fourth level
  - Fifth level
    - Sixth level
- 1. Seventh level
  - 1. Eighth level
    - 1. Ninth level

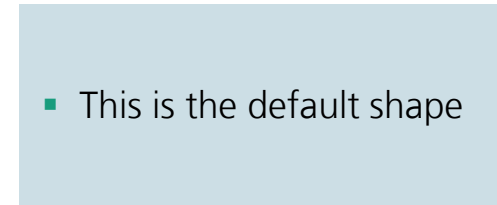


To apply the correct formatting of the pre-defined levels, use "Decrease List Level"/"Increase List Level" for indentation (see screenshot) or use Shift + Alt + ← / →

### AutoShapes



- This is the default text field



Note: Automatic indentations only work with placeholders. Therefore, only the first bullet point can be predefined in a standard text field..

### Standard symbols

French quotation marks:

- « (Alt + 0171 from the numeric keypad)
- » (Alt + 0187 from the numeric keypad)

Dash:

- (Alt + 0151 from the numeric keypad)

# Mini style guide

## Footer

Kopf- und Fußzeile

Folie Notizen und Handzettel

In Folie einschließen

Datum und Uhrzeit

Automatisch aktualisieren

04.11.2021

Sprache: Deutsch (Deutschland) Kalendertyp: Gregorianisch

Fest

04.11.2021

Foliennummer

Fußzeile

© Fraunhofer

Auf Titelfolie nicht anzeigen

Übernehmen Für alle übernehmen Abbrechen

Vorschau

You can customize the footer via "Insert" → Header and Footer.

The classification can be customized using the add-in.

You can customize the logo selection as well as the corresponding copyright using the add-in.

# Mini style guide

Design frame



# Mini style guide

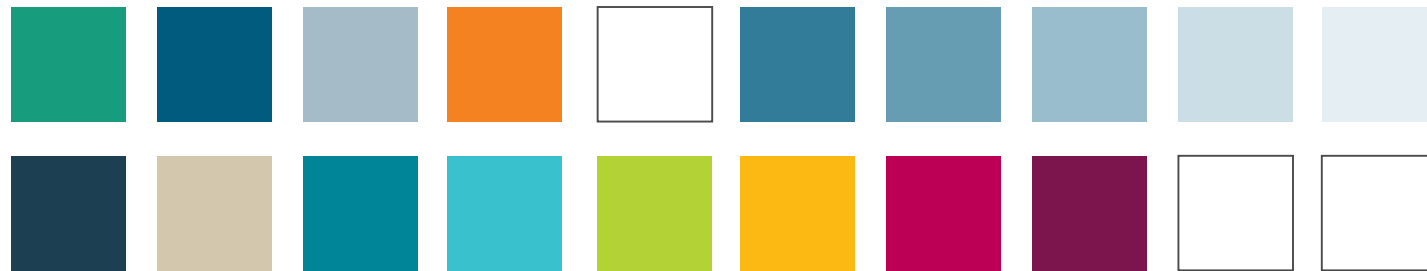
## Design colors



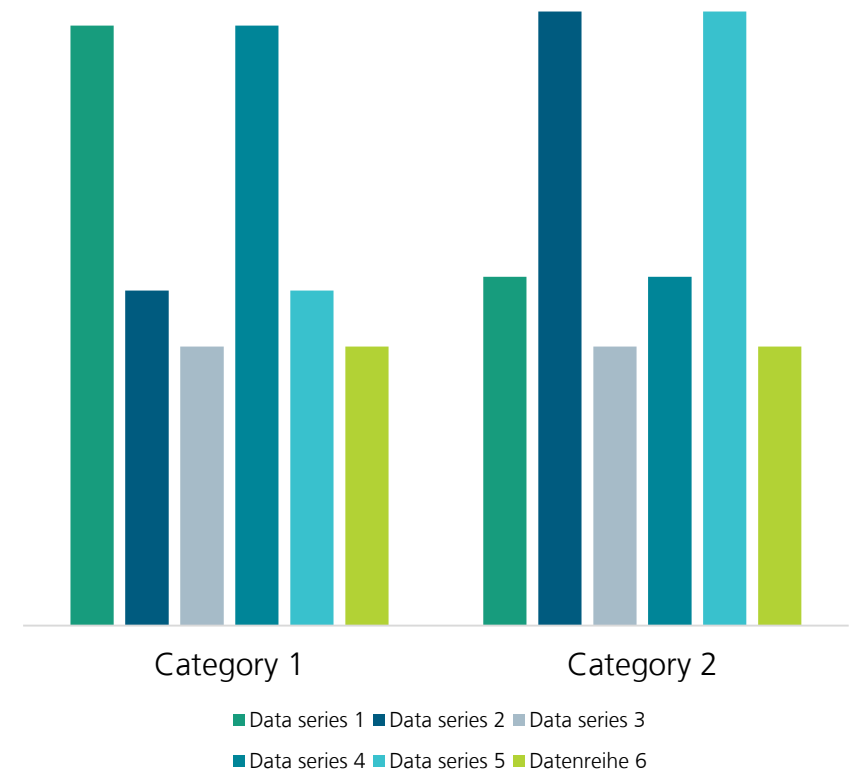
### Design colors



### Custom colors



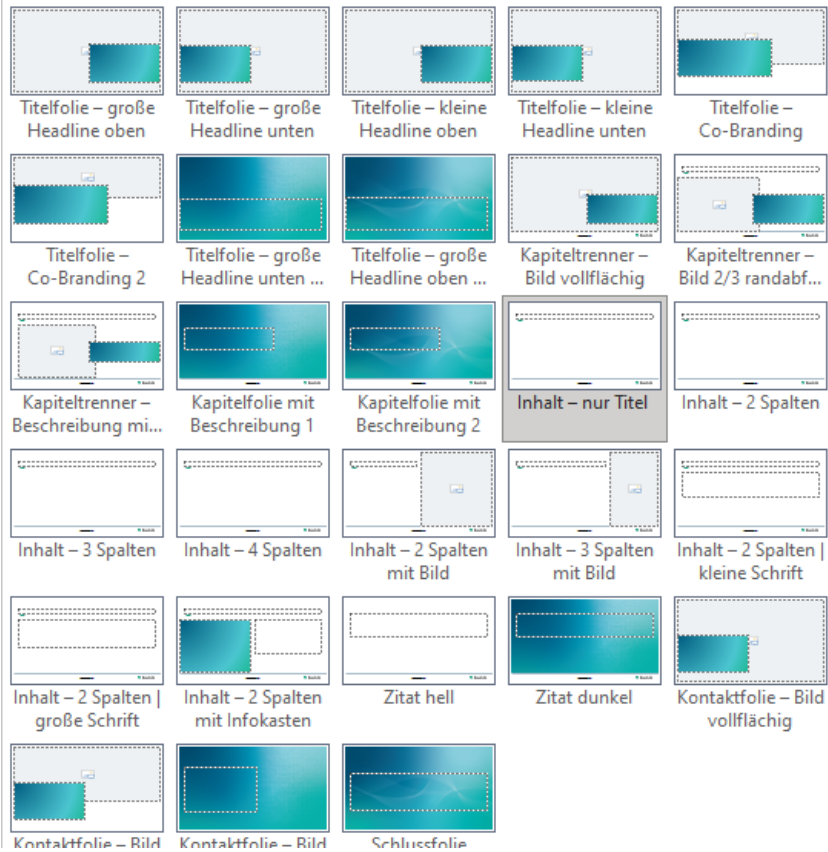
### Color order in charts



# Mini style guide

## Layouts

### Fraunhofer\_Master\_16-9





Fraunhofer Institute for  
Technological Trend Analysis INT

Headline, Frutiger LT Com Lt,  
32 pt

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Subline/speaker/date  
Frutiger LT Com Bd, 16 pt

