The Analysis Procedure – An Overview

TOF

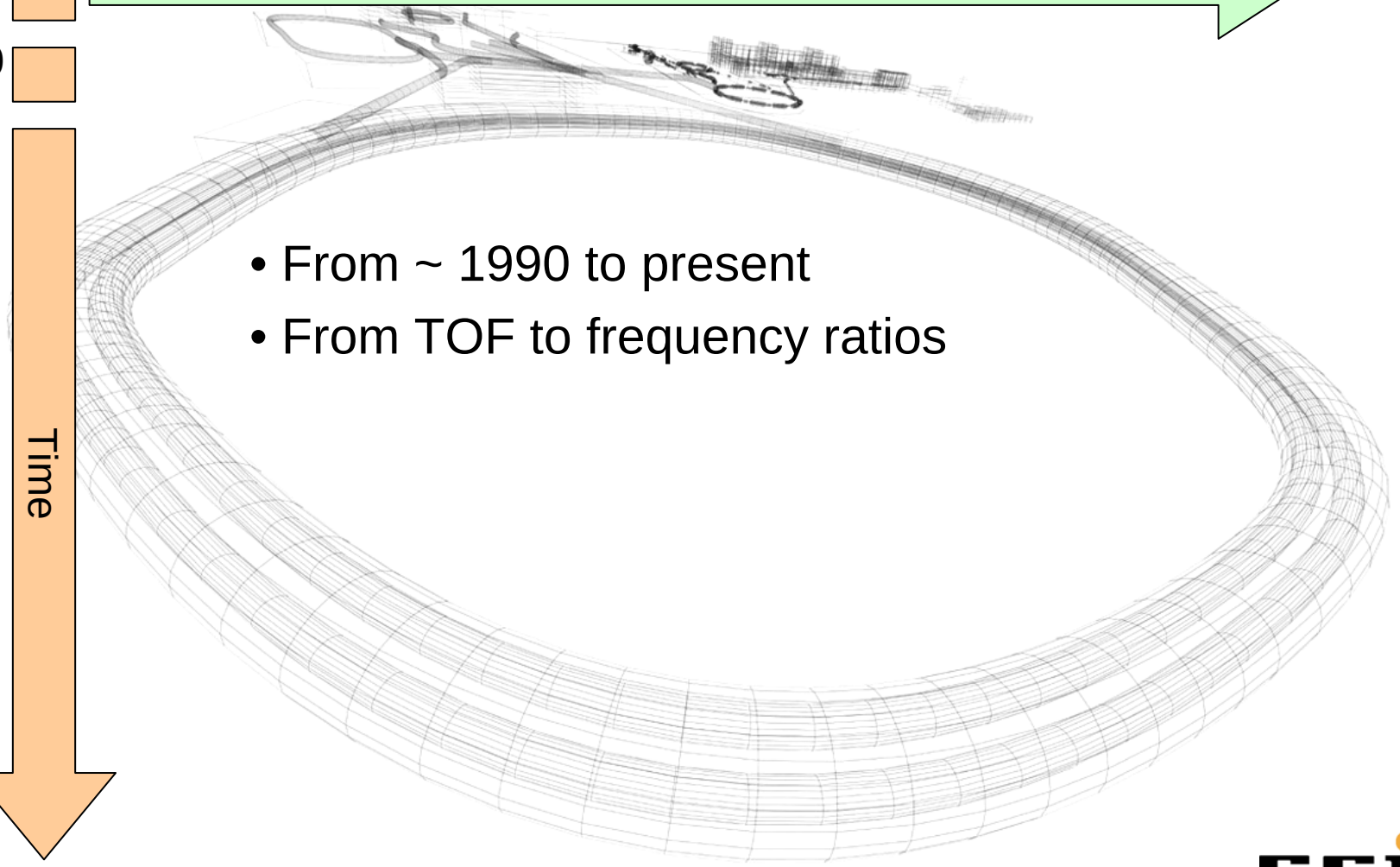
Frequency Ratio

Analysis

~1990

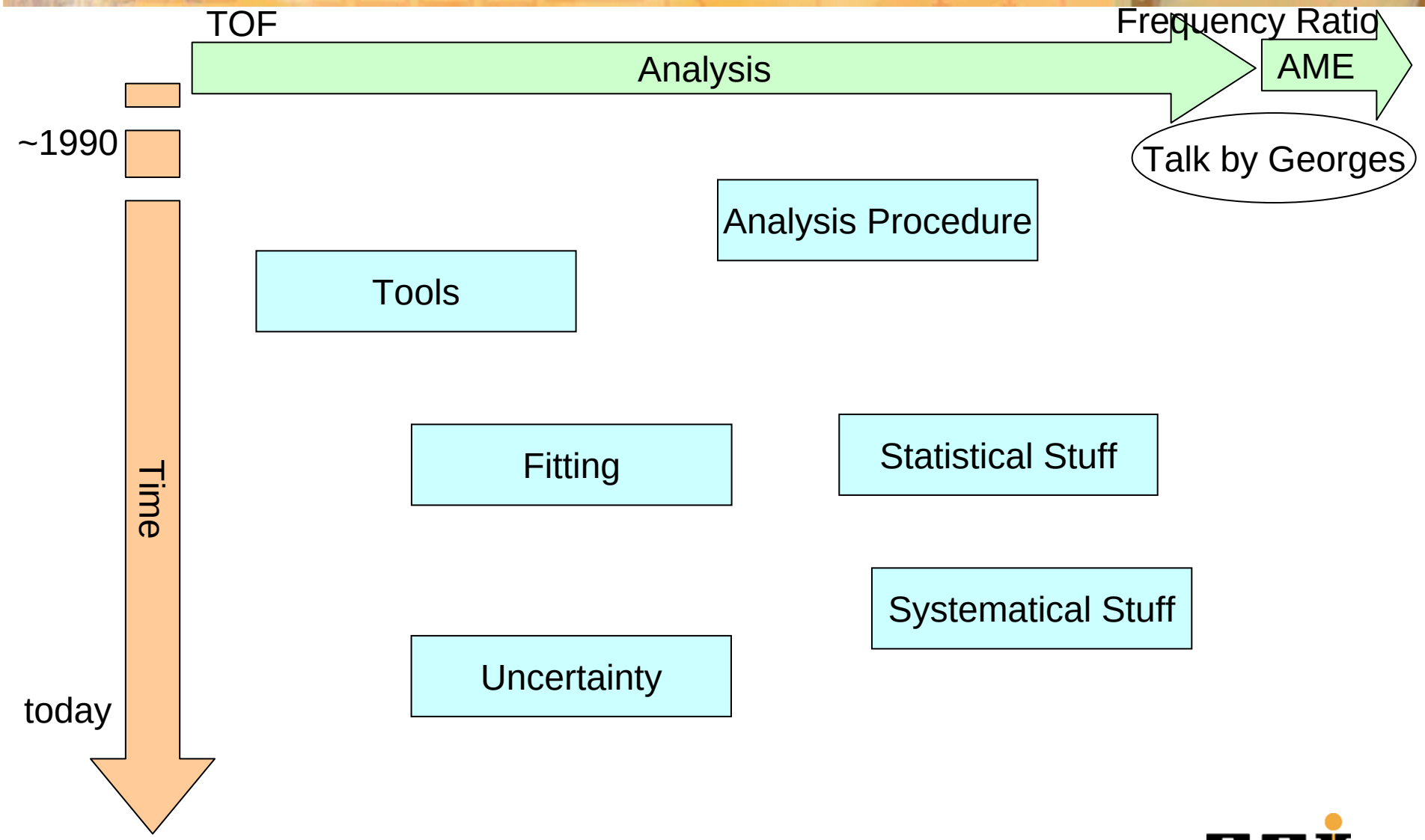
Time

today



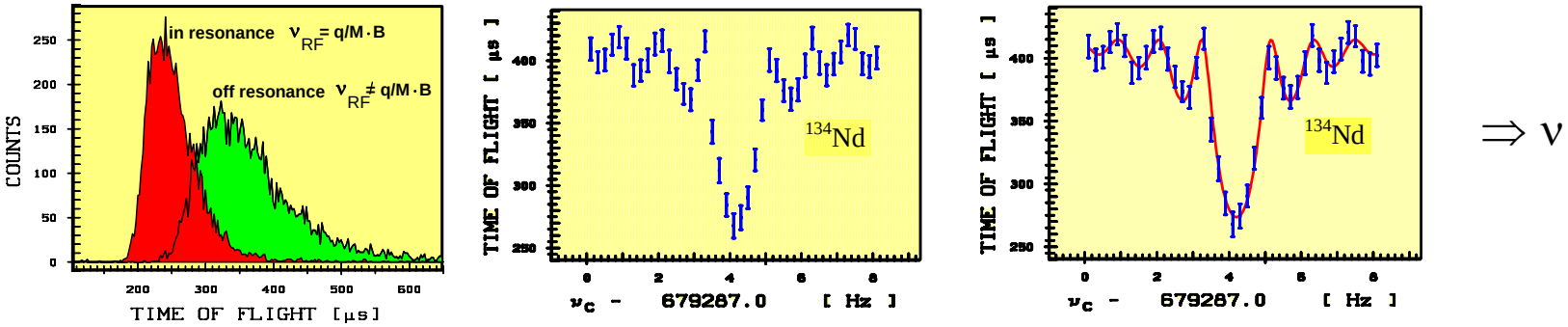
- From ~ 1990 to present
