XXVII FIG CONGRESS
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Volunteering for the future – Geospatial excellence for a better living

The Reconstruction of the Medieval Unit of Length Based on the Sizes of Contemporary Round Churches

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and

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(Hungary)

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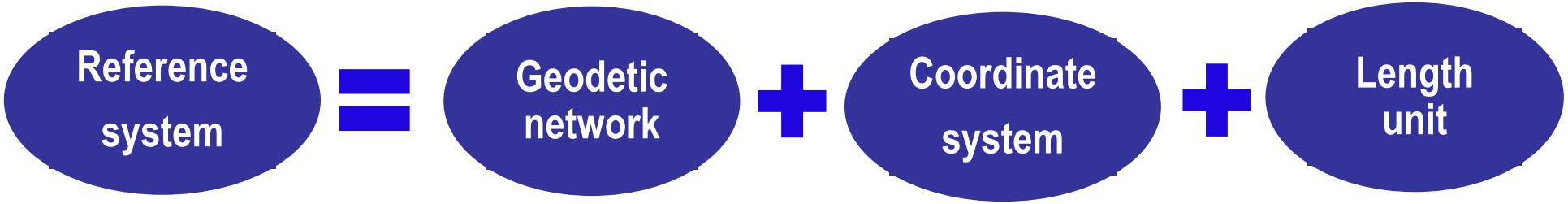
The parts of reference system in surveying



„frame” geodetic framework „infrastructure”	3D 2D 1D	**metre** system (today)

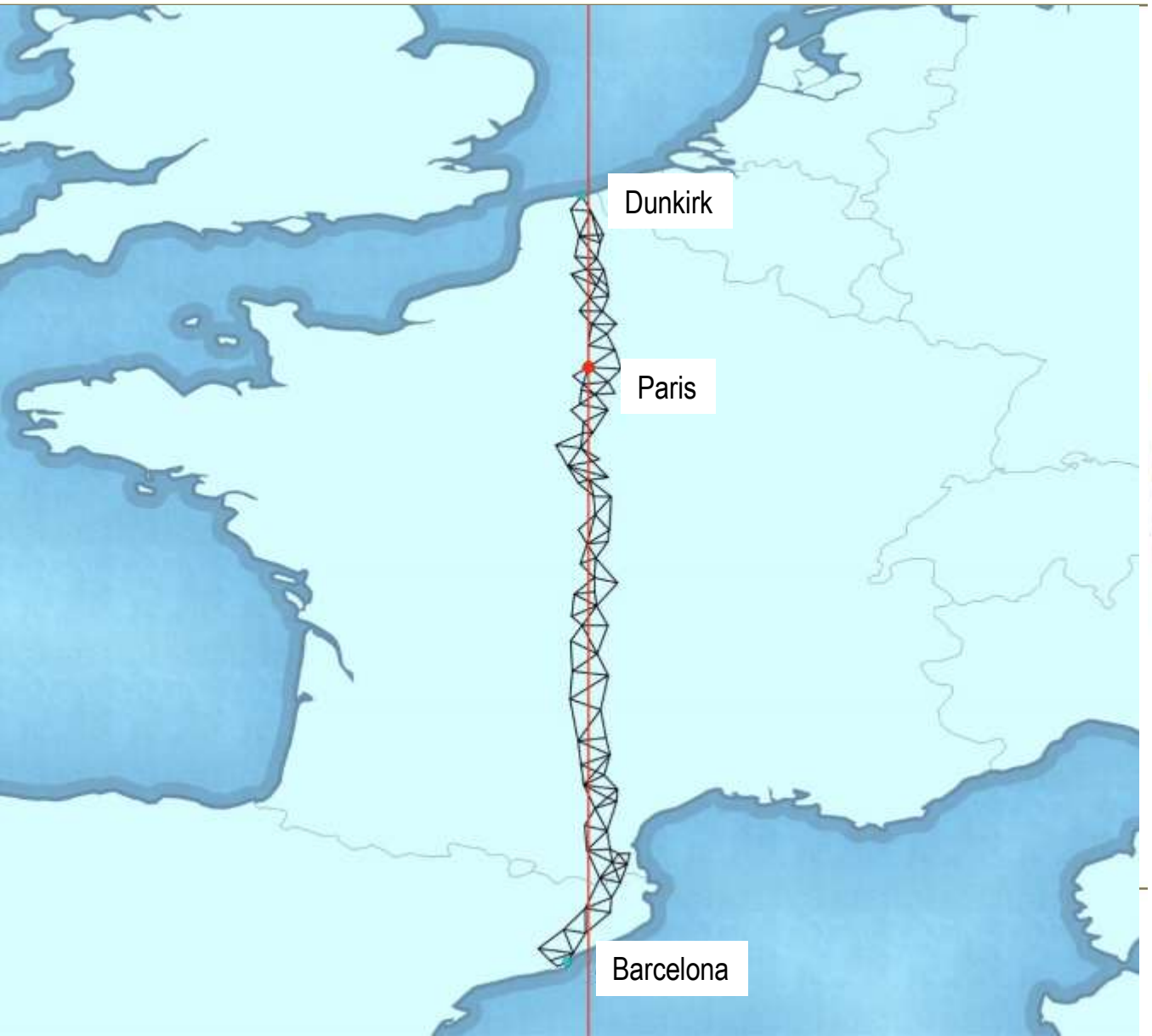
1983

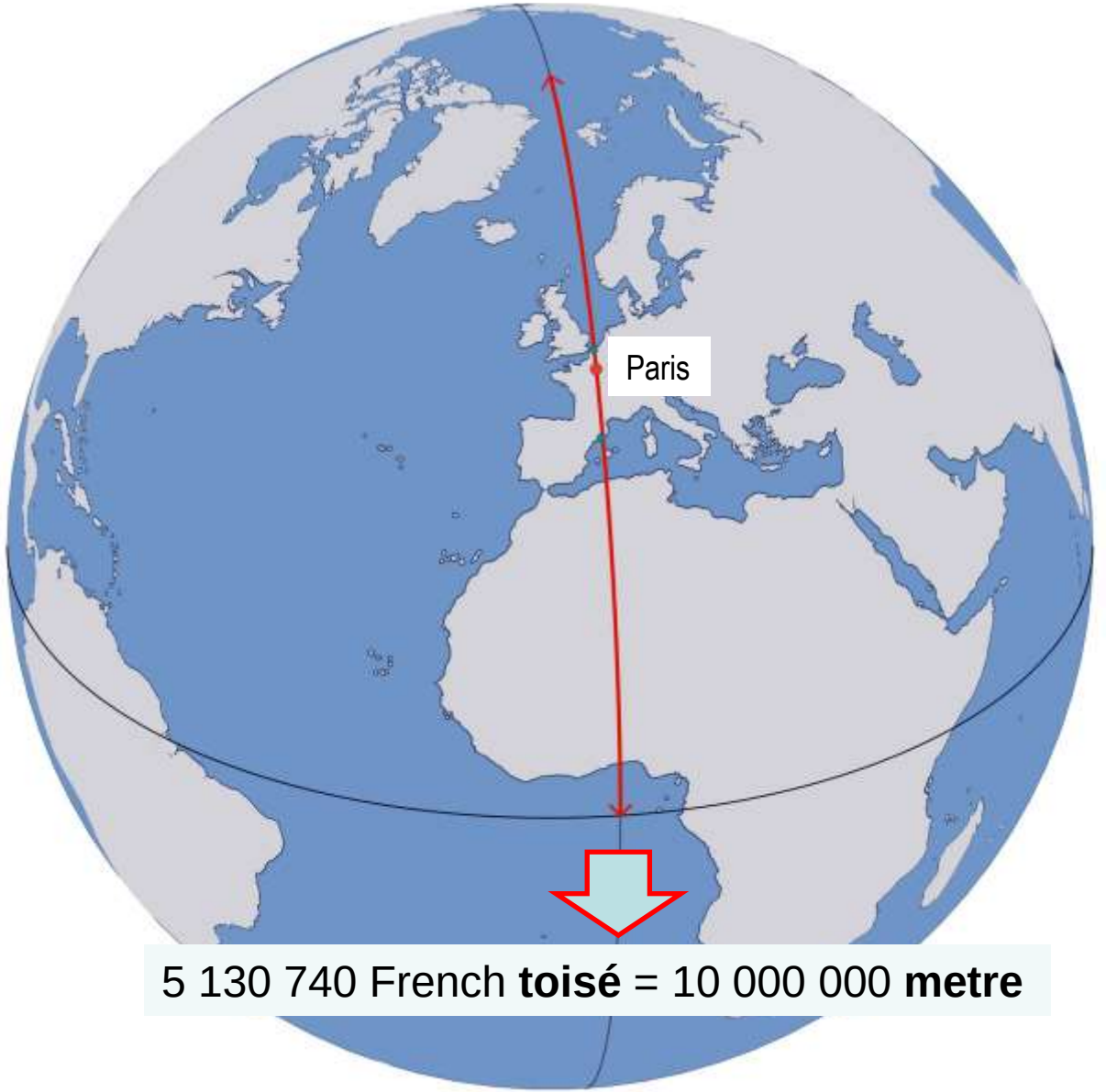
Definition of the **metre**: the length of the path travelled by light in vacuum in 1/299 792 458 of a second

About the history of meter, the todays length unit

1793

Originally defined as one **ten-millionth** of the distance from the Equator to the North Pole





5 130 740 French **toisé** = 10 000 000 **metre**

The Medieval French units of lengths

5 130 740 **toisé** = 10 000 000 **metre**

1 toisé = 1.949 metre

	toisé (fathom)	pieds (foot/feet)	pouces (inch/es)	lignes (line/s)	metric system
1 toisé (French fathom)	**1**	6	72	864	**1.949 metre**
1 pied (French foot)		**1**	12	144	**32.48 cm**
1 pouce (French inch)			**1**	12	**2.71 cm**
1 ligne (French line)				**1**	**0.23 cm**

The conversion from the old French system of measurement to the metre is **known exactly**.