Subline/speaker/date  
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Headline, Frutiger LT Com Lt,  
32 pt



Fraunhofer Institute for  
Technological Trend Analysis INT

Headline, Frutiger LT Com Lt,  
24 pt  
Maximum 3 lines

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**Subline/speaker/date**  
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**Maximum 3 lines**

Subline/speaker/date  
Frutiger LT Com Bd, 14 pt

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Headline, Frutiger LT Com Lt,  
24 pt  
Maximum 3 lines

Subline, Frutiger LT Com Bd, 16 pt

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Headline, Frutiger LT Com Lt,  
32 pt

Speaker 1, speaker 2, speaker 3

Optional area for co-branding

Headline, Frutiger LT Com Lt,  
32 pt

Subline/speaker/date, Frutiger LT Com Bd, 16 pt  
Maximum 2 lines

Eye-catcher,  
Frutiger LT Com Bd

Optional area for co-branding

Subline, Frutiger LT Com Bd, 16 pt

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Headline, Frutiger LT Com Lt,  
32 pt

Speaker 1, speaker 2, speaker 3

Eye-catcher,  
Frutiger LT Com Bd

Headline, Frutiger LT Com Lt,  
32 pt

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Subline/speaker/date, Frutiger LT Com Bd, 16 pt  
Maximum 2 lines

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Maximum 3 lines**

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01

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## 2. Section name

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- Sub-title 2
- Sub-title 3

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**1. Section name**

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rex landum.«**

**Max Mustermann,**  
Lorem ipsum



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Max Mustermann,  
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2. Sit ite causticus aurum eum explindus. Staus ex landuam it wexus rius laudanum ibisw tum. Dolor situs cum habilitarum exlan dum it exus rius laudanum ibis tum itum caiusticus auru rius laudanum ibis tum. Lorem et exit vulnareus plexus. m eum explindus. Lorem et exit vulnareus plexus. Sit i laudanum ibis tum exus rius laudanum ibis tum. Sit i laudanum ibis tum exus rius laudanum ibis tum. Dolor situs cum habilitarum exlan dum it exus rius laudanum ibis tum itum caiusticus auru rius laudanum ibis tum. Lorem et Dolor situs cum habilitarum exlan dum it exus.

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1
- Level 1

# Headline, Frutiger LT Com Bd, 24 pt

Subline, Frutiger LT Com Lt, 20 pt

---

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1



## Headline, Frutiger LT Com Bd, 16 pt

---

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus.

# Headline, Frutiger LT Com Bd, 24 pt

Subline, Frutiger LT Com Lt, 20 pt

---

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1



Headline, Frutiger LT Com Bd,  
22 pt, dolorx cumatia ex  
landum.«

Max Mustermann,  
Lorem ipsum

# Headline, Frutiger LT Com Bd, 24 pt, two columns with text and images

Subline, Frutiger LT Com Lt, 20 pt

---

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1



# Headline, Frutiger LT Com Bd, 24 pt, two columns with text and graphics

Subline, Frutiger LT Com Lt, 20 pt

---

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1

Lorem et exit vulnareus plexus. Sit i laudanum ibis tum. Lorem et exit vulnareus tum caiusticus s cum habilitarum exlan dum it exus rius laudanum ibis tum itum aurum eum explindus. Status laus rius laudanum ibis. Status laus rius



# Headline, Frutiger LT Com Bd, 24 pt, bullet list

Subline, Frutiger LT Com Lt, 20 pt

1

## Option 1, 16 pt

LT Com Lt, 14 pt. Dolor situs cum habilitarum itum dolor situs ipsum est

2

## Option 2, 16 pt

LT Com Lt, 14 pt. Dolor situs cum habilitarum itum dolor situs ipsum est

3

## Option 3, 16 pt

LT Com Lt, 14 pt. Dolor situs cum habilitarum itum dolor situs ipsum est

## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1

# Headline, Frutiger LT Com Bd, 24 pt, bullet list

Subline, Frutiger LT Com Lt, 20 pt

Frutiger LT Com Bd,  
16 pt, Lorem et exit  
vulnareus plexus. Sit i  
laudanum ibis tum.  
Lorem et exit vulnarus  
tum causticus s cum  
habilitarum exlan dum  
it exus rius laudanum  
ibis tum itum aurum  
eum explindus.

1

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.

2

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.

3

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.

4

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.

# Headline, Frutiger LT Com Bd, 24 pt, three columns

Subline, Frutiger LT Com Lt, 20 pt

---

## Headline, Frutiger LT Com Bd, 16 pt

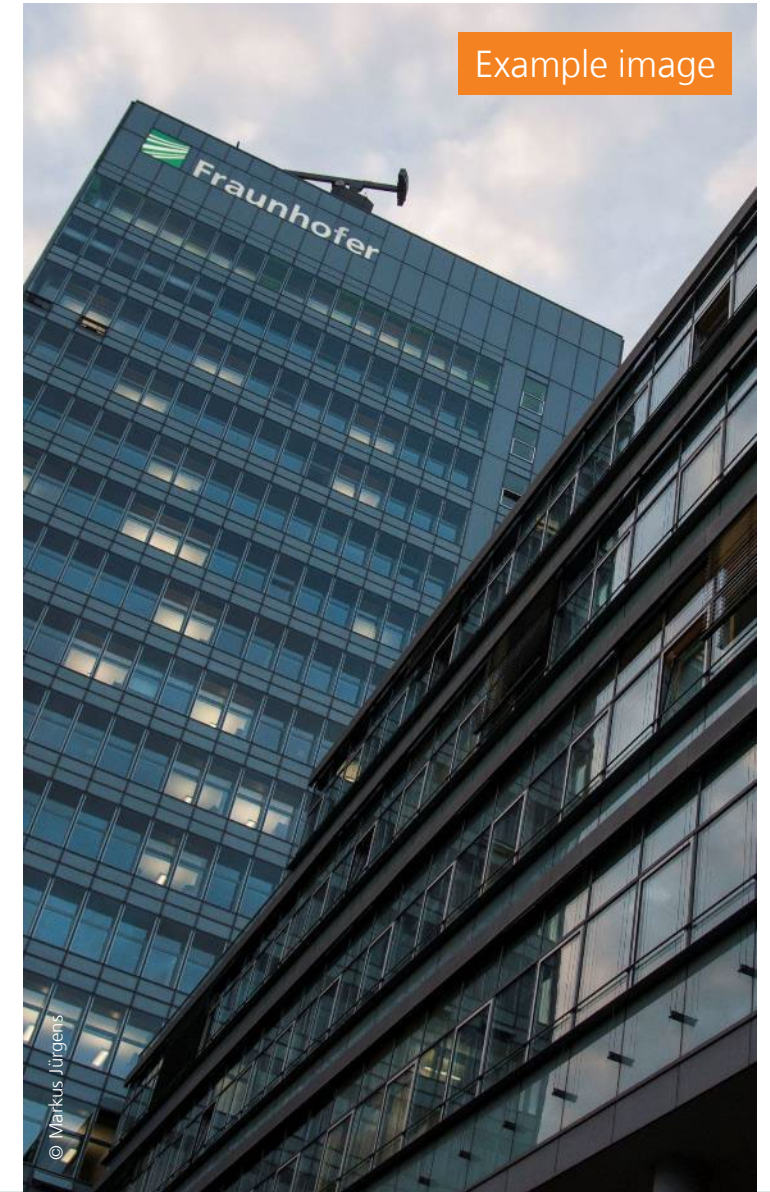
Copy Frutiger LT Com Lt, 14 pt. Staus ex  
landuam it wexus rius laudanum ibisw tum.  
Dolor situs cum habilitarum:

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3

1. Level 1
2. Level 1
3. Level 1
4. Level 1
5. Level 1
6. Level 1
  1. Level 2
    1. Level 3

Highlights, Frutiger LT Com Bd, 16 pt, dolor cumatia habilitarum itum  
alanenter status ex landum

Example image



# Headline, Frutiger LT Com Bd, 24 pt, three columns with text and images

Subline, Frutiger LT Com Lt, 20 pt

---

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

## Headline, Frutiger LT Com Bd

1. Staus ex landuam it wexus rius laudanum ibisw tum.
2. Dolor situs cum habilitarum exlan dum it caiusticus auru rius laudanum ibis tum.
3. Lorem et exit vulnareus plexus. m eum explindus.