- From TOF to frequency ratios

The Overview on the Overview...



Sketch of Analysis Procedure

- Determine Time-of-Flight (TOF) for each frequency step (more details later)
- Plot TOF versus Frequency
- Make a fit (mdl, ⇒ Frank)



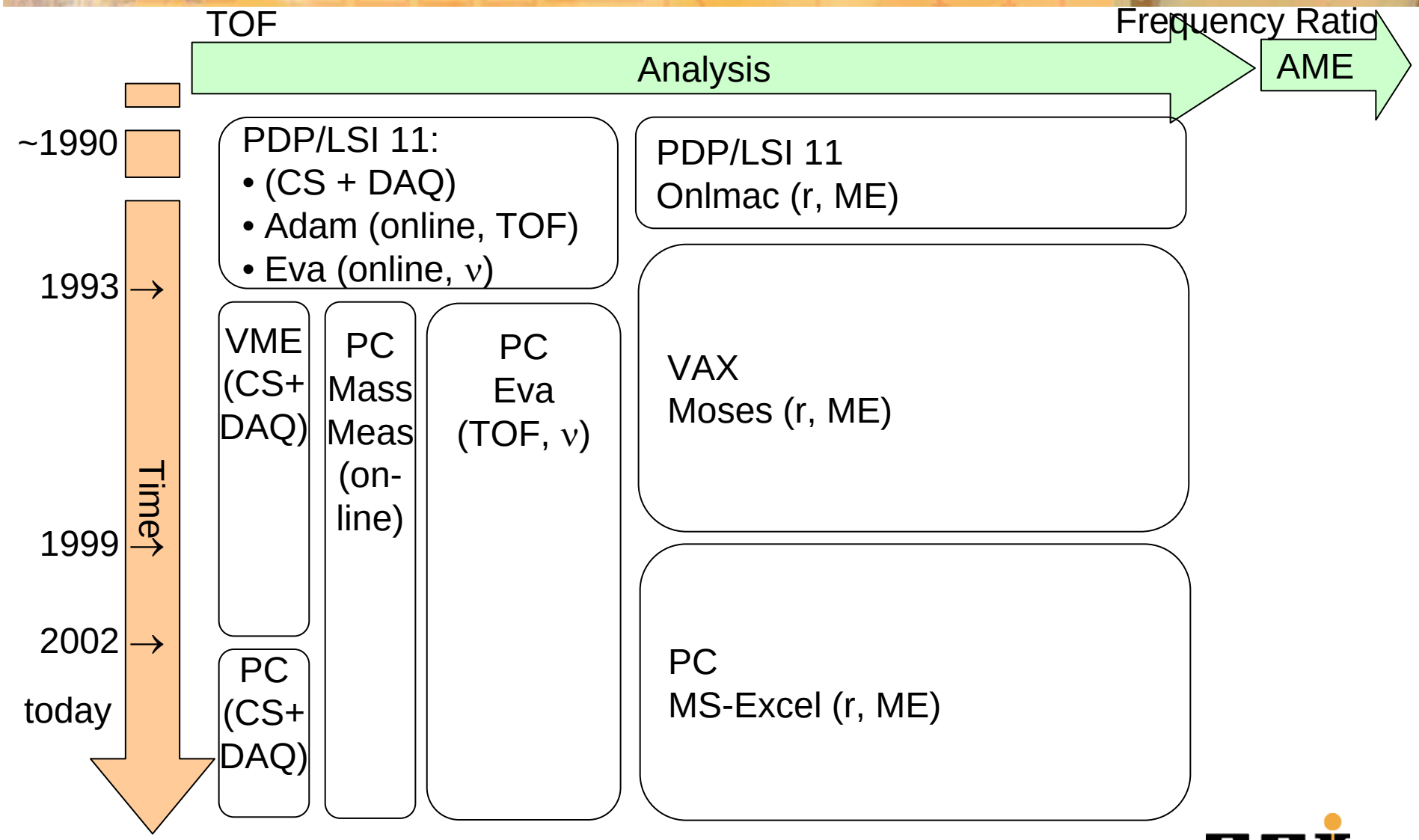
- Check/correct for contamination (⇒ Frank)
- Same procedure for species of interest and reference nuclide!
- Consider systematic effects (mdl)
- Calculate frequency ratio, $r = \nu_{ref} / \nu$ ⇐ experimental result! (not a mass value)