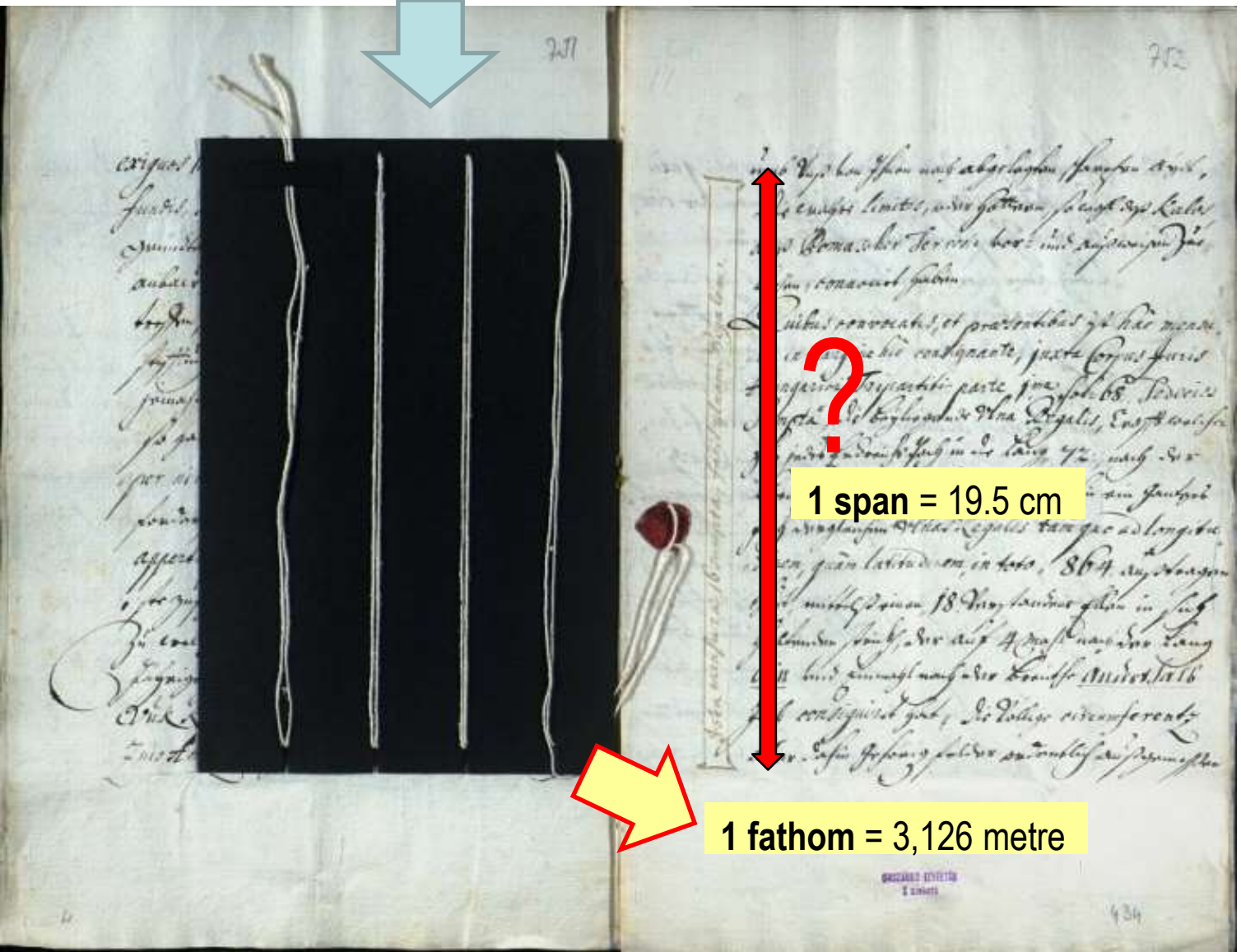
The Medieval Hungarian units of lengths

	öl (fathom)	láb (foot/feet)	arasz (span/s)	hüvelyk (inch/es)	metric system
1 öl (Hungarian fathom)	**1**	10	16	120	**~3.126 metre**
1 láb (Hungarian foot)		**1**		12	**~31.3 cm**
1 arasz (Hungarian span)			**1**	7.5	**~19.5 cm**
1 hüvelyk (Hungarian inch)				**1**	**~26.1 mm**

The conversion is very **uncertain,** because these values are derived from the length of a single length of rope.

What is the size of Hungarian fathom?
Why is this value uncertain?

The only copy of royal fathom from 1702, the rope:

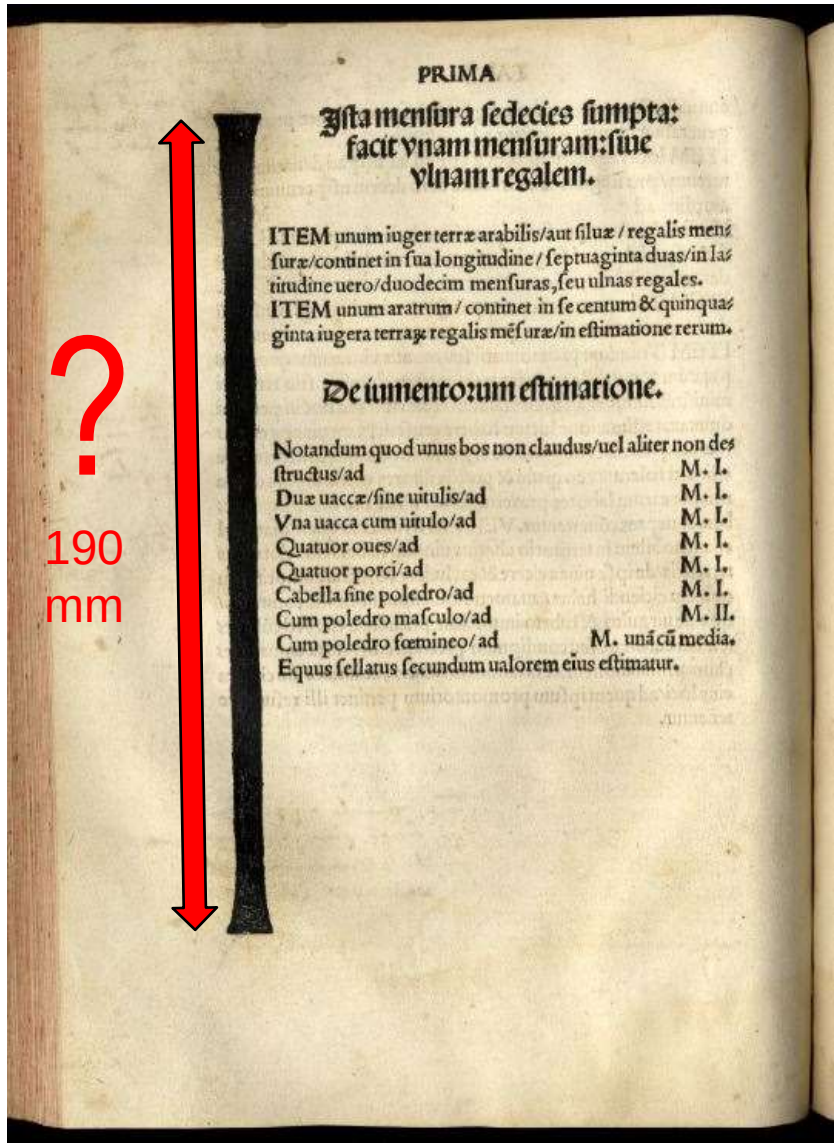


We know only one single copy, which turned up in the Hungarian central archives. This copy is a royal-fathom long measuring rope, which was attached to a report.

It was said to be 3.126 m. This value is recognised as the “official” metric length of the medieval royal Hungarian fathom.

Furthermore, a unit of length corresponding to one span was drawn in the report.

What is the size of Hungarian span?
Why is this value uncertain?



PRIMA

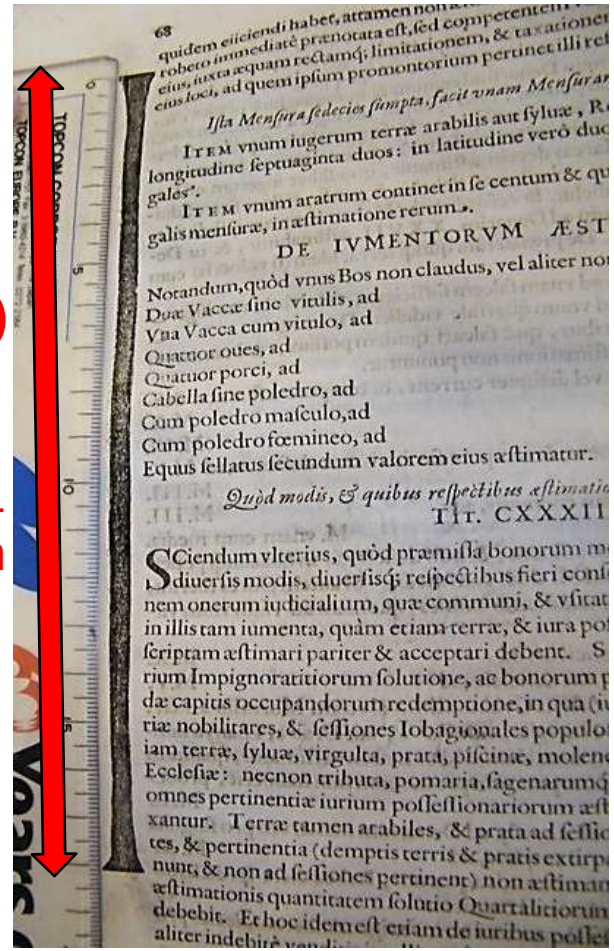
Ista mensura sedecies sumpta: facit vnam mensuram: siue vlnam regalem.

ITEM unum iuger terræ arabilis/aut siluæ / regalis mensuræ/continet in sua longitudine / septuaginta duas/in latitudine uero/duodecim mensuras, seu ulnas regales.
ITEM unum aratrum / continet in se centum & quinquaginta iugera terræ regalis mẽsuræ/in estimatione rerum.

De iumentorum estimatione.

Notandum quod unus bos non claudus/uel aliter non destructus/ad M. I.
Duæ uaccæ/sine uitulis/ad M. I.
Vna uacca cum uitulo/ad M. I.
Quatuor oues/ad M. I.
Quatuor porci/ad M. I.
Cabella sine poledro/ad M. I.
Cum poledro masculo/ad M. II.
Cum poledro fœmineo/ad M. unã cũ media.
Equus sellatus secundum ualorem eius estimatur.