## Headline, 16 pt

---

1. Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum.
2. Sit ite causticus aurum eum explindus. Staus ex landuam it wexus rius laudanum ibisw tum. Dolor situs cum habilitarum exlan dum it exus rius laudanum ibis tum itum caiusticus auru rius laudanum ibis tum. Lorem et exit vulnareus plexus. m eum explindus.



# Headline, Frutiger LT Com Bd, 24 pt, three columns with text and images

Subline, Frutiger LT Com Lt, 20 pt

---



## Headline

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.



## Headline

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.



## Headline

Copy Frutiger LT Com Lt, 14 pt. Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus.

# Headline, Frutiger LT Com Bd, 24 pt, four columns with text and images

Subline, Frutiger LT Com Lt, 20 pt

---



## Headline 14 pt

Copy Frutiger LT Com Lt, 14 pt.  
Dolor situs cum habilitarum itum  
alusi causticus imanenter Status  
ex landum it exus rius laudanum  
ibis tum. Lorem et exit vulnareus  
plexus.



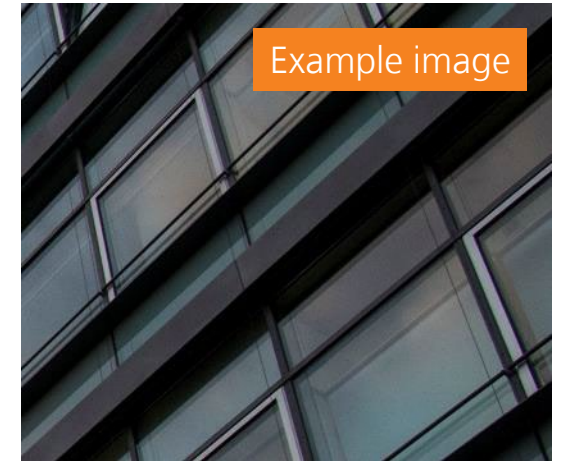
## Headline 14 pt

Copy Frutiger LT Com Lt, 14 pt.  
Dolor situs cum habilitarum itum  
alusi causticus imanenter Status  
ex landum it exus rius laudanum  
ibis tum. Lorem et exit vulnareus  
plexus.



## Headline 14 pt

Copy Frutiger LT Com Lt, 14 pt.  
Dolor situs cum habilitarum itum  
alusi causticus imanenter Status  
ex landum it exus rius laudanum  
ibis tum. Lorem et exit vulnareus  
plexus.



## Headline 14 pt

Copy Frutiger LT Com Lt, 14 pt.  
Dolor situs cum habilitarum itum  
alusi causticus imanenter Status  
ex landum it exus rius laudanum  
ibis tum. Lorem et exit vulnareus  
plexus.

# Headline, Frutiger LT Com Bd, 24 pt, four columns with text and images

Subline, Frutiger LT Com Lt, 20 pt



## Headline 14 pt

Copy Frutiger LT Com Lt,  
14 pt. Dolor situs cum  
habilitarum



## Headline 14 pt

Copy Frutiger LT Com Lt,  
14 pt. Dolor situs cum  
habilitarum



## Headline 14 pt

Copy Frutiger LT Com Lt,  
14 pt. Dolor situs cum  
habilitarum



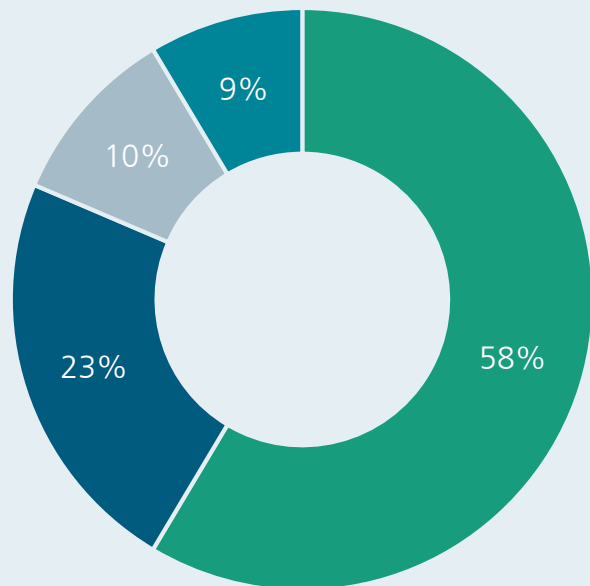
## Headline 14 pt

Copy Frutiger LT Com Lt,  
14 pt. Dolor situs cum  
habilitarum

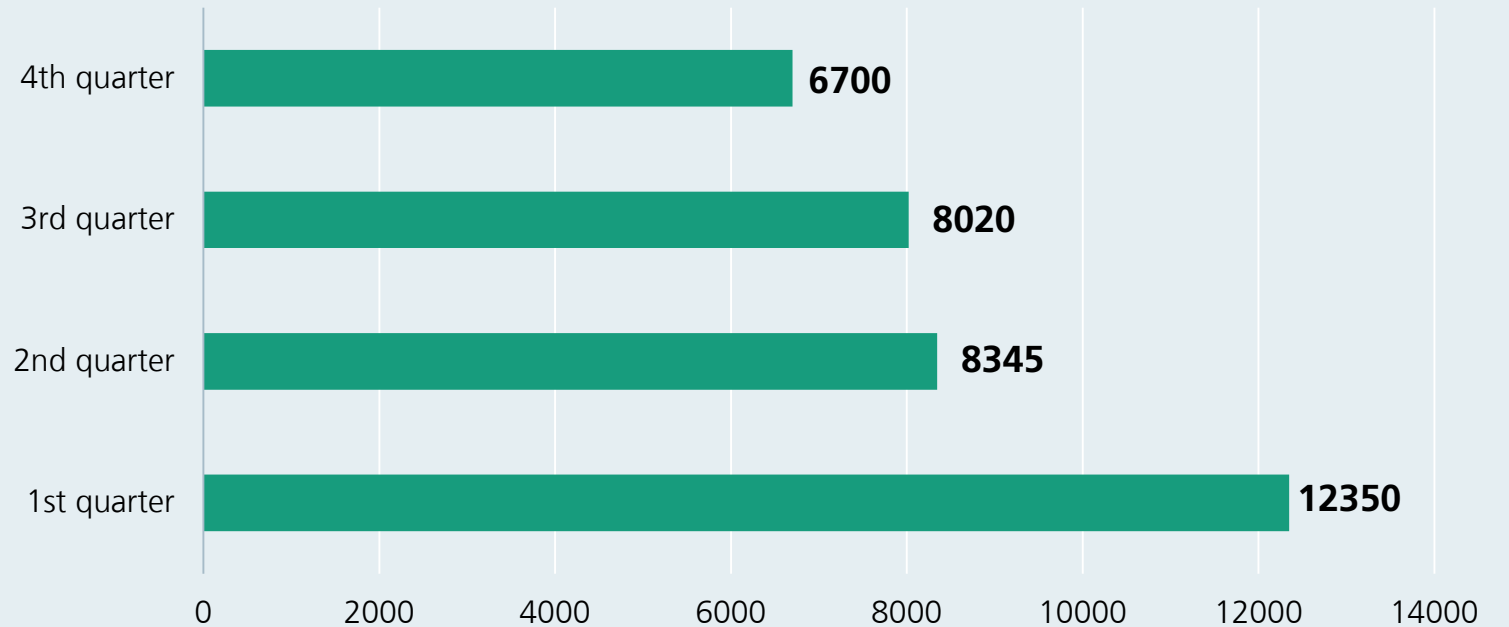
# Headline, Frutiger LT Com Bd, 24 pt, pie and bar chart, 24 pt

Subline, Frutiger LT Com Lt, 20 pt

Frutiger LT Com Bd, 16 pt Dolor  
situs cum habilitarum itum.