TOF

Analysis

r

Tools...


TOF
Analysis
Frequency Ratio
AME
~1990
1993 →
1999
2002 →
today
Time
PDP/LSI 11:
• (CS + DAQ)
• Adam (online, TOF)
• Eva (online, ν)
VME (CS+ DAQ)
PC (CS+ DAQ)
PC Mass Meas (on-line)
PC Eva (TOF, ν)
PDP/LSI 11
Onlmac (r, ME)
VAX
Moses (r, ME)
PC
MS-Excel (r, ME)

Statistic Stuff I – "Birge Ratio"

TOF → Analysis → Frequency Ratio → AME

~1990

Time

today

inner error: results from individual errors

(normal propagation of errors)

$$\sigma_{\text{int}}^2 = \frac{1}{\sum_i \frac{1}{\sigma_i^2}}$$

outer error: fluctuation around mean value

$$\sigma_{\text{ext}}^2 = \frac{\sum_i \frac{1}{\sigma_i^2}(\nu_i - \bar{\nu})^2}{(n-1)\sum_i \frac{1}{\sigma_i^2}}$$

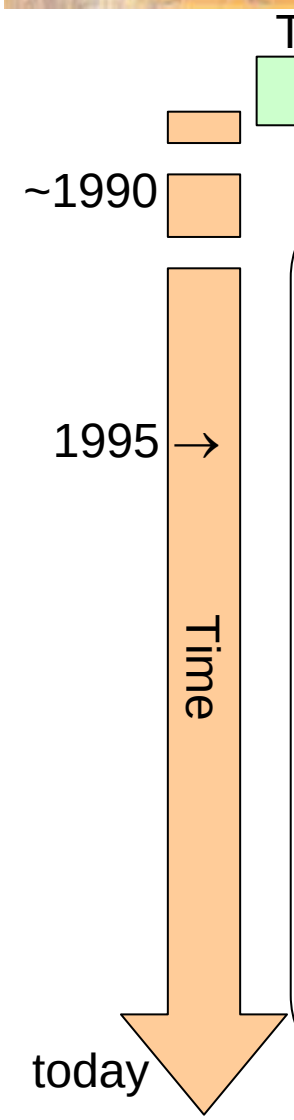
Birge: inner error ≈ outer error: fluctuation purely statistical