?
190 mm



quidem eiiciendi habet, attamen non
robero immediatè prænotata est, sed competenter
eius, iuxta æquam rectamq; limitationem, & ta
eius loci, ad quem ipsum promontorium pertinet illi re

Ista Mensura sedecies sumpta, facit vnam Mensura

ITEM vnum iugerum terræ arabilis aut syluæ, R
longitudine septuaginta duos: in latitudine verò duo
gales".
ITEM vnum aratrum continet in se centum & qu
galis mensuræ, in æstimatione rerum.

DE IVMENTORVM ÆST

Notandum, quòd vnus Bos non claudus, vel aliter no
Duæ Vaccæ sine vitulis, ad
Vna Vacca cum vitulo, ad
Quatuor oues, ad
Quatuor porci, ad
Cabella sine poledro, ad
Cum poledro masculo, ad
Cum poledro fœmineo, ad
Equus sellatus secundum valorem eius æstimatur.

Quòd modis, & quibus respectibus æstimati

TIT. CXXXII

SCiendum vlterius, quòd præmissa bonorum m
diuersis modis, diuersisq; respectibus fieri conti
nem onerum iudicialium, quæ communi, & vsitat
in illis tam iumenta, quàm etiam terræ, & iura po
scriptam æstimari pariter & acceptari debent. S
rium Impignoratitiorum solutione, ac bonorum p
dæ capitis occupandorum redemptione, in qua (i
riæ nobilitares, & sessiones Iobagionales populo
iam terræ, syluæ, virgulta, prata, piscinæ, molen
Ecclesiæ: necnon tributa, pomaria, sagenarumq
omnes pertinentiæ iurium possessionariorum æst
xantur. Terræ tamen arabiles, & prata ad sessio
tes, & pertinentia (demptis terris & pratis extirp
nunt, & non ad sessiones pertinent) non æstiman
æstimationis quantitatem solutio Quartalitiorum
debebit. Et hoc idem est etiam de iuribus posses
aliter indebitè

?
181 mm

The Werbőczi „Tripartitum” statue book has
50 editions, but the size of span is changes
between 18.1 and 19.2 cm…

The fathom is equal span times 16: 2.9 - 3.1 metres…

What is our idea?

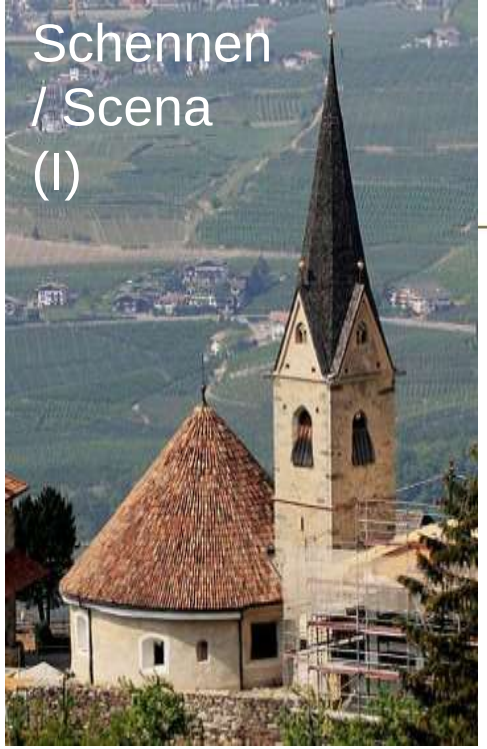
… the Reverse Engineering

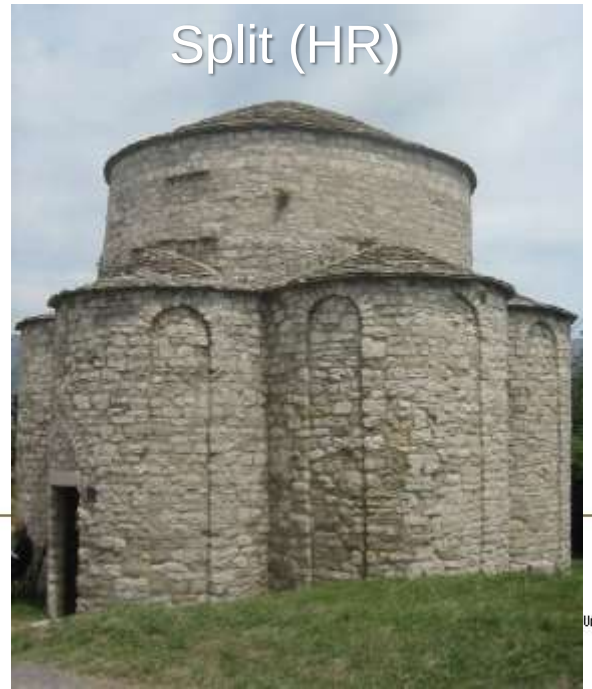
1. The medieval buildings were built by **„plans”**
2. There should be used the **contemporary unit** of length (foot or span at that time)
3. Because of practical reasons, the dimensions of buildings were provided in **round multiples**

If these assumptions are true, all we have to do is find a suitable building from the age when the contemporary measurement system was used, measure its dimensions very precisely and from the dimensions we can recalculate, **reconstruct** the **former length unit**’s values in meter.

Round churches in Central-Eastern Europe

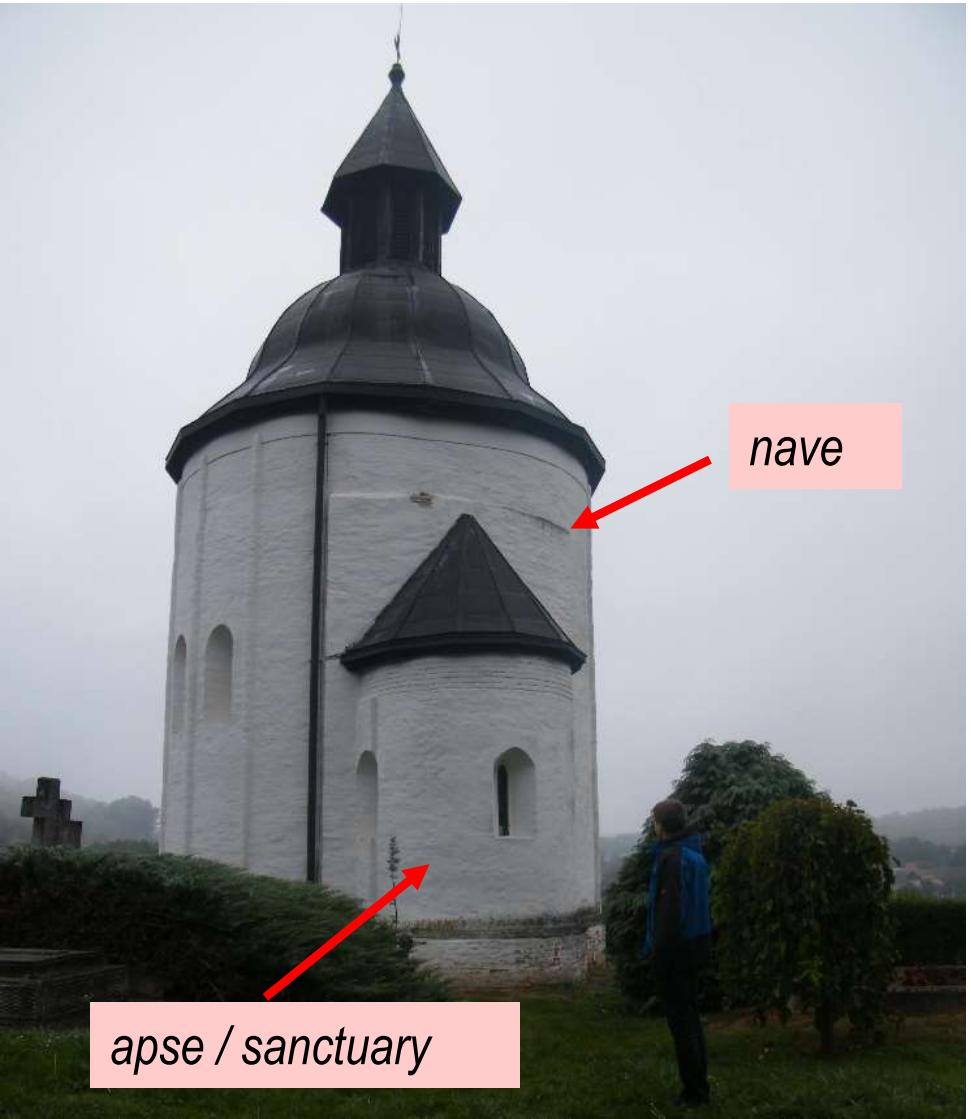
…as guardians

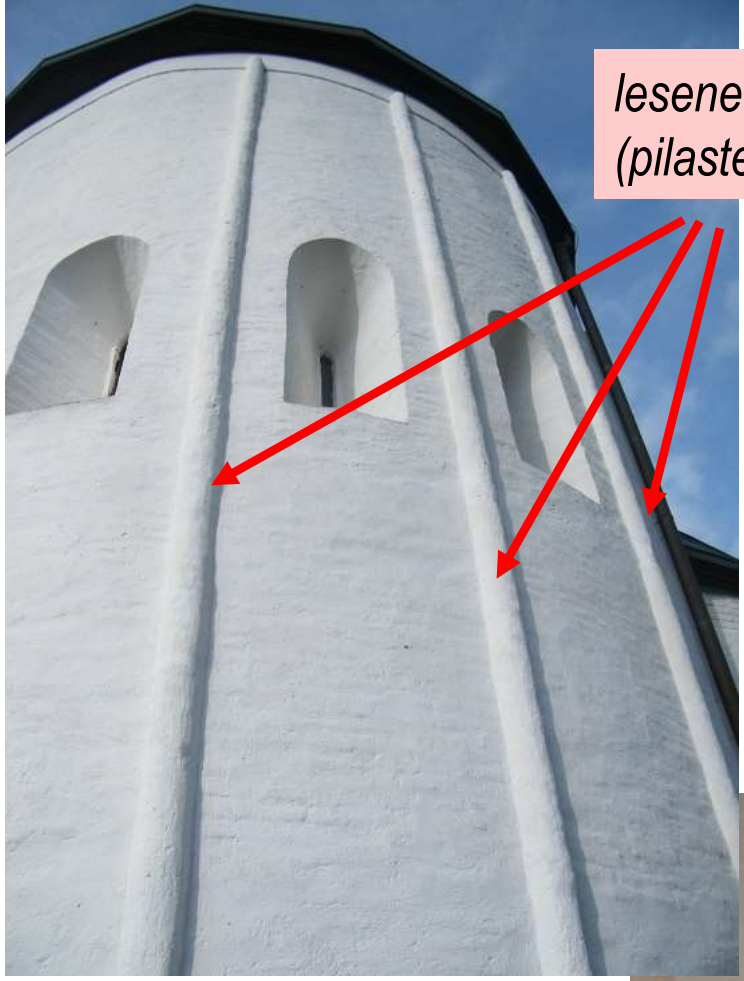




kościół okrężny
rundkirche
chiesa rotonda
okrogla cerkev
okrúhly kostol
kulatý kostel
okrugla crkva
körtemplom