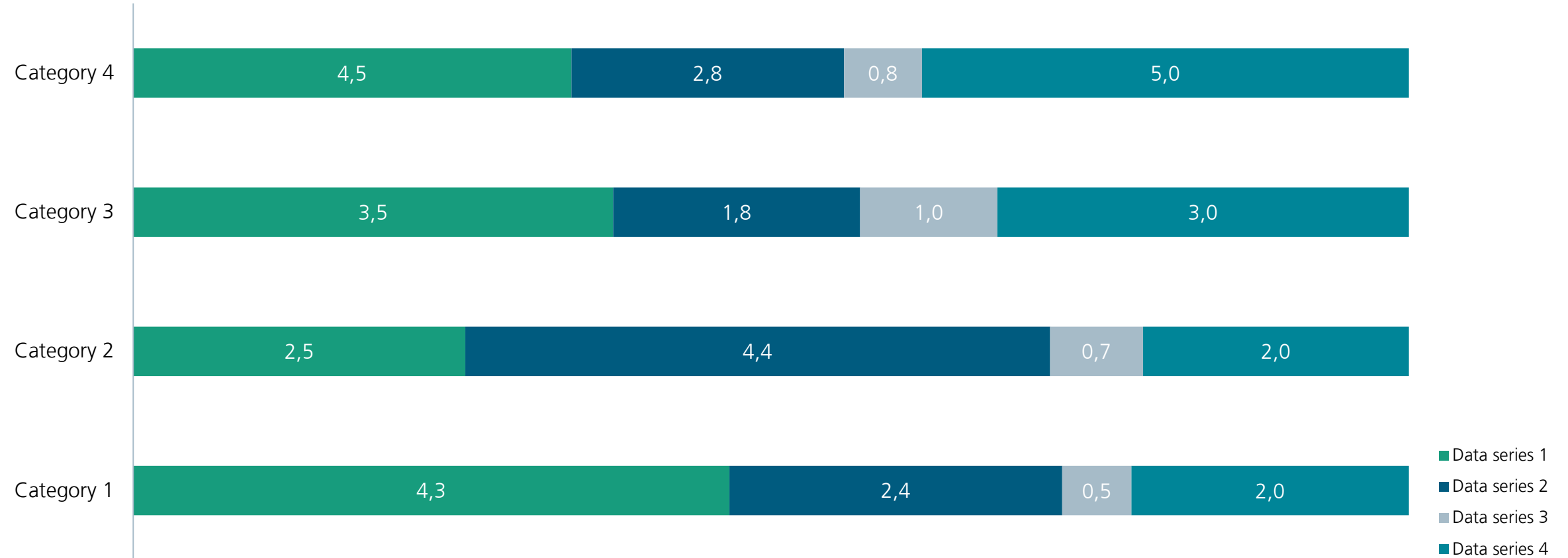


Frutiger LT Com Bd, 16 pt  
Dolor situs cum habilitarum itum.



# Headline, Frutiger LT Com Bd, 24 pt, bar chart

Subline, Frutiger LT Com Lt, 20 pt

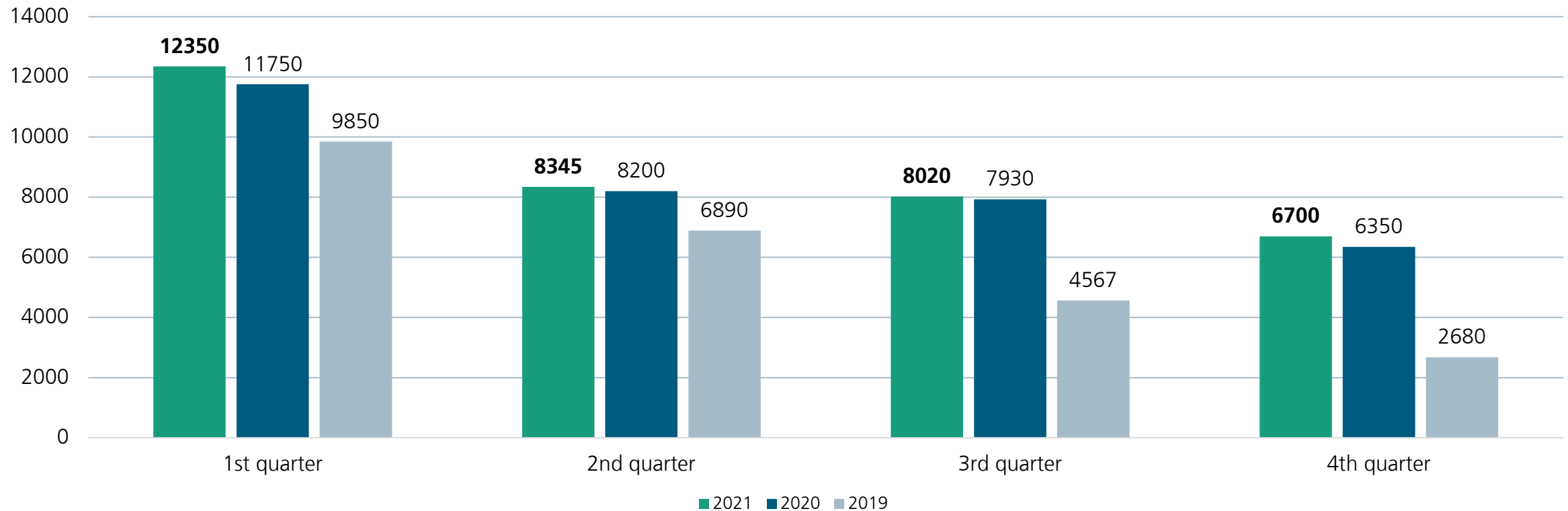


# Headline, Frutiger LT Com Bd, 24 pt, bar chart

Subline, Frutiger LT Com Lt, 20 pt

Copy Frutiger LT Com Lt 14 pt

Dolor situs ipsum dolorem cum habilitarum itum.