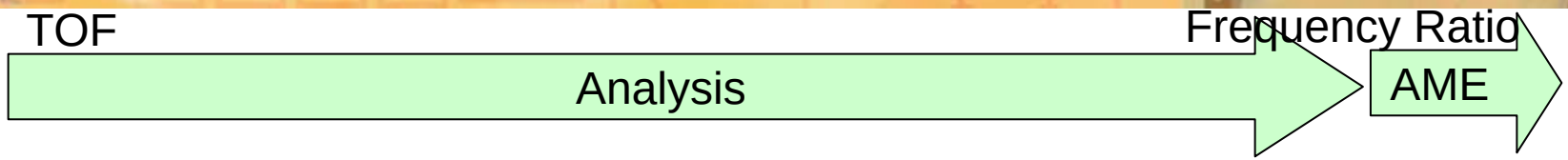
Birge ratio R(Birge) = σ (outer)/ σ(inner) ≈ 1: ideal case!

R. T. Birge, Phys. Rev. 40 (207) 1932

H. Stolzenberg, PhD thesis, Mainz, 1992

Statistic Stuff II – How to calc TOF





TOF

$$TOF = \frac{\sum n_i t_i}{\sum n_i}$$

Error of TOF (old procedure)

Standard deviation of actual TOF spectrum
only for "high countrate"
typical case: only one count per spectrum

Error of TOF (new procedure)

$$\delta_{stat} = \frac{\sigma_{TOF}}{\sqrt{N_{ions}}}, \sigma_{TOF} : \text{all(!) summed data}$$

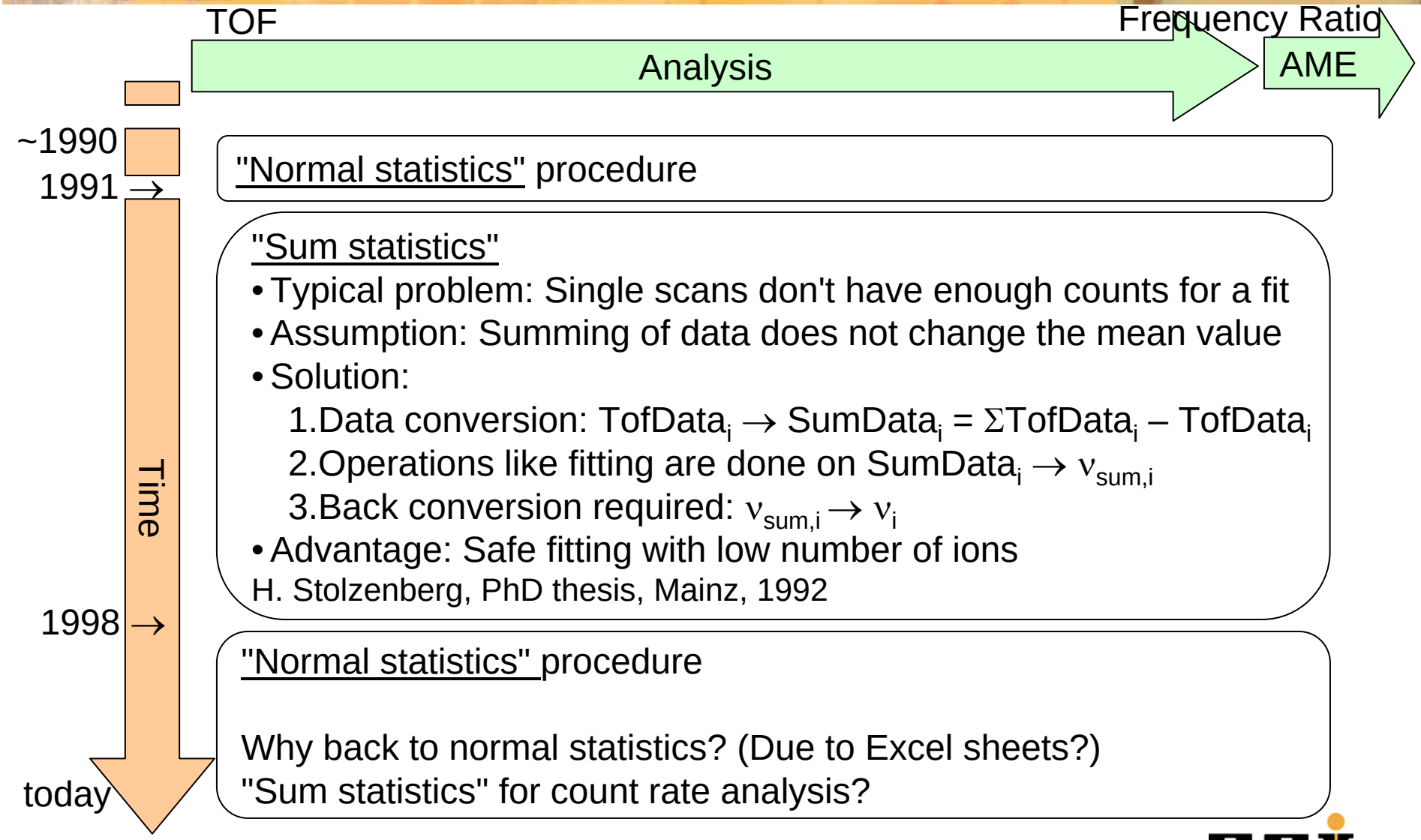
$$\delta_{app} = \frac{\sigma_{instab}}{\sqrt{N_{scan}}}, \sigma_{instab} : \text{characteristic for set-up}$$