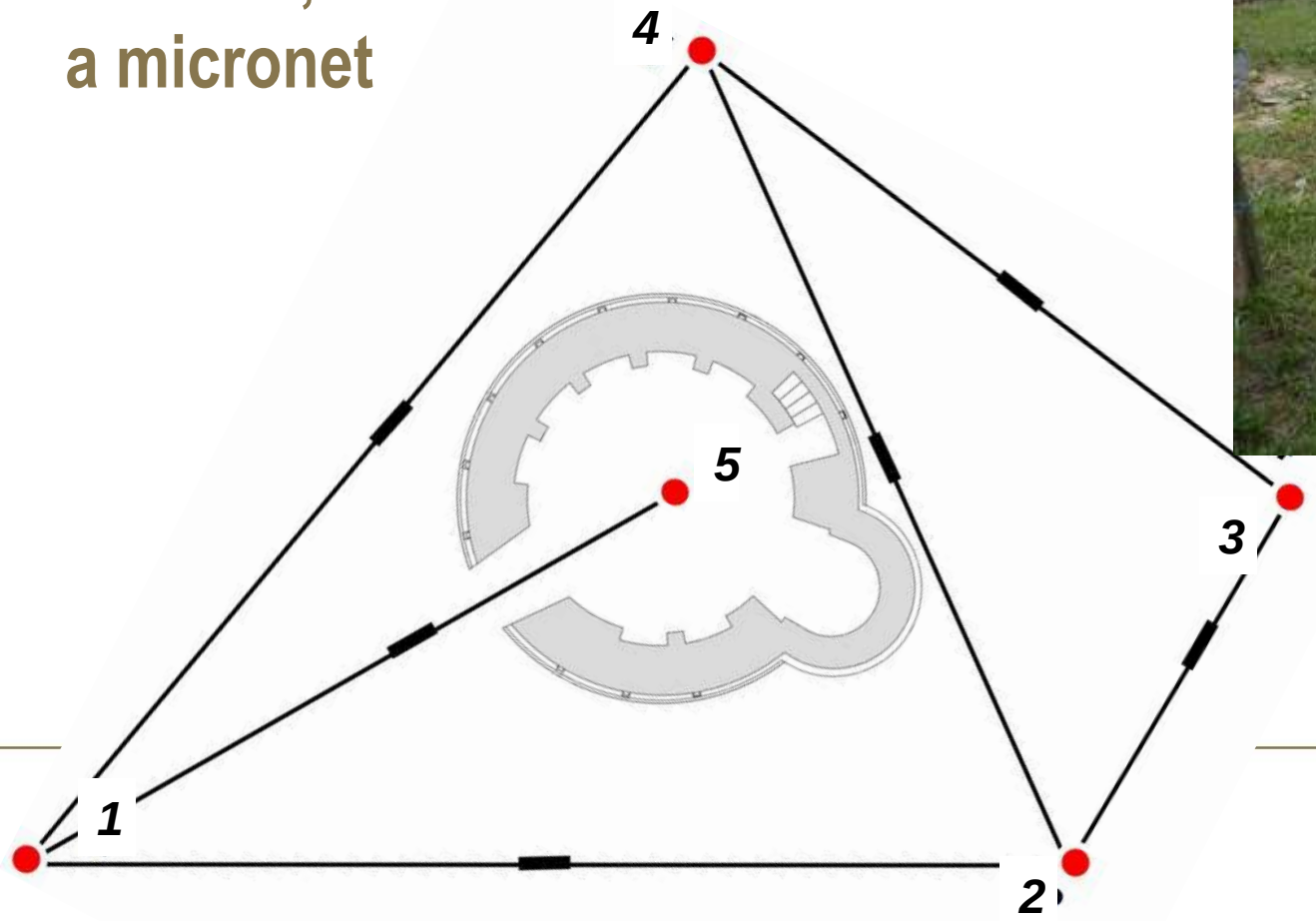
First example: Saint Anne round church in Kallósd (Hungary)



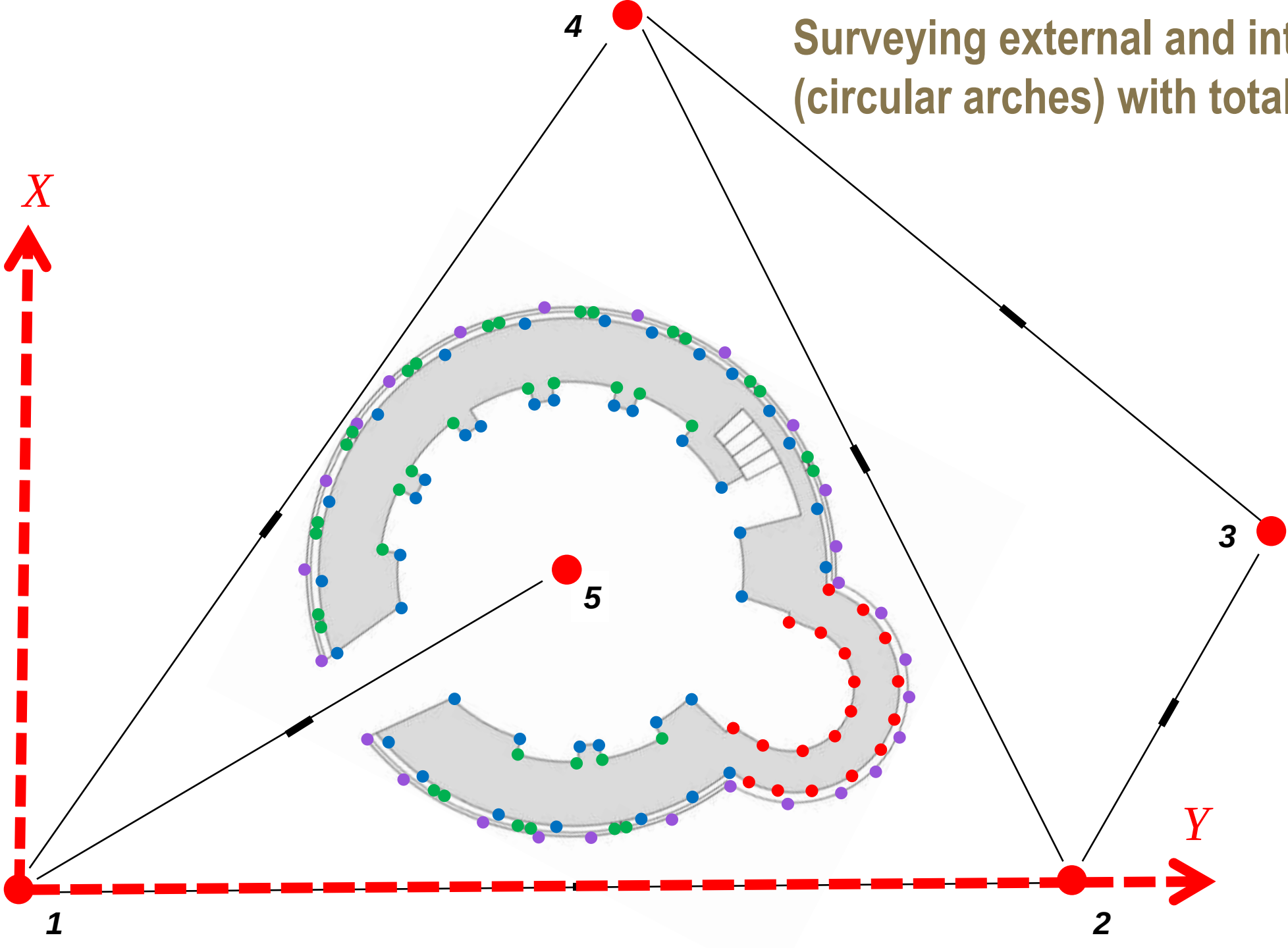


- Kallósd is a small sack village in Zala county
- The church was built around 1270
- Renovated between 1989 and 1993