# Headline, Frutiger LT Com Bd, 24 pt, Table

Subline, Frutiger LT Com Lt, 20 pt

## Headline, Frutiger Bd, 14 pt, Sitiorepudae ommos voloraum

Headline	Fact 1	Fact 2	Fact 3
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000
<b>Sum</b>	<b>0 000 000</b>	<b>0 000 000</b>	<b>0 000 000</b>

# Headline, Frutiger LT Com Bd, 24 pt, Table

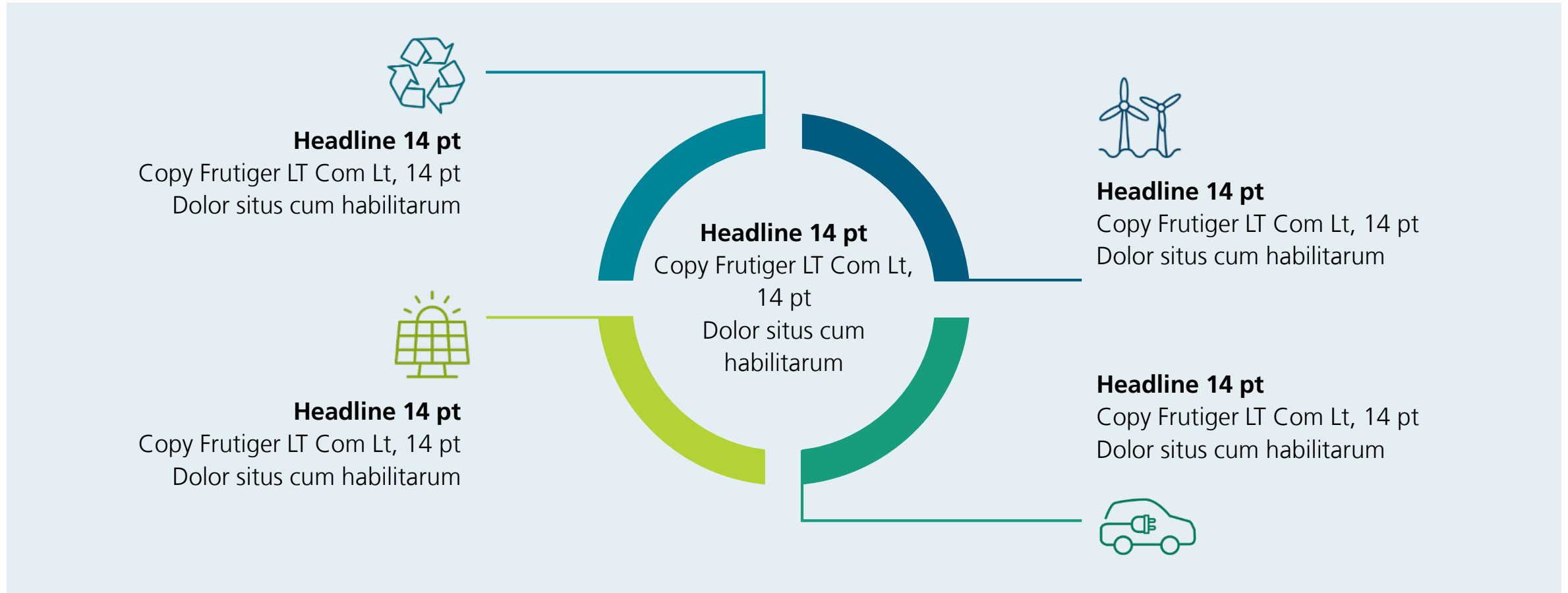
Subline, Frutiger LT Com Lt, 20 pt

## Headline, Frutiger Bd, 14 pt, Sitiorepudae ommos voloraum

Headline	Fact 1	Fact 2	Fact 3	Fact 4	Fact 5
Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
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Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
Copy	0 000 000	0 000 000	0 000 000	0 000 000	0 000 000
<b>Sum</b>	<b>0 000 000</b>	<b>0 000 000</b>	<b>0 000 000</b>	<b>0 000 000</b>	<b>0 000 000</b>

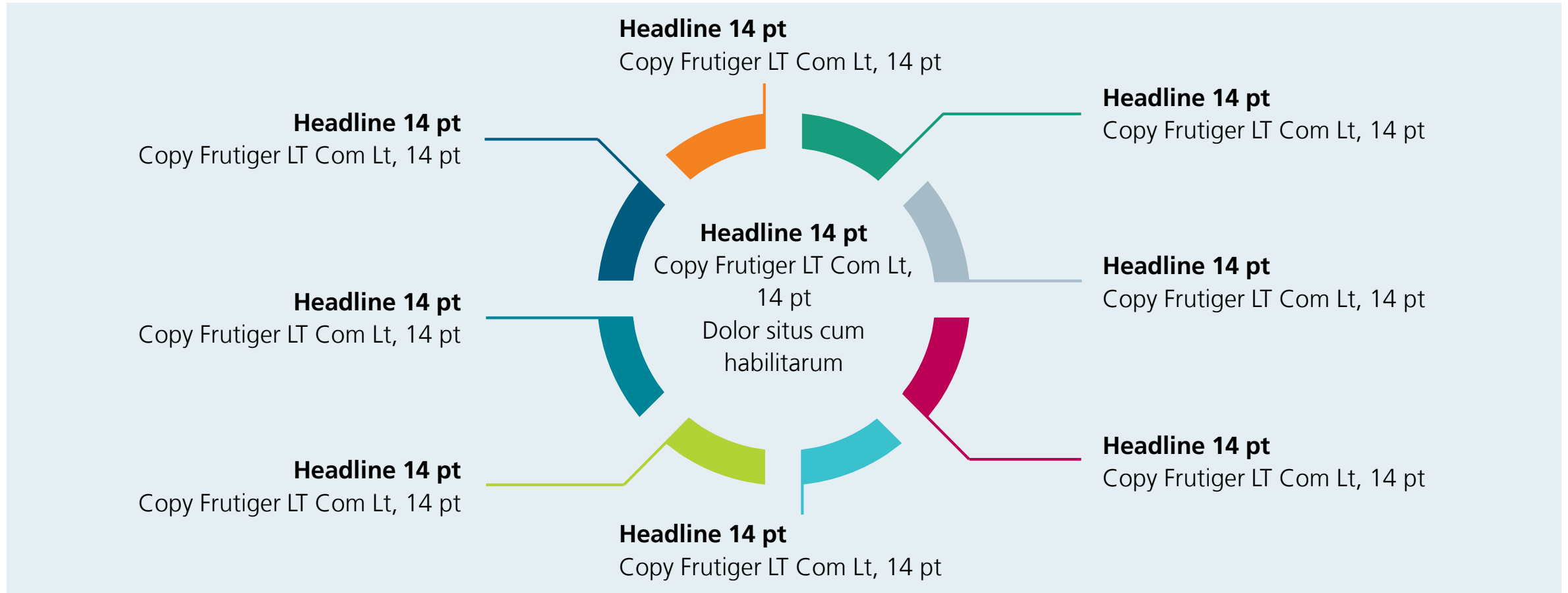
# Headline, Frutiger LT Com Bd, 24 pt, 4-part pie chart