$$\Rightarrow \delta_{TOF} = \sqrt{\delta_{stat}^2 + \delta_{app}^2}$$

D. Beck, PhD thesis, Mainz, 1997

$\delta_{app} = 0$

Statistic Stuff III – "Sum Statistics"



"Normal statistics" procedure

"Sum statistics"

- Typical problem: Single scans don't have enough counts for a fit
- Assumption: Summing of data does not change the mean value
- Solution:
  1. Data conversion: $TofData_i \rightarrow SumData_i = \Sigma TofData_i - TofData_i$
  2. Operations like fitting are done on $SumData_i \rightarrow \nu_{sum,i}$
  3. Back conversion required: $\nu_{sum,i} \rightarrow \nu_i$
- Advantage: Safe fitting with low number of ions

H. Stolzenberg, PhD thesis, Mainz, 1992

"Normal statistics" procedure

Why back to normal statistics? (Due to Excel sheets?)
"Sum statistics" for count rate analysis?

Fitting...

TOF → Analysis → Frequency Ratio → AME

~1990

Gauss:
- no real meaning of fit parameters (except centre)
- Georg: "Gauss passt immer"

1995 → today (Time)

"Mike-Fit":
- each fit parameter is related to properties of the ions/trap.
- some parameters need high statistics for their determination
- only a few parameters are needed for fitting on-line data
- perfect description of line shape, smaller statistical error

(talk by Frank)

M. König, PhD thesis, Mainz, 1995.
M. König et al., Int. J. Mass Spectr. Ion Proc. 142 (1995) 95.

$r = \frac{\nu_{REF}}{\nu}$, Accuracy... ($\Rightarrow$ talk by Alban)

TOF → Frequency Ratio

Analysis → AME

~1990 → 2000 → today: Time

Old Procedure:

$$\Delta r = \sqrt{\Delta r_{stat}^2 + \Delta r_{syst}^2}, \Delta r_{syst} = const = 1 \cdot 10^{-7}$$