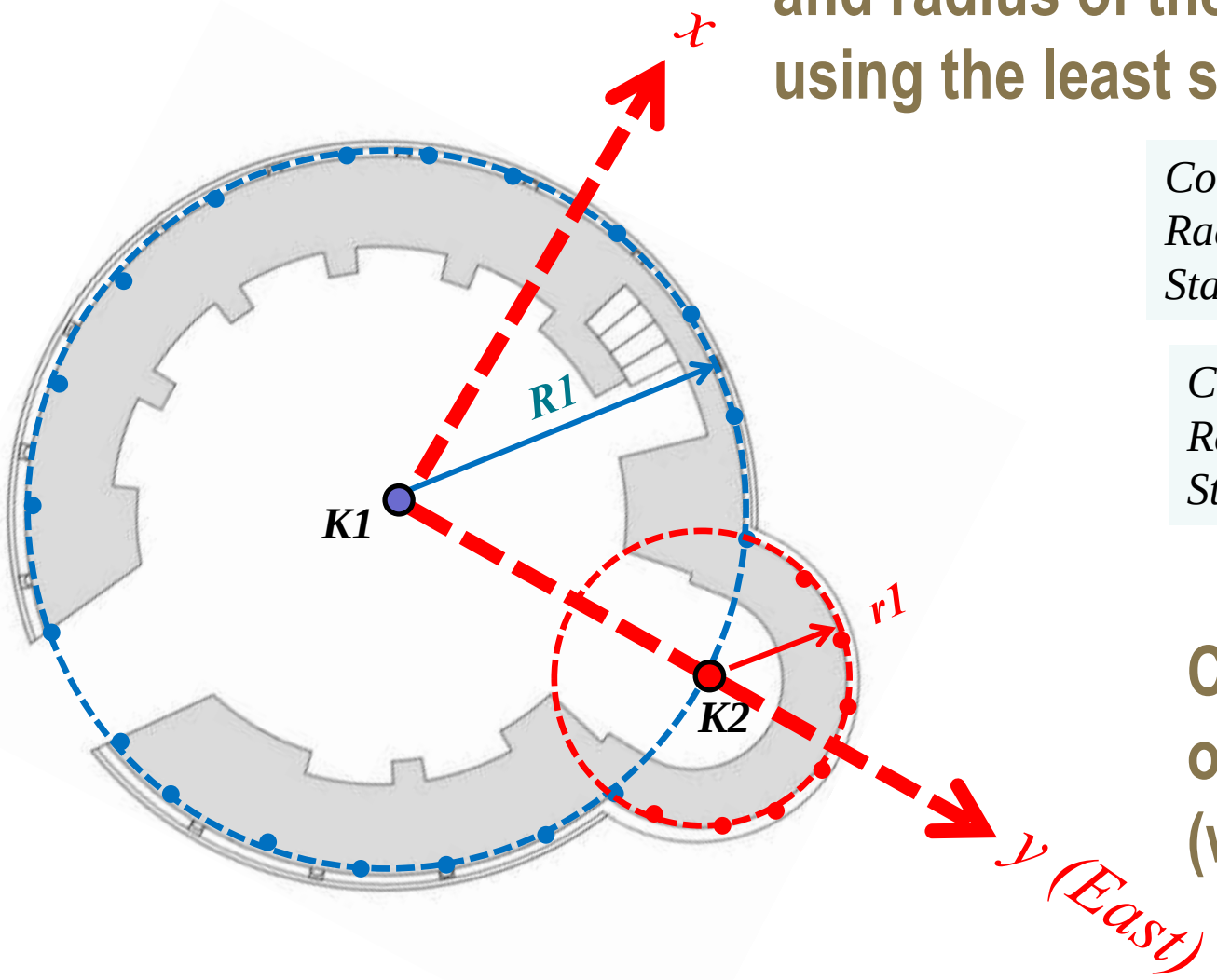
First of all:
we need a local
network,
a micronet



Surveying external and internal walls (circular arches) with total station



Calculating the centre (coordinates) and radius of the regression circles using the least squares method



We have 8 regression circles in this church

Coordinates: K1 (Y, X)
Radius: R1
Standard Deviations: RMS Y, RMS X, RMS R1

Coordinates: K2 (Y, X)
Radius: r1
Standard Deviations: RMS Y, RMS X, RMS r1

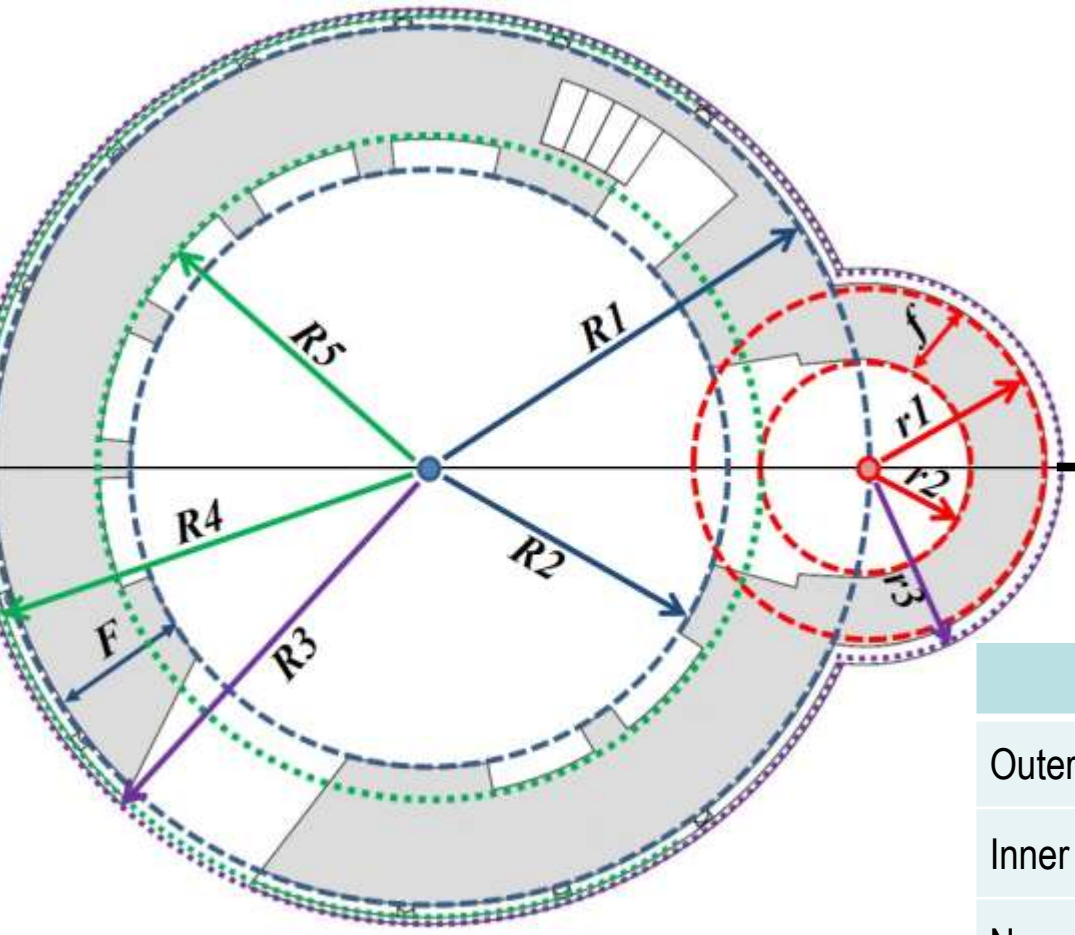
...

Coordinate transformation to the original system (where K1 -K2 is East direction)

*Coordinates: K1 **(y, x)***
*Radius: **R1***
*Standard Deviations: **RMS y, RMS x, RMS R1***

...

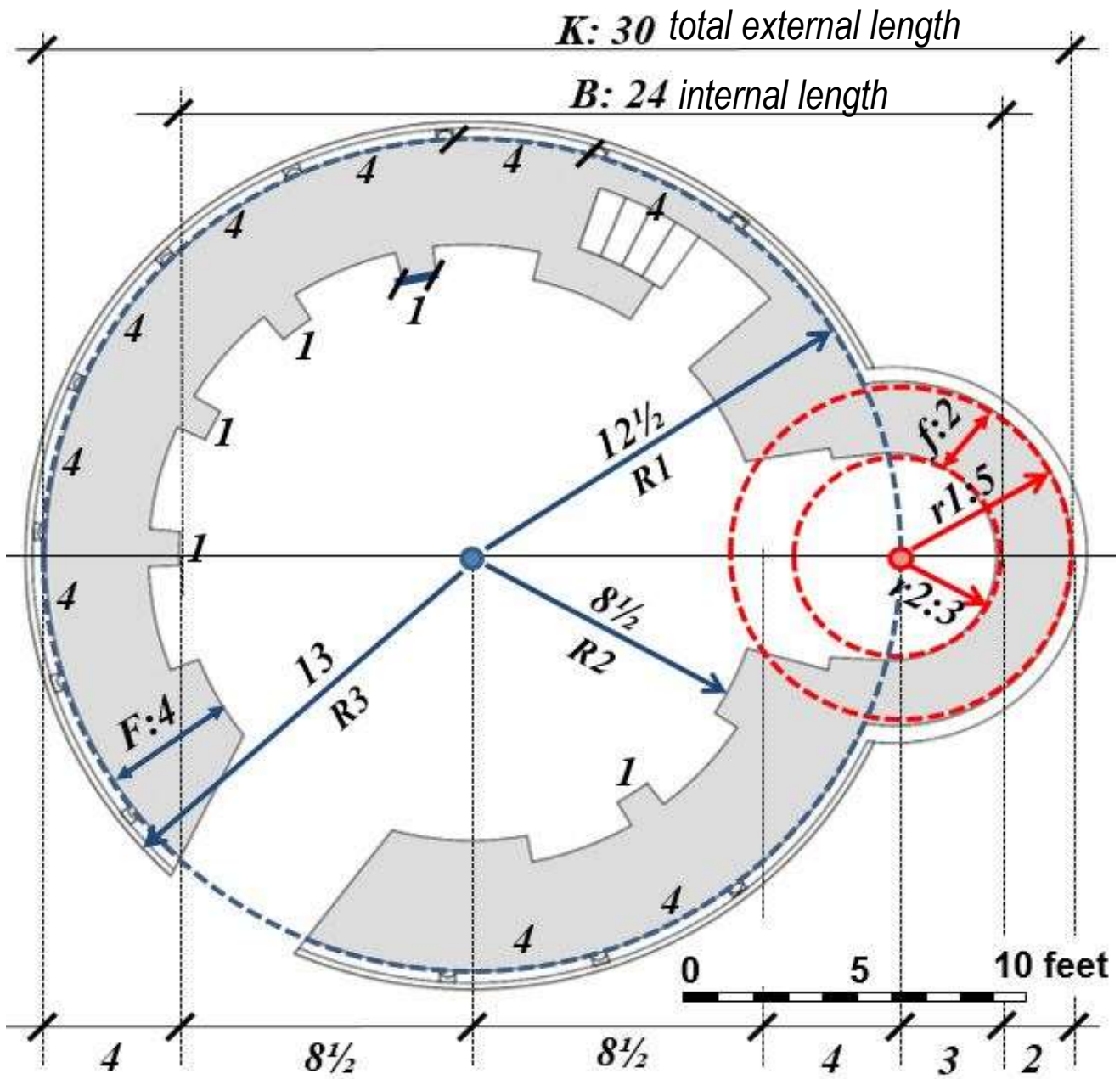
Centres cordinates, radii and its RMS of the different regression circles



The center coordinates are mainly the same

The standard deviations are a few millimetres

description		*y*	*x*	*r*	*RMS y*	*RMS x*	*RMS r*
Outer radius of nave	***R1***	249.949	149.751	3.937	0.004	0.005	0.003
Inner radius of nave	***R2***	249.922	149.726	2.681	0.003	0.003	0.002
Nave foundation wall	***R3***	249.928	149.743	4.100	0.004	0.004	0.003
Lesenes	***R4***	249.930	149.742	4.038	0.003	0.003	0.002
Sitting niches	***R5***	249.906	149.733	2.946	0.002	0.002	0.001
Outer radius of sanctuary	***r1***	253.820	149.758	1.627	0.003	0.008	0.006
Inner radius of sanctuary	***r2***	253.773	149.729	0.980	0.008	0.017	0.012
Sanctuary foundation wall	***r3***	253.812	149.745	1.775	0.008	0.016	0.010