Subline, Frutiger LT Com Lt, 20 pt



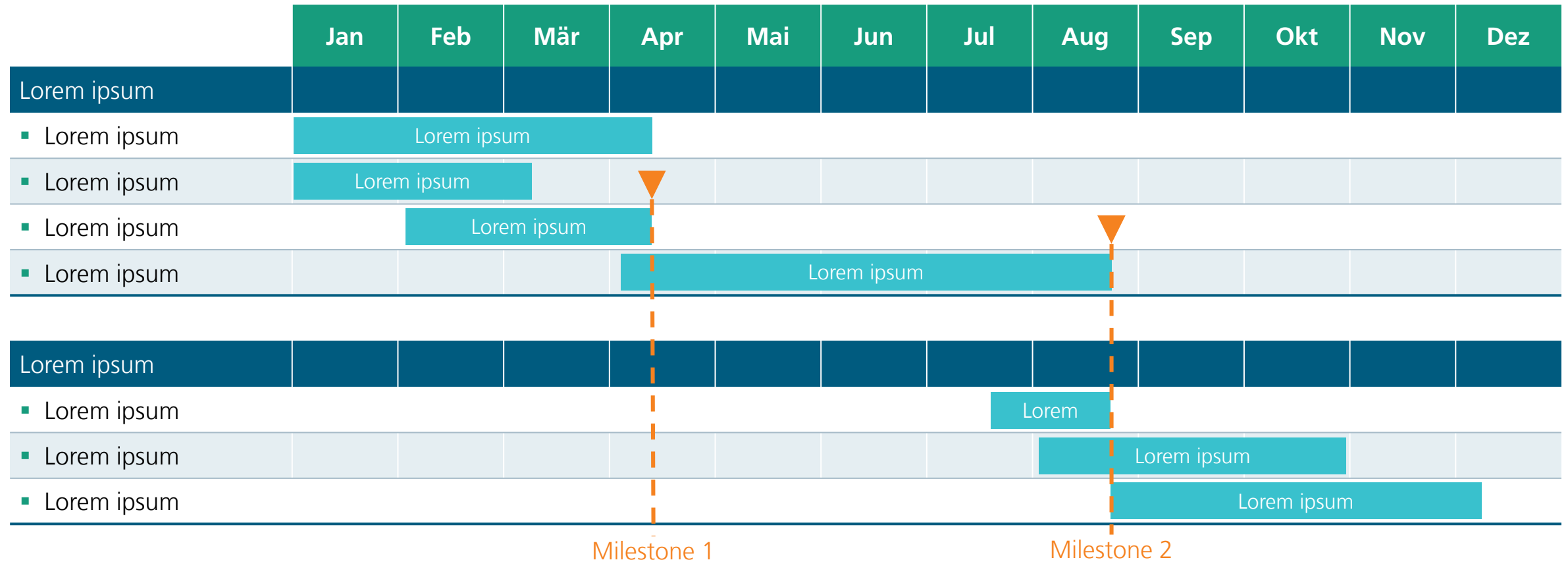
# Headline, Frutiger LT Com Bd, 24 pt, 8-part pie chart

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, schedule

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, cycle

Subline, Frutiger LT Com Lt, 20 pt

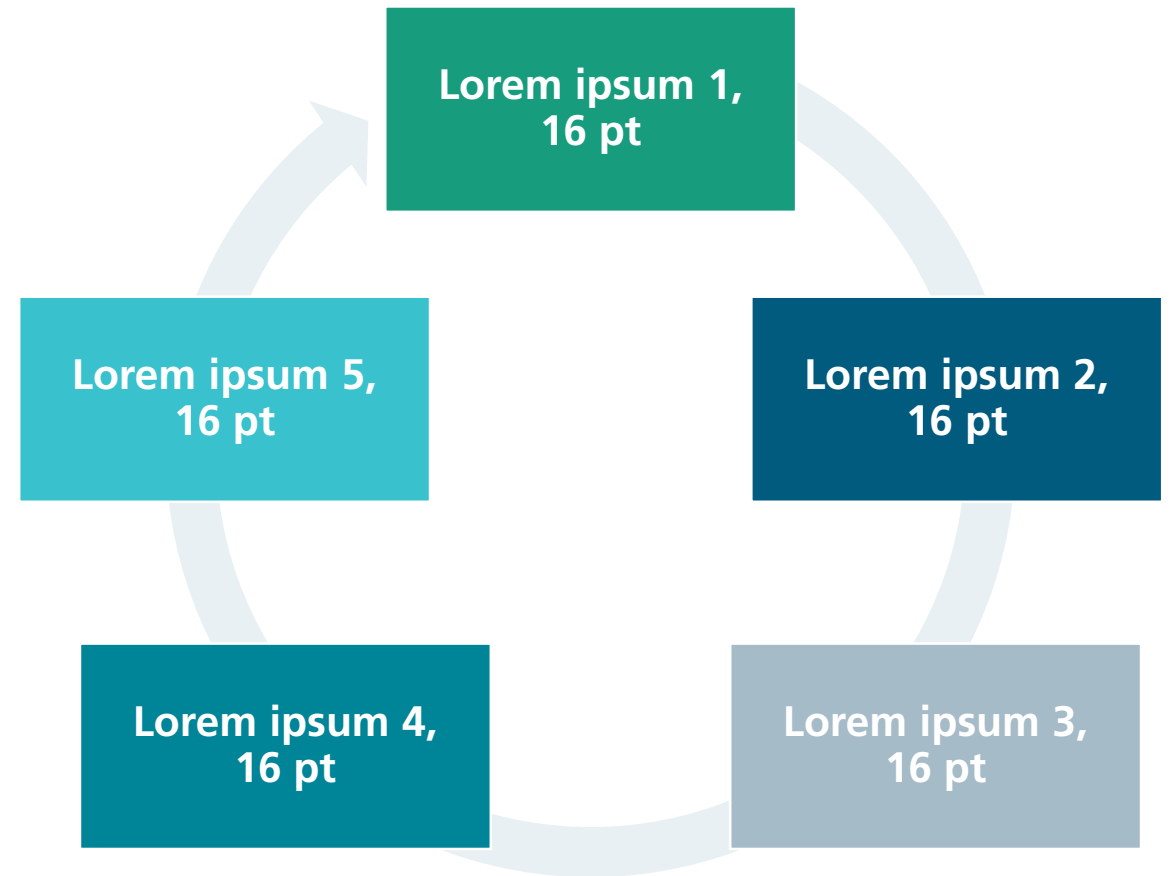
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## Headline, Frutiger LT Com Bd, 16 pt

Copy Frutiger LT Com Lt, 14 pt Dolor situs cum habilitarum itum alusi causticus imanenter Status ex landum it exus rius laudanum ibis tum. Lorem et exit vulnareus plexus. Sit itum caiusticus aurum eum explindus. Status landum it exus rius laudanum ibis. Let exit vulnareus plexus causticus imanenter Status ex landum.