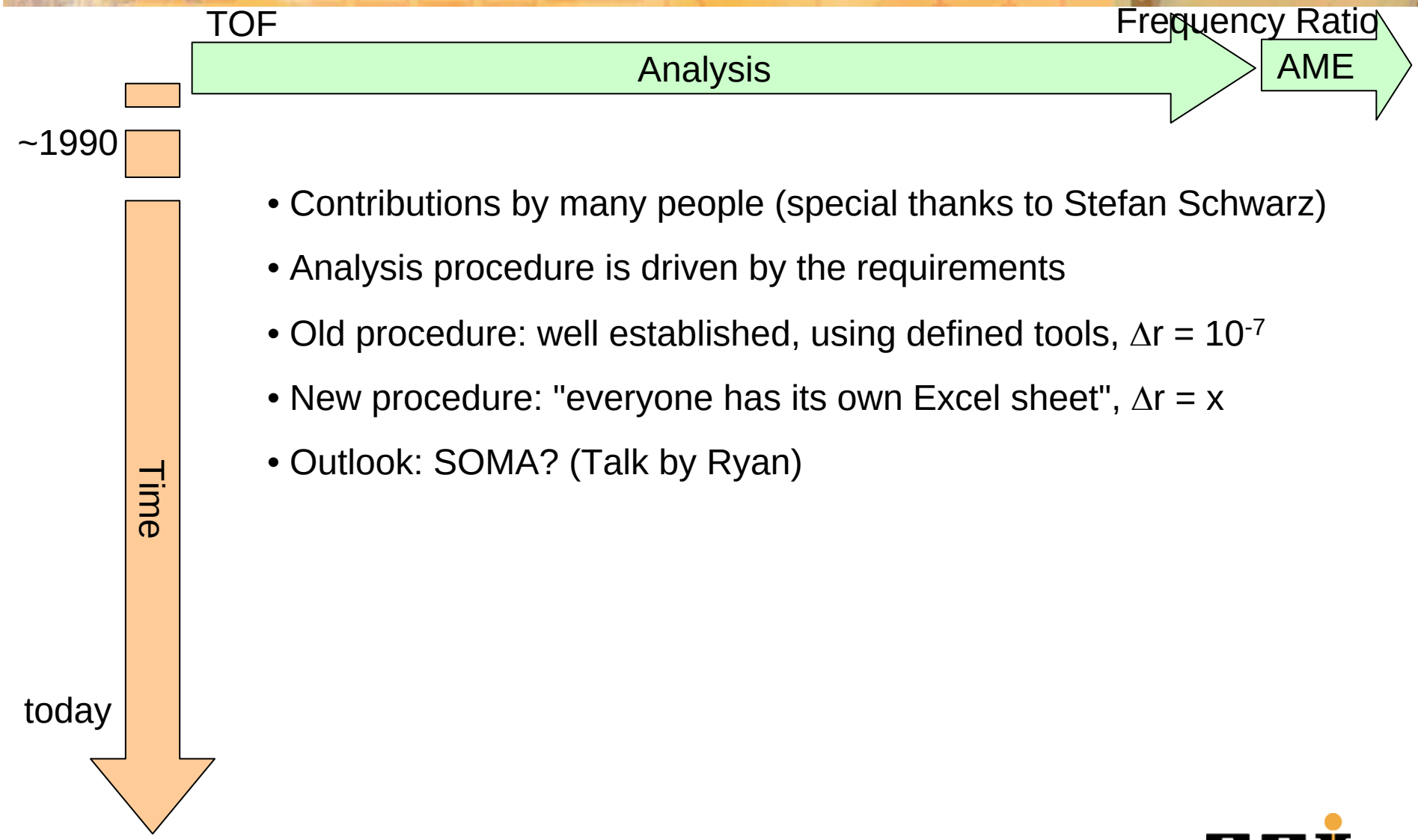
$$\Delta r \approx 1 \cdot 10^{-7}$$

- over-estimation of uncertainties?
- systematic uncertainties not really included in analysis

New Procedure:

- systematic uncertainty no longer constant!
- systematic effects included in the analysis
  1. count rate dependence
  2. magnetic field drift (linear drift, ν at "central time")
  3. mass dependent frequency shift
- usage of C-clusters for calibration
- multiple (n>2) mass relations

Conclusion...



- Contributions by many people (special thanks to Stefan Schwarz)
- Analysis procedure is driven by the requirements
- Old procedure: well established, using defined tools, $\Delta r = 10^{-7}$
- New procedure: "everyone has its own Excel sheet", $\Delta r = x$
- Outlook: SOMA? (Talk by Ryan)