Floor plan of the Kallósd round church in the Hungarian royal feet

NAVE:

foundation radius:
13 *feet*

outer wall radius:
12,5 *feet*

inner wall radius:
8,5 *feet*

thickness of wall:
4 *feet*

APSE:

outer wall radius:
5 *feet*

inner wall radius:
3 *feet*

thickness of wall:
2 *feet*

length of the chruch: ***30*** *feet (****3 fathom****)*

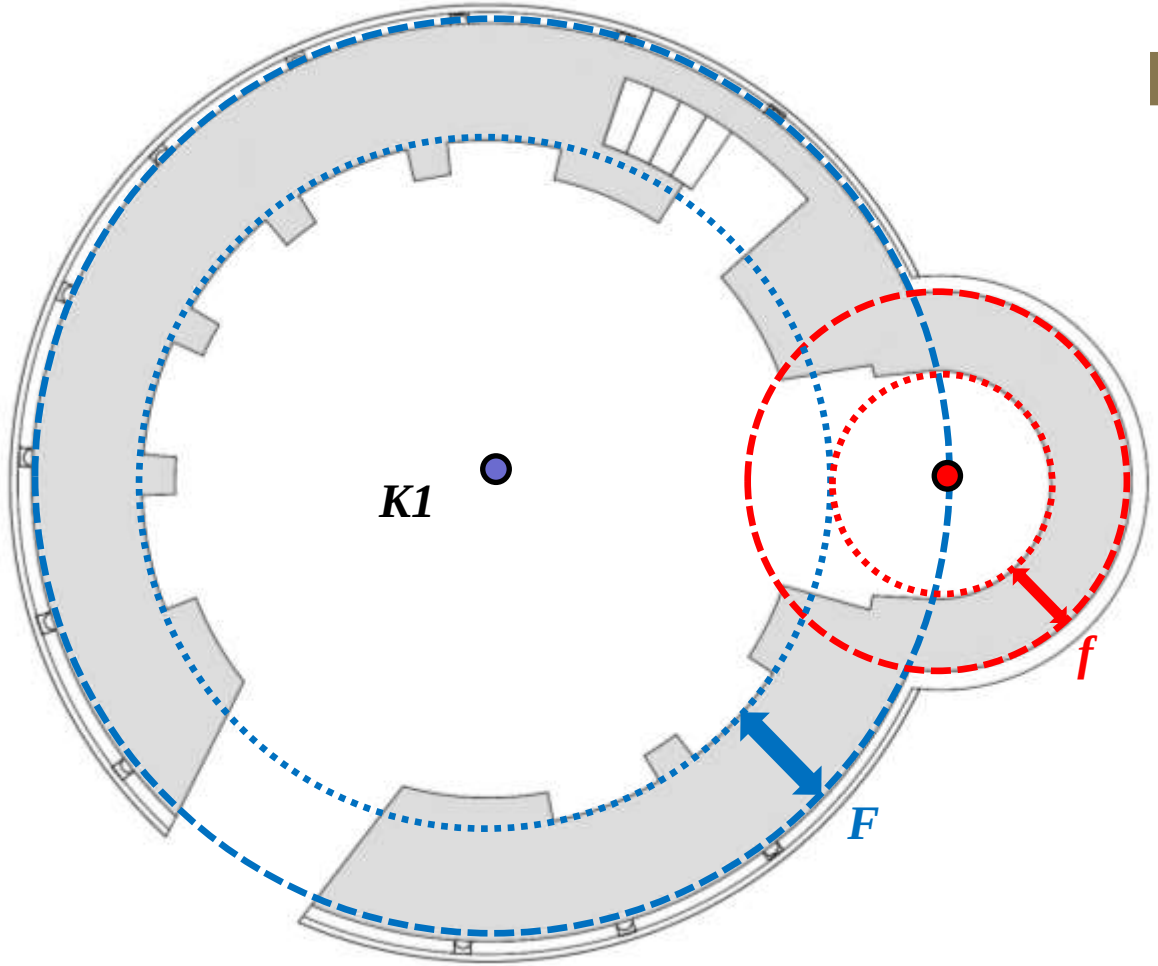
Reconstruction of the medieval royal foot from the sizes of the Kallósd round church

number of items in the former unit

Description of sizes		Distance (metre)	Pieces	Feet (cm)	Weight
Outer radius of nave (from 20 points)	*R1*	3.937	12.5	31.5	3
Inner radius of nave (from 20 points)	*R2*	2.671	8.5	31.4	3
Outer radius of sanctuary (from 8 points)	*r1*	1.627	5	32.5	1
Inner radius of sanctuary (from 6 points)	*r2*	0.980	3	32.7	1
Outer length of the church *(2R1+r1)*	*K*	9.501	30	31.7	2
Inner length of the church *(2R2+F+r2)*	*B*	7.588	24	31.6	2
Thickness of nave wall *(R1-R2)*	*F*	1.266	4	31.6	2
Thickness of sanctuary wall *(r1-r2)*	*f*	0.647	2	32.4	1
Lesene width (12)		0.155	0.5	31.0	1
Distance between lesenes (10)		1.267	4	31.7	1
Column width at sitting niches (5)		0.314	1	31.4	1

As weighted average:

1 foot: **31.8 cm**



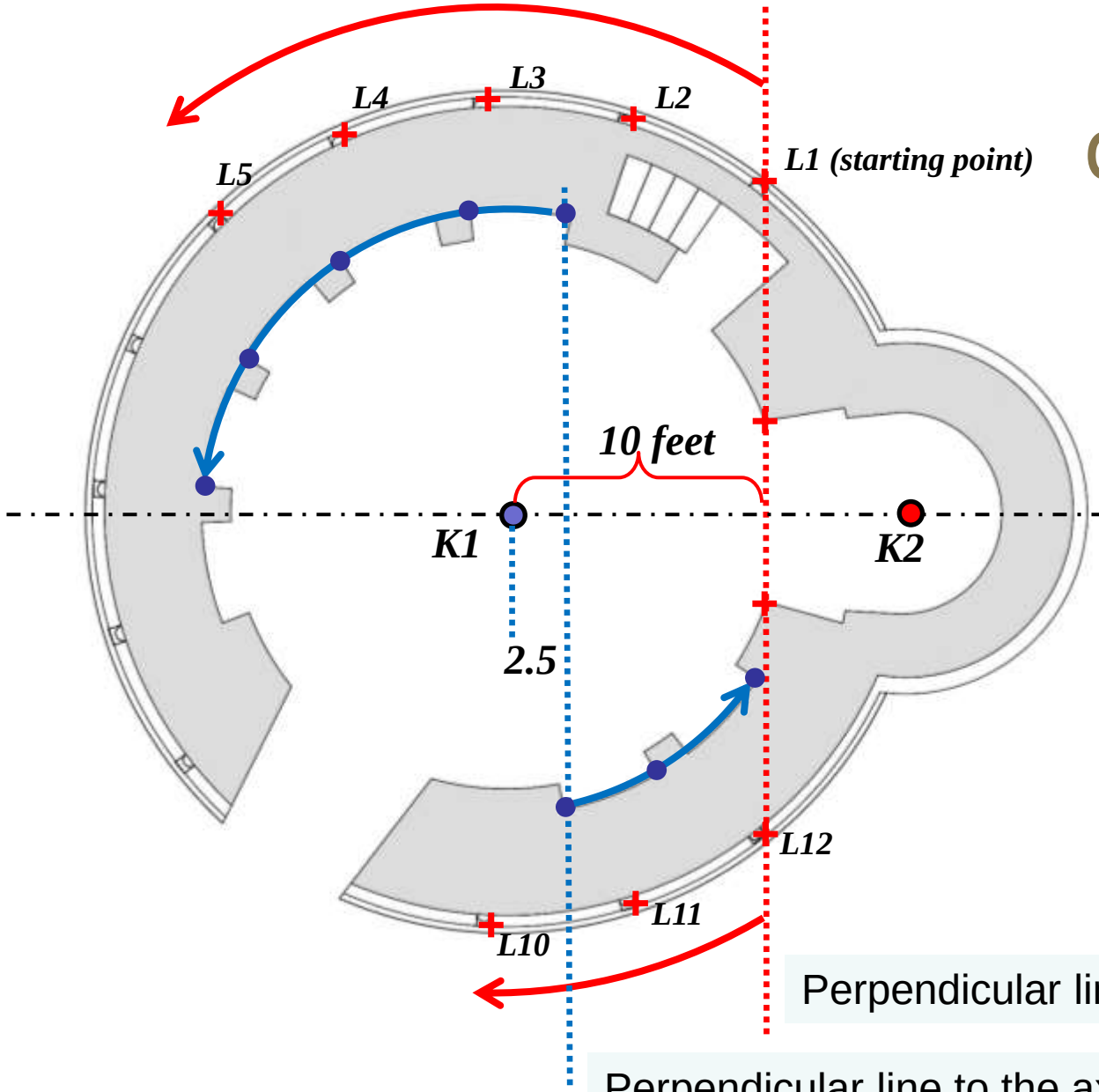
Regularity in geometry

- The center of the apse fit on the outer wall circle of nave.

- The inner wall circle of apse is tangential to the inner wall circle of nave.

- The thickness of apse wall is the half of the nave wall.