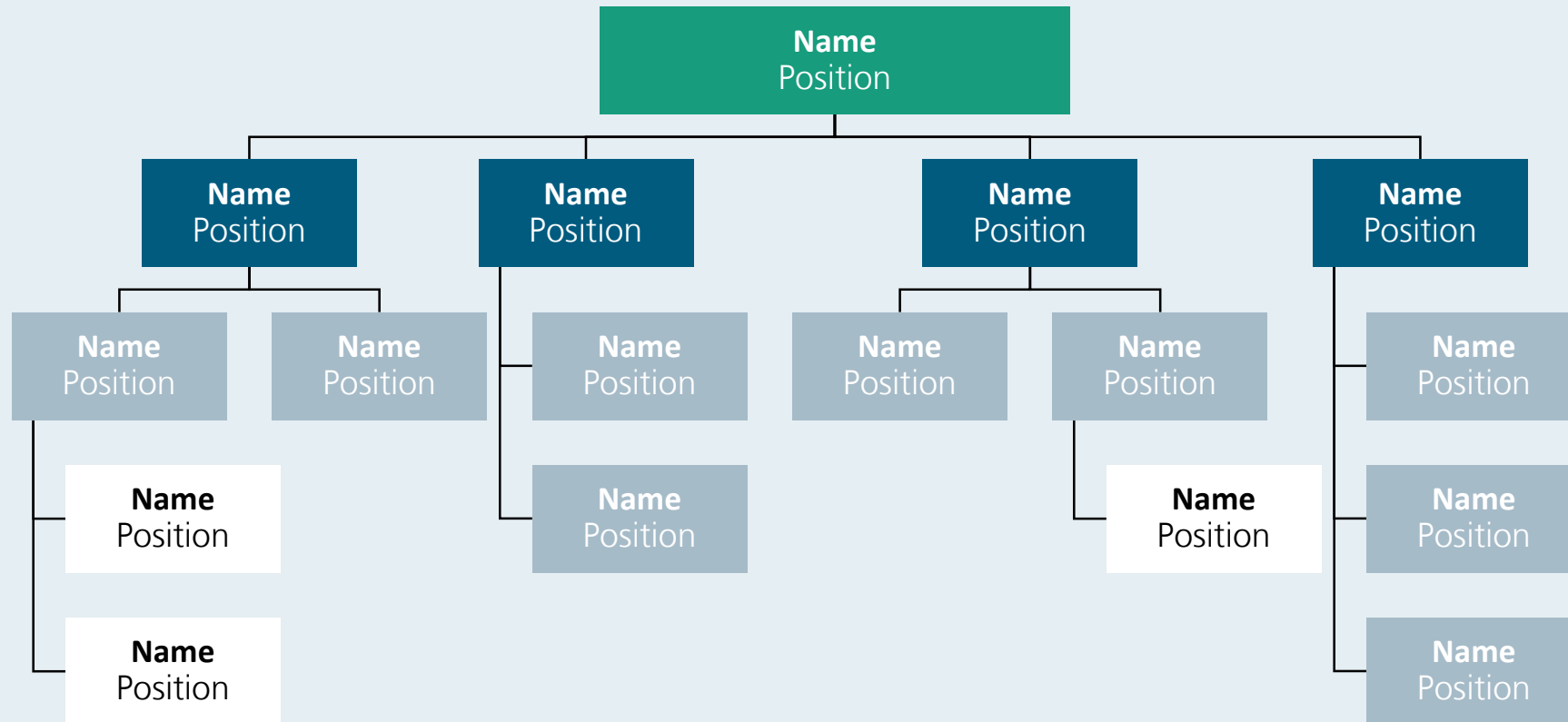
## Headline, Frutiger LT Com Bd, 14 pt

- Level 1
- Level 1
- Level 1
  - Level 2
    - Level 3
- Level 1



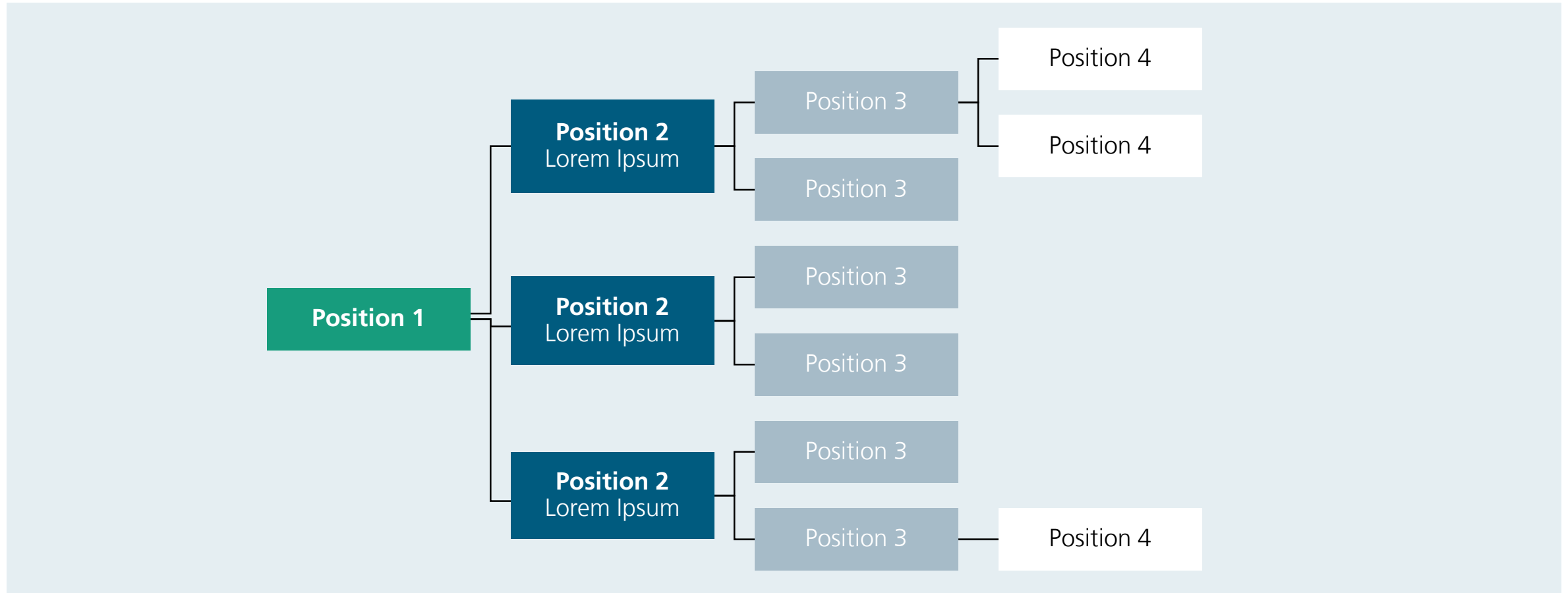
# Headline, Frutiger LT Com Bd, 24 pt, organization chart

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, horizontal organization chart

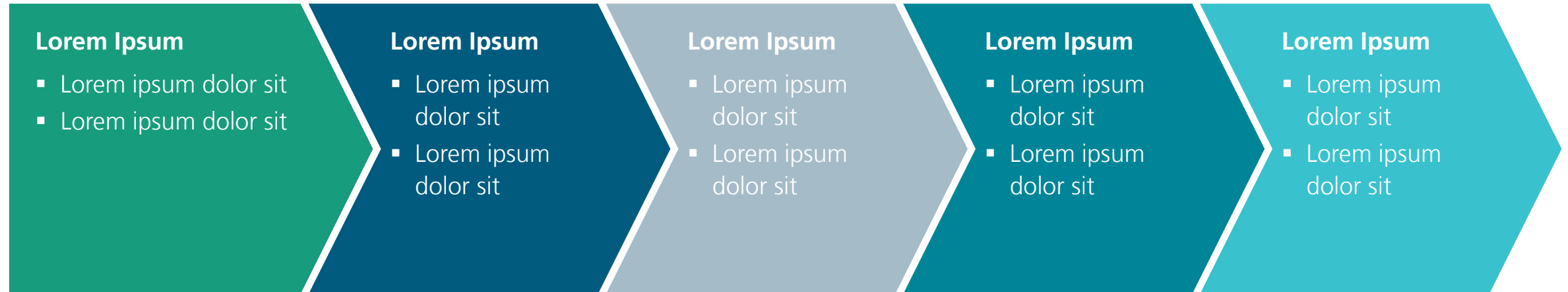
Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, process