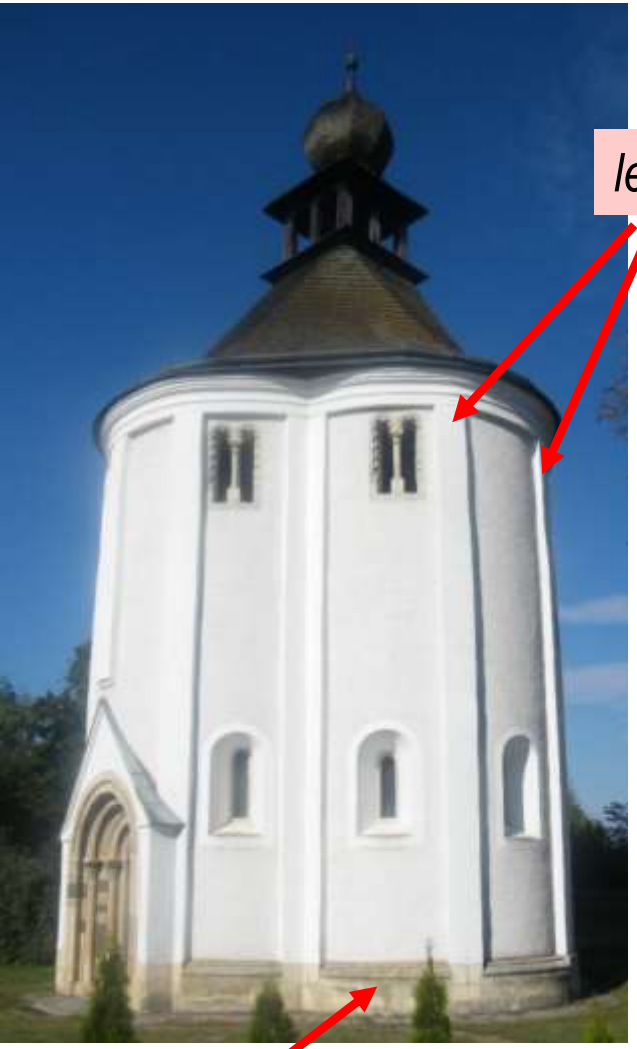
$$\frac{F}{2} = f$$

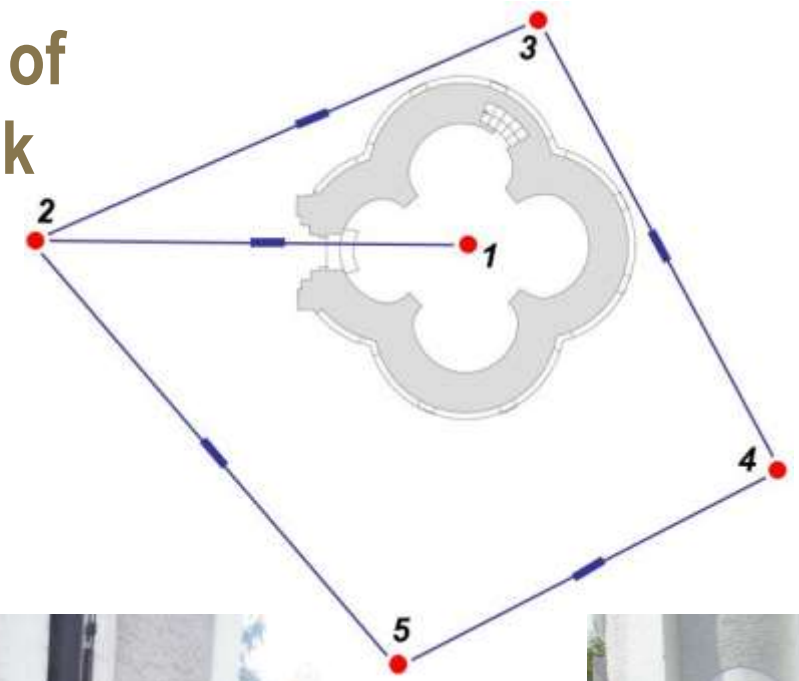


Other regularities:

- lesenes (pilaster strips)
- sitting bays (niches)

Example 2: The round chapel of St James with four vault in Ják

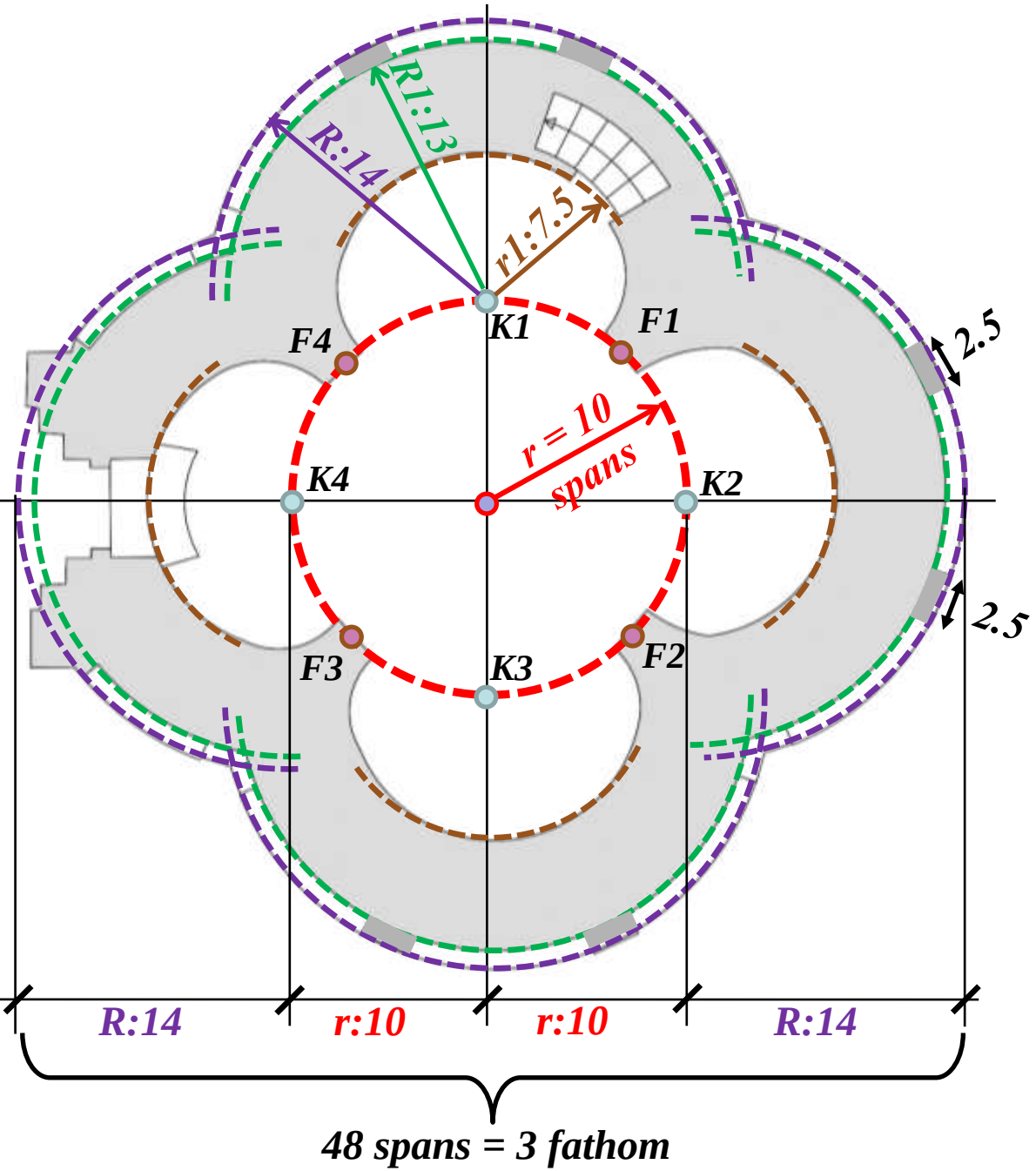




The church was built around 1250

The original walls are easily identifiable and the building itself is symmetrical and geometrically regular

We identified 3 circles (arcs) in each vault: the inner and outer wall points and the outer foundation points



The geometry/sizes of Ják chapel

K and ***F*** points situated on the same circle.

This circle's radius is **10** span.

The sizes of tis chapel are not determined on foot but in span

The radius of foundation circle is **14** spans

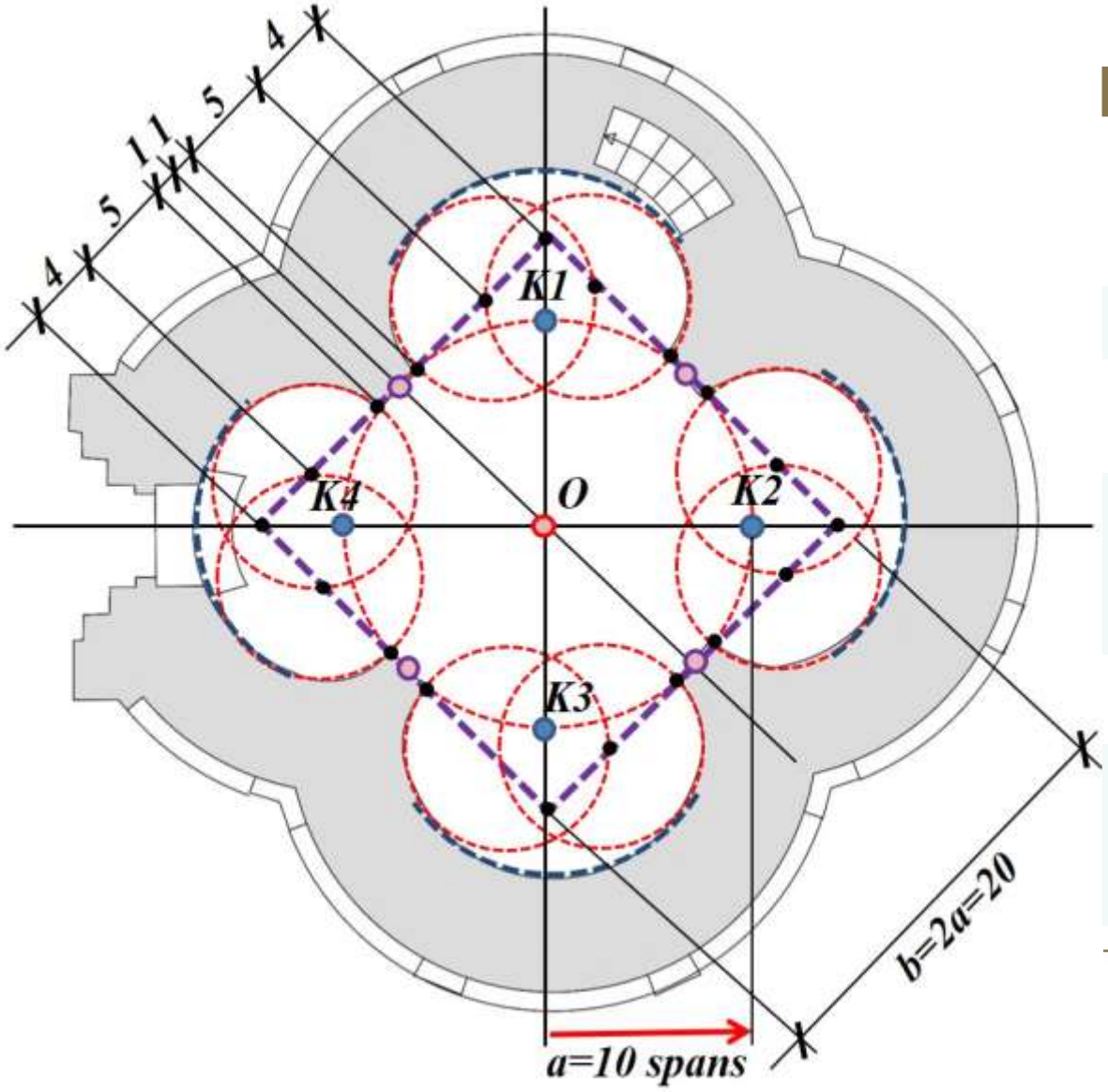
Radius of outer wall: **13** spans

Radius of inner wall: **7.5** spans

The width of the pilasters is **2.5** spans

The total outer length is **48** spans, it is exactly **3 fathom**

Editing and setting the inner arc



The length of the square's side is 20 spans.

We have been able to reconstruct the selection of the centres of the small circles. These are also round numbers in spans..

This is how they could mark the curve of the inner walls. This arc is made up of three circular arches.

Reconstruction of the medieval royal span from the sizes of the Ják chapel

number of items in the former unit

Description of sizes		Distance (metre)	Pieces	Span (cm)	Weight
1st arc,) radius of inner wall (from 8 points)	*r1*	1.492	7.5	19.9	1
st1 arc, radius of outer wall (from 12 points)	*R1*	2.620	13	20.2	2
1st arc, radius of foundation wall (from 16 points)	*RL1*	2.815	14	20.1	2
2nd arc, radius of inner wall (from 6 points)	*r2*	1.501	7.5	20.0	1
2nd arc, radius of outer wall (from 16 points)	*R2*	2.603	13	20.0	2
2nd arc, radius of foundation wall (from 16 points)	*RL2*	2.799	14	20.0	2
3rd arc, radius of inner wall (from 6 points	*r3*	1.487	7.5	19.8	1
3rd arc, radius of outer wall (from 13 points)	*R3*	2.607	13	20.1	2
3rd arc, radius of foundation wall (from 17 points)	*RL3*	2.795	14	20.0	2
4st arc, radius of inner wall (from 6 points	*r4*	1.515	7.5	20.2	1
4st arc, radius of outer wall (from 7 points)	*R4*	2.608	13	20.1	2
4st arc, radius of foundation wall (from 11 points)	*RL4*	2.803	14	20.0	2
Outer length of the church (East-West)	*K*		48	20.0	2
Outer length of the church (North-South)	*K*		48	20.1	2

As weighted average:

1 span: **20.0 cm**

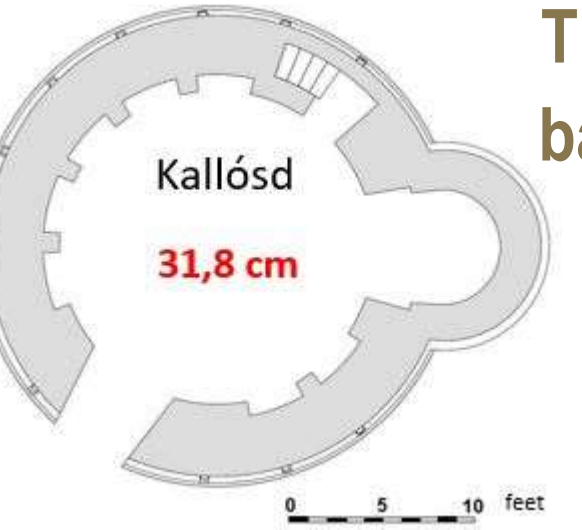
*1.6

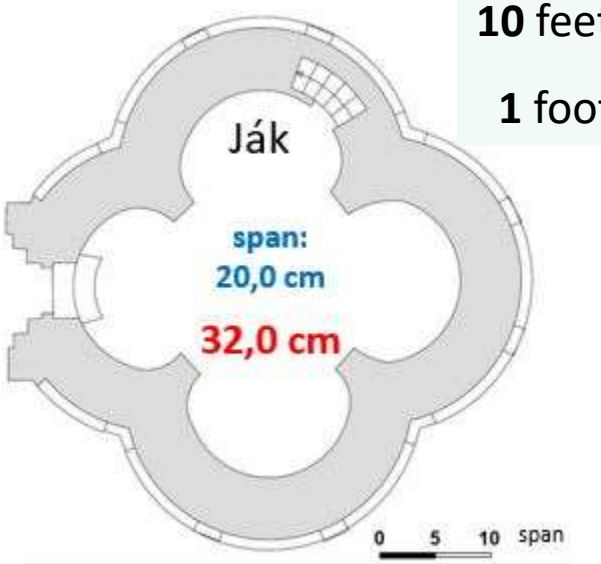
1 foot: **32.0 cm**

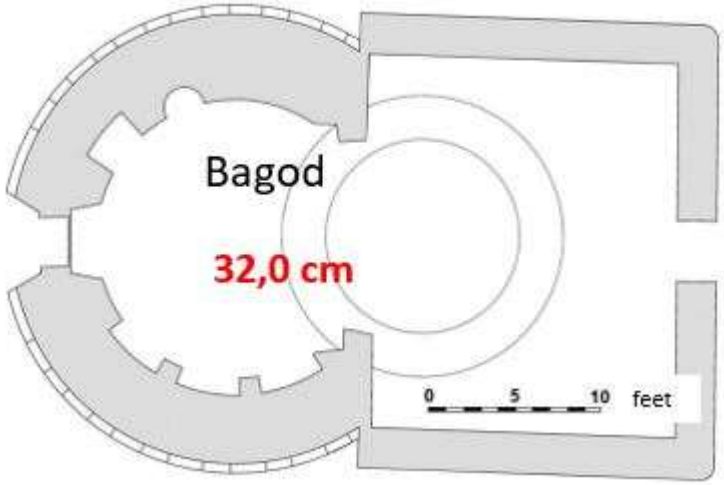
The metric value of the Hungarian Royal Foot based on the study of 7 medieval buildings

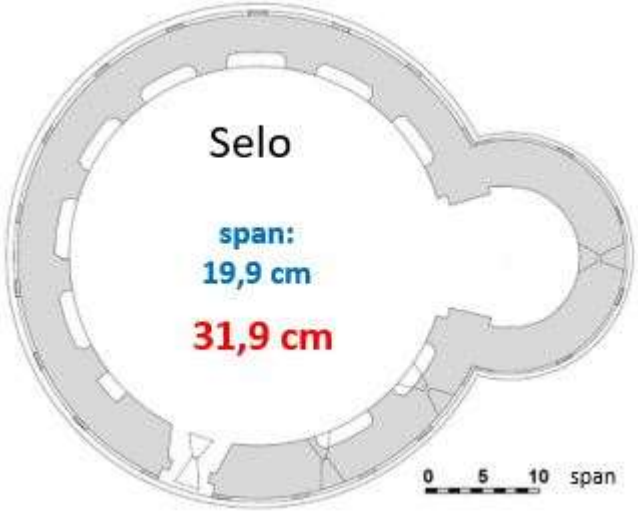
10 feet = **16** spans

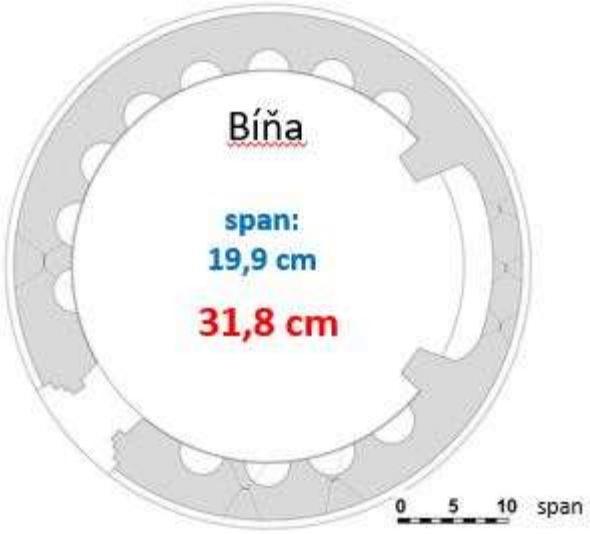
1 foot = **1.6** spans

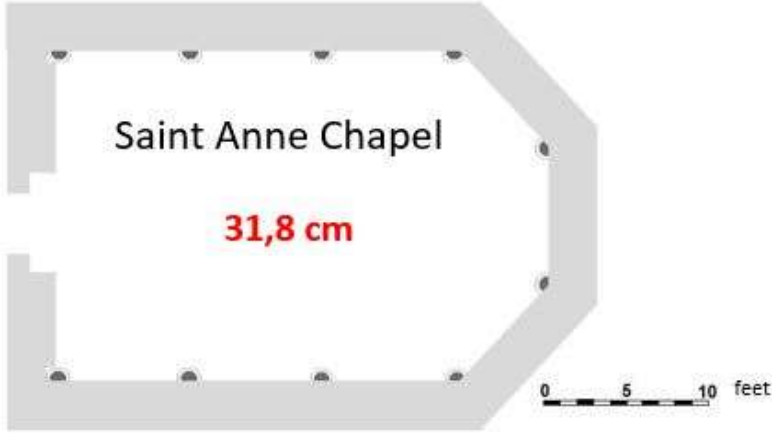












The improved metric values of Medieval Hungarian units of lengths

	öl (fathom)	láb (foot/feet)	arasz (span/s)	hüvelyk (inch/es)	metric system	metric system
1 öl (Hungarian fathom)	**1**	10	16	120	**3.186 metre**	~3.126 metre
1 láb (Hungarian foot)		**1**		12	**31.9 cm**	~31.3 cm
1 arasz (Hungarian span)			**1**	7.5	**19.9 cm**	~19.5 cm
1 hüvelyk (Hungarian inch)				**1**	**26.6 mm**	~26.1 mm

Thank you for your attention!

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