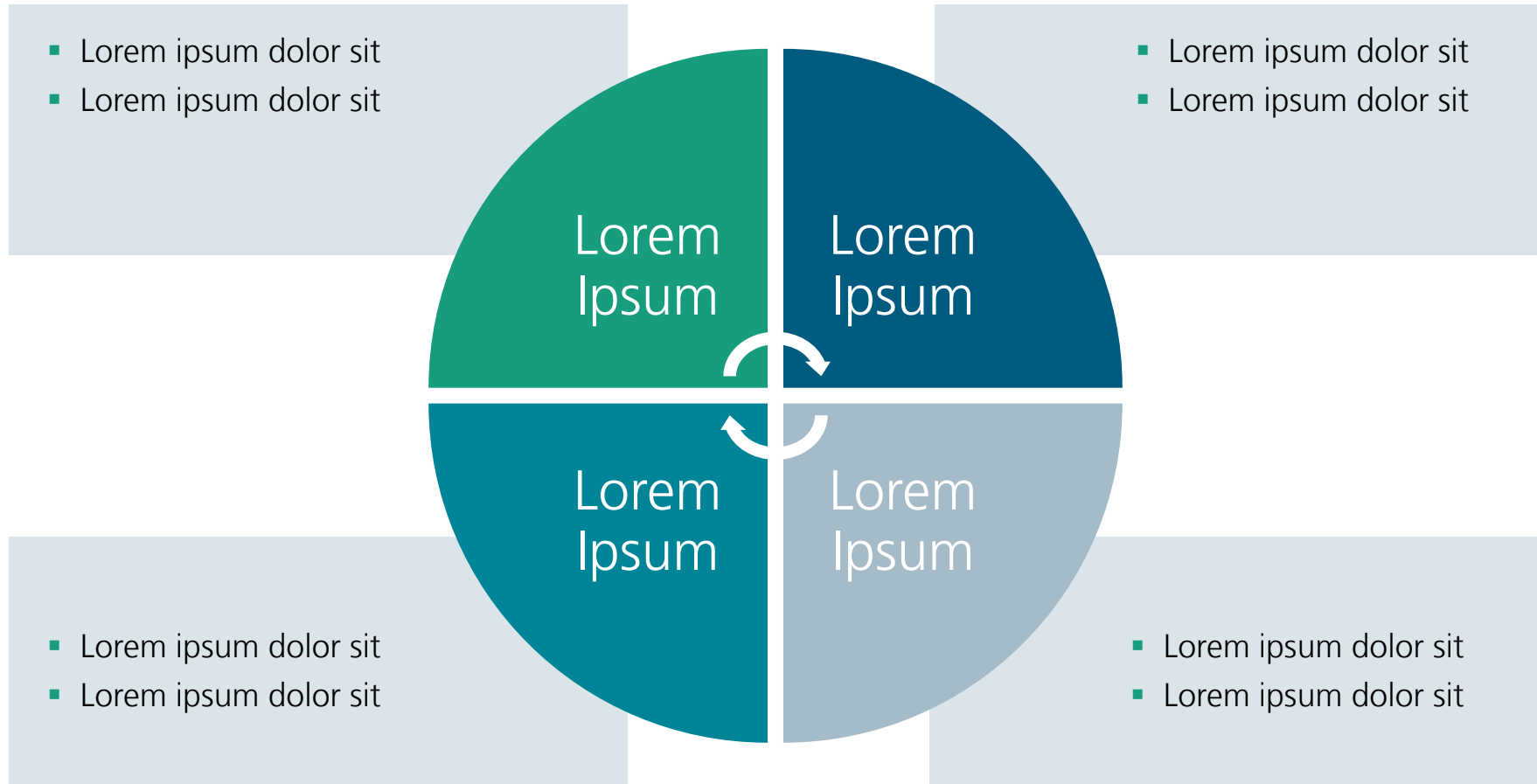
Subline, Frutiger LT Com Lt, 20 pt

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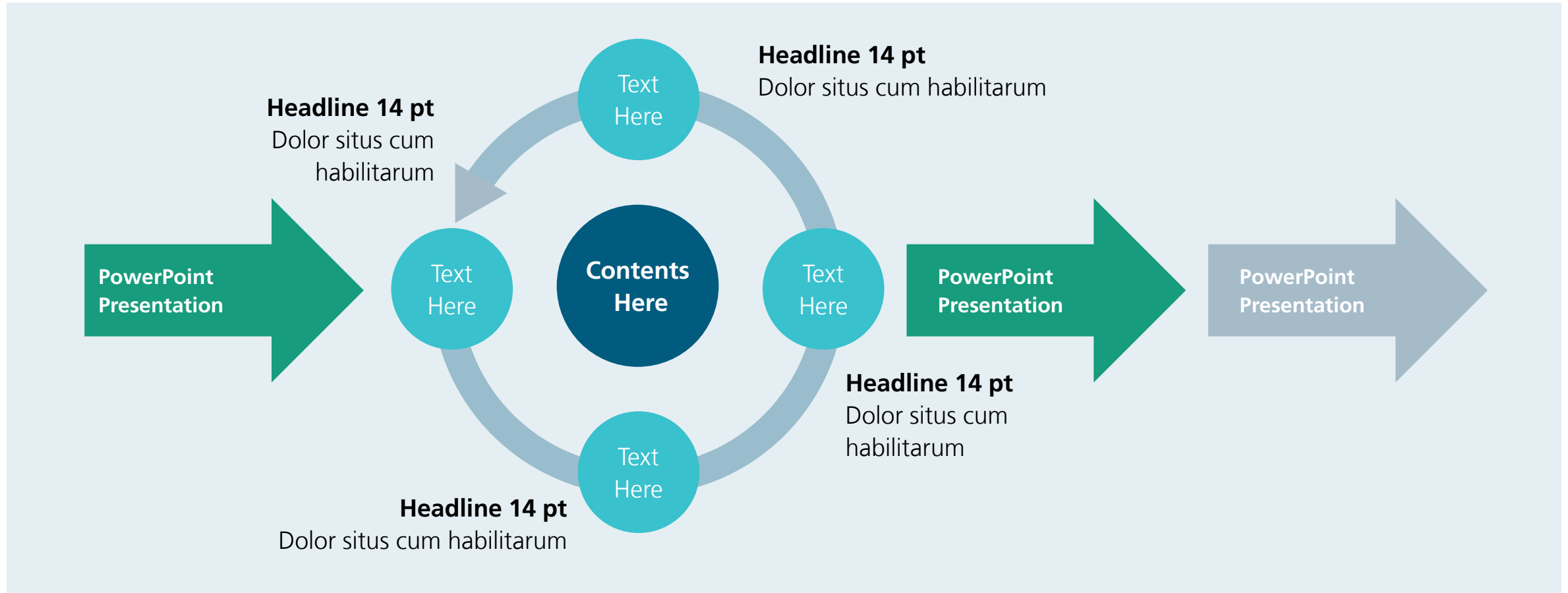
# Headline, Frutiger LT Com Bd, 24 pt, process

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, infographic

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, general icons

Subline, Frutiger LT Com Lt, 20 pt



# Headline, Frutiger LT Com Bd, 24 pt, icons for Fraunhofer lead markets

Subline, Frutiger LT Com Lt, 20 pt

Digital economy

Mobility sector

Plant, mechanical and Health care sector  
vehicle engineering

Chemical industry

Food industry

Energy sector

Construction  
industry

Aerospace  
economy



# Headline, Frutiger LT Com Bd, 24 pt, icons for FSF

Subline, Frutiger LT Com Lt, 20 pt

Bioeconomy

Next Generation  
Computing

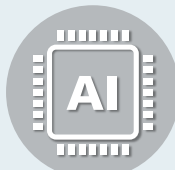
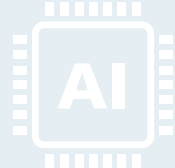
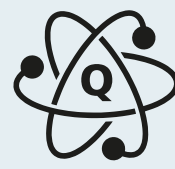
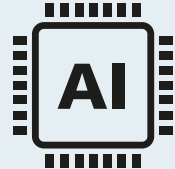
Digital  
Healthcare

Artificial  
Intelligence (AI)

Quantum  
Technologies

Resource Efficiency and  
Climate Technologies

Hydrogen  
Technologies



# Contact

---

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**Fax +49 12 3456-XXXX**

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Fraunhofer Institute for  
Technological Trend Analysis INT



Fraunhofer Institute for  
Technological Trend Analysis INT

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---

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Fraunhofer Institute for  
Technological Trend Analysis INT

# Contact

---

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**Fax +49 12 3456-XXXX**

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Street XY

12345 City

[www.fraunhofer.de](http://www.fraunhofer.de)

# Thank you for your attention!